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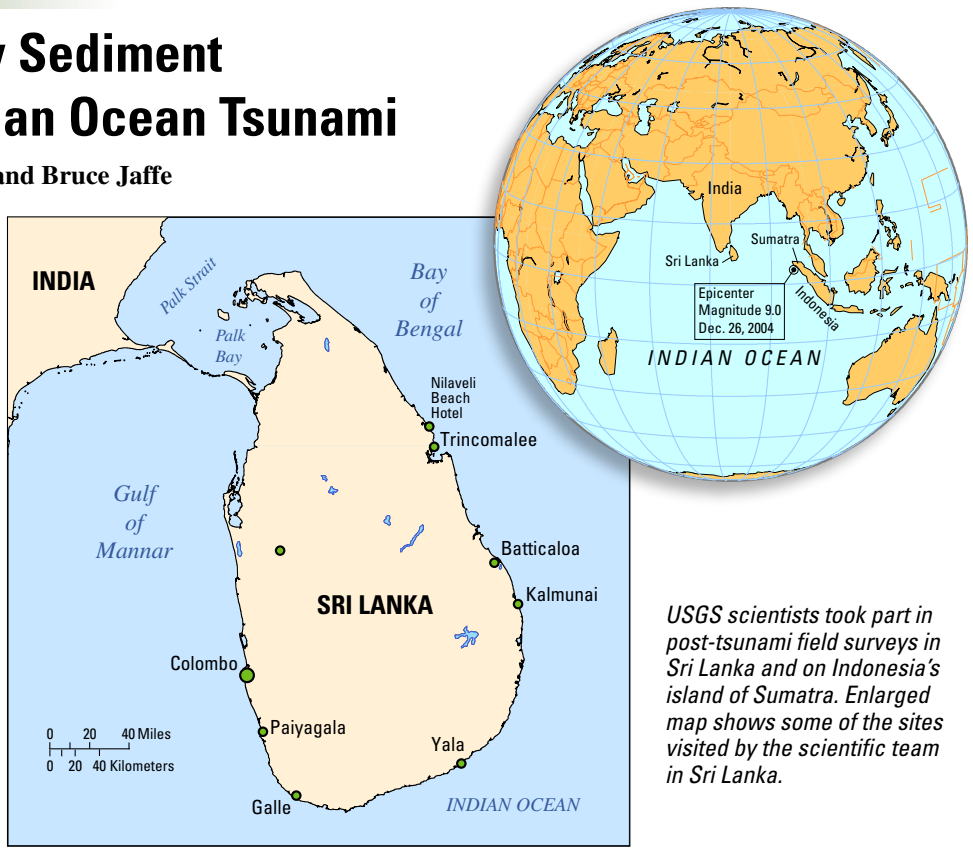
Fieldwork

USGS Scientists Study Sediment Deposited by 2004 Indian Ocean Tsunami

By Helen Gibbons, Jennifer Leigh Oates, and Bruce Jaffe



USGS scientists took part in post-tsunami field surveys in Sri Lanka and on Indonesia's island of Sumatra. Enlarged map shows some of the sites visited by the scientific team in Sri Lanka.

In January, U.S. Geological Survey (USGS) scientists traveled to countries on the Indian Ocean to study sediment deposited by the devastating tsunami of December 26, 2004. They hope to gain knowledge that will help them to identify ancient tsunami deposits in the geologic record—which extends much farther into the past than written records—and so compile a history of tsunamis that can be used to assess a region's future tsunami risk.

"The USGS shares a common interest with scientists around the world to reduce the devastating effects of earthquakes and tsunamis on society," said **Lisa Robbins**, director of the USGS Center for Coastal and Watershed Studies in St. Petersburg, FL. "The goal of the USGS is to help improve the world's scientific knowledge of these events, so that measures can be taken to reduce the effects of future earthquakes and tsunamis."

Bruce Jaffe (Santa Cruz, CA) and **Robert Morton** (St. Petersburg, FL) worked in Sri Lanka from January 9-15, 2005, with an international survey team headed by **Philip Liu** of Cornell University. **Guy Gelfenbaum** (Menlo Park, CA) worked on Indonesia's island of Sumatra from January 18-31 with an international survey team headed by **Yoshinobu Tsuji** of Tokyo University's Earthquake Research Institute.

The survey teams gathered data on estimated wave heights, extent of inundation, tsunami sand deposits, erosion by the tsunami, flow directions, and other information related to the physical aspects of the tsunami waves that may disappear quickly. The team in Indonesia, much closer to the epicenter of the earthquake that caused the tsunami, also looked for evidence of

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*Damage at Kalmunai, eastern Sri Lanka. The ground is littered with boats that were swept inland, sediment deposits, bricks, and other debris. This view is an excerpt from a panoramic image (posted at URL **http://soundwaves.usgs.gov/2005/02/**) that was created by **Gerry Hatcher** (USGS, Santa Cruz, CA) from photographs taken by survey-team members.*

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Fieldwork, continued

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coastal subsidence. USGS scientists focused on the sediment deposited by the tsunami, from which they hope to learn not only about the recent tsunami but, ultimately, about past tsunami history and future tsunami risk. By examining the thickness and grain-size distribution of a tsunami deposit, for example, scientists may be able to deduce wave height and flow velocity—two of the most important factors in determining the destructive power of a tsunami. By studying deposits from recent tsunamis, scientists hope to be better able to identify tsunami deposits in the geologic record—to distinguish them from large-storm deposits, for example. Where an ancient tsunami deposit is identified, the characteristics of the deposit may yield information about the tsunami wave that deposited it. Where more than one tsunami deposit is preserved in a sedimentary sequence, the record may help scientists to determine how often tsunamis are likely to occur.

Harindra (Joe) Fernando *(second from left), a professor from Arizona State University and also a native Sri Lankan, gathers eyewitness accounts from survivors in Paiyagala, southwestern Sri Lanka, on the property of a Catholic church whose schoolhouse was destroyed by the tsunami. The white bucket at the young women's feet contains toys and wooden blocks that they have collected from the rubble and are washing with water from the well at right—their way of making progress toward the community's long-term goal of rebuilding the school. Third from left is reporter* ***William Hermann*** *of the* Arizona Republic*, who traveled with the scientific team in Sri Lanka. Photograph by* ***Bob Morton****.*

"The historical record of tsunamis is too short to accurately define tsunami risk for most of the world," says **Jaffe**. "Even Japan, which has the longest written record in the world [dating to about A.D. 700], has an active research program to extend the record of tsunamis farther into the past by using tsunami deposits." Some countries, including Sri Lanka, one of the hardest hit by the December tsunami, have only a sparse

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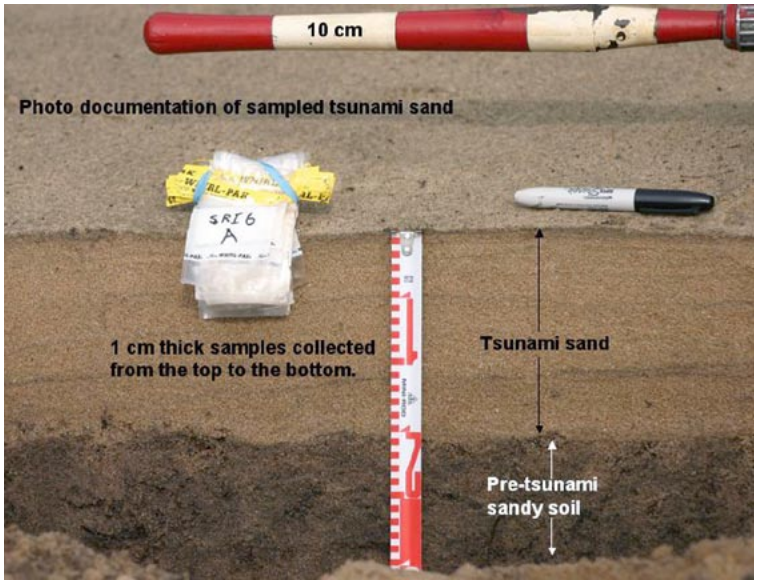

Tsunami deposit at Nilaveli Beach Hotel, east coast of Sri Lanka. Photograph by ***Bretwood Higman****, University of Washington.*

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written record of previous tsunamis. In such cases, says **Jaffe**, "the sedimentary record of tsunamis may provide the best evidence of a region's risk from tsunamis."

The survey in Sri Lanka was the third survey of a tsunami-ravaged coast for **Jaffe**, who is principal investigator for the USGS Tsunami Hazard Assessment Project. He was a member of an international team that traveled to Papua New Guinea to document the 1998 tsunami (see URL **http://walrus.wr.usgs.gov/tsunami/itst.html**), and later led an international team that documented tsunami sedimentation from the 2001 Peru tsunami (see URL **http://walrus.wr.usgs.gov/peru2/**). He has also studied sedimentary evidence of catastrophic tsunami events in Java (1974 tsunami) and the U.S. Pacific Northwest (1700 tsunami). **Jaffe's** tsunami research focuses on (1) inverse sediment-transport modeling of tsunami deposits to estimate tsunami flow velocity, (2) identification of past tsunami deposits, and (3) developing methods to use tsunami deposits to extend the record of tsunamis beyond the historical record.

Bob Morton has particular expertise in large-storm deposits, and his recent tsunami research has focused on distinguishing

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Topography—Natural and Altered—Affects Tsunami's Severity

Uneven patterns of coastal destruction caused by the Indian Ocean tsunami—some areas devastated, others nearby only slightly damaged—illustrate what scientists who make mathematical models of tsunamis have learned over time: tsunami waves are extremely sensitive to details of nearshore and coastal topography. Data like those gathered in Sri Lanka—plus higher-resolution maps of the nearshore sea floor, where available—will help scientists fine-tune their mathematical models and more accurately predict the behavior of future tsunamis.

Some variations in the effects of December's tsunami resulted from natural variations in topography. The tsunami waves were higher, as might be expected, along shorelines that directly faced the tsunami's line of approach. High waves also struck shorelines facing away from the tsunami's origin, for example, on the southwest coast of Sri Lanka. This phenomenon is predicted by models that show tsunami energy wrapping around islands in shore-parallel "edge waves." In Galle, Sri Lanka, unusually high runup heights, nearly 40 ft in some areas, are believed to have been caused by focusing of the tsunami's energy by the sides of a nearby submarine canyon. In other areas, the tsunami's energy was reduced by offshore topography—for example, buffered by offshore reefs.

*Stranded boat rests atop a sand dune that tsunami waves barely topped on a beach at Yala in southern Sri Lanka. Similar dunes can be seen down the coast. In the middle ground, the dune had been removed to improve the ocean view from the Yala Safari Game Lodge, leaving it vulnerable to the tsunami's full force. Photograph by **Bob Morton**.*

Some variations in the tsunami's effects resulted, tragically, from human alterations of the landscape. At the Yala Safari Game Lodge, a resort on the edge of Sri Lanka's Yala National Park, a high sand dune had been removed to improve the ocean view. On adjacent stretches of beach, where the dune was intact, the tsunami waves barely crested the dune. "Where the dune was gone," says **Bob Morton**, "the tsunami roared right through," demolishing the hotel and killing more than 175 people. **Morton** called the tragic loss of life and property at the resort "one of the most striking examples we were able to bring back from the field—where human activities increased the coastal hazards."

Before: Rooms at the Yala Safari Game Lodge, scanned from an advertisement given to the scientific team by a Sri Lankan resident.

*After: Site of the demolished Yala Safari Game Lodge. Note the light vertical tiles that can also be seen in the "before" shot. Photograph by **Bob Morton**.*

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tsunami deposits from storm deposits (see related article in *Sound Waves*, October 2002, at URL **http://soundwaves.usgs.gov/2002/10/index.html**). Both tsunamis and large storms, particularly hurricanes, are capable of inundating coastal regions and depositing sandy sediment over broad areas landward of the beach. Correctly identifying a sandy bed in the geologic record as either a tsunami or a storm deposit is important for an accurate assessment of a region's risk from tsunamis or large storms. **Morton** hopes to understand better how the recent tsunami affected the Sri Lankan coast so that he can compare tsunami coastal-change data with hurricane coastal-change data collected after the busy 2004 hurricane season in Florida. A member of the USGS Tsunami Hazards Assessment project, **Morton** is also the principal investigator for the USGS National Assessment of Shoreline Change project, which addresses the problem of beach erosion and shoreline change threatening coastal populations and community infrastructures in the United States (see URL **http://coastal.er.usgs.gov/shoreline-change/**.)

Guy Gelfenbaum, who also is a member of the USGS Tsunami Hazards Assessment project, is working with **Jaffe** and **Morton** on efforts to distinguish large-storm deposits from tsunami deposits. **Gelfenbaum** examined tsunami deposits in Papua New Guinea in 1998 and in Peru in 2001. His recent work includes collaborating with **Giles Lesser** (USGS, Menlo Park, CA) to model sediment transport and coastal evolution of Willapa Bay, WA, in response to large Cascadia subduction-zone earthquakes and associated tsunamis.

As of this writing, **Bruce Jaffe** and **Bob Morton** are back in the United States and have graciously shared some of their initial findings and photographs. **Guy Gelfenbaum** is due back soon. Stay tuned for future articles about the work of these three scientists.

New USGS Web Sites

- On the recent field survey in Sri Lanka: "The December 26, 2004, Indian Ocean Tsunami: Initial Findings on Tsunami Sand Deposits, Damage, and Inundation in Sri Lanka," URL **http://walrus.wr.usgs.gov/tsunami/srilanka05/**
- On how the tsunami was triggered (including an animation): "Tsunami Generation from the 2004 M=9.0 Sumatra Earthquake," URL **http://walrus.wr.usgs.gov/tsunami/sumatraEQ/**

*Debris left in the trees, like this door in Yala, Sri Lanka, helped the scientists measure the tsunami wave heights. Photograph by **Bob Morton**.*

*Car transported by the tsunami in Yala, Sri Lanka. Note airbag on driver's side. Photograph by **James Goff**, Geoenvironmental Consultants, New Zealand.*

Journalists Accompanied the Scientific Team in Sri Lanka

The survey team in Sri Lanka was accompanied by journalists, including **Tom Paulson** of the *Seattle Post-Intelligencer*, **William Hermann** of the *Arizona Republic*, and **Quirin Schiermeier** of the scientific journal *Nature*. The journalists' articles not only describe the scientists' activities and findings but also paint a vivid picture of the tsunami-torn areas and the tsunami survivors. To read them online, go to the search engines on the publications' Web sites (at URLs **http://seattlepi.nwsource.com/search/, http://www.azcentral.com/arizonarepublic/**, and **http://www.nature.com/news/**) and type in the keywords "tsunami," "Sri Lanka," and the journalist's last name.

Additional insights are provided by informal online journals—Web logs, or "blogs"—kept by **Paulson** and **Schiermeier**. **Paulson's** entry for January 17, 2005, offers some thoughts on the fast pace set by the scientists: "I don't remember ever being so tired for so long on assignment. I've traveled in Africa, India and Asia—often under difficult circumstances in remote areas—but I'd have to say nothing was quite as exhausting as covering this story. The scientists were determined to study as many sites as possible within the week, before the data disappeared and while eyewitness memories were fresh. Every day was a new region, with a 12-hour sprint from site to site, followed by a search for a place to stay the night...." And on the scientists themselves: "As frenzied and nerdy as that bunch was, I'll miss them." **Schiermeier's** entry for the same day touches on some emotional aspects of the trip: "I'm still struggling to cope with the things I have seen and heard over the last few days. I guess all the team members feel the same. When we said our goodbyes in the lobby of the Trans Asian hotel in Colombo, we confessed what a conflicting experience this has been for us: doing science, even having some good fun, amidst all the grief and the destruction." Read more at URL **http://blog.seattlepi.nwsource.com/tsunami/** (**Paulson's** blog) and URL **http://www.nature.com/news/2005/050110/full/050110-10.html** (**Schiermeier's** blog).

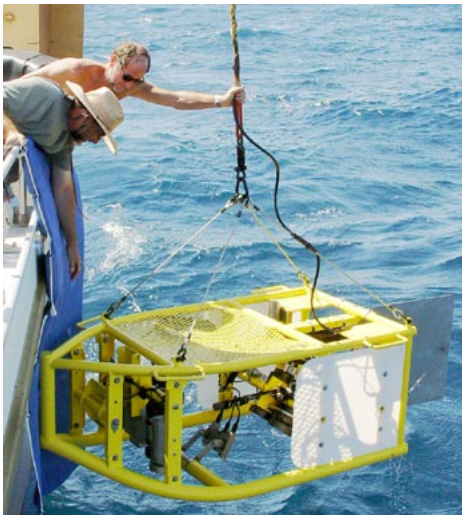
Mapping the Sea Floor on the San Pedro Shelf, Southern California

By Brian Edwards, Pete Dartnell, and Eleyne Phillips

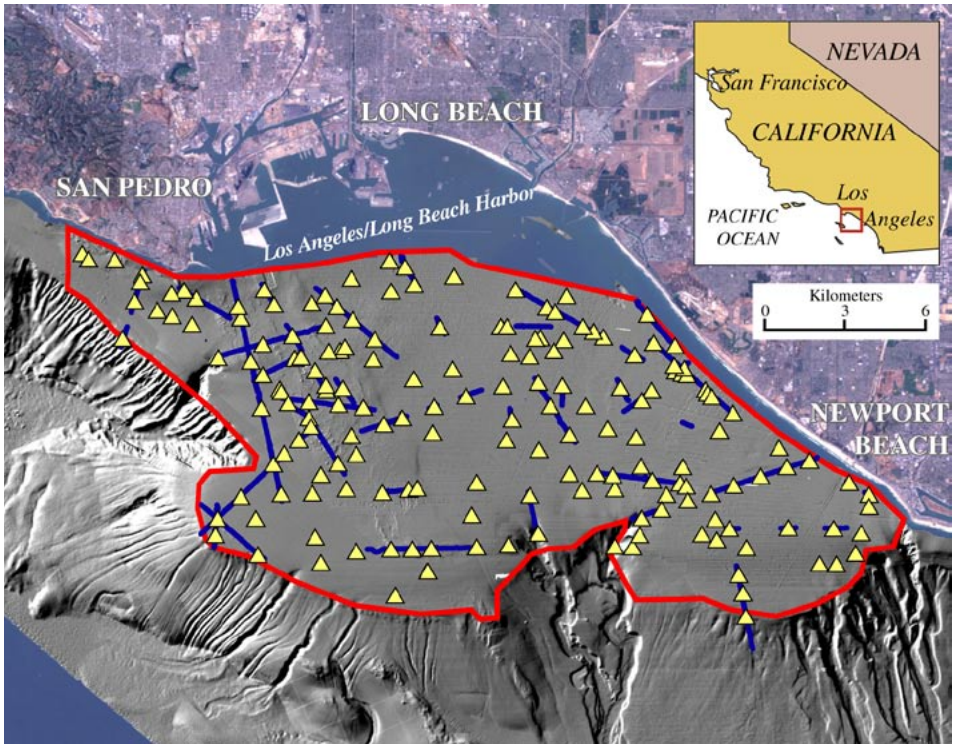
U.S. Geological Survey (USGS) scientists with the Western Coastal and Marine Geology Team (WCMG) are leading an interdisciplinary study to map sea-floor composition and habitat on the San Pedro shelf, a part of the continental shelf off southern California. Offshore of the populous Los Angeles metropolitan area, the San Pedro shelf is affected by recreational and commercial fisheries and is at risk from numerous human impacts, such as sanitation outfalls, shipping, anchor dragging, sand mining for beach replenishment, and waste disposal. This tectonically active area is also cut by numerous faults, whose earthquake potential could pose both shaking and tsunami hazards to onshore communities.

Brian Edwards, **Pete Dartnell**, and contractor **Eleyne Phillips** will use multibeam-sonar data collected on the shelf during the late 1990s as a detailed base map from which to

- understand and quantify controls on multibeam-backscatter intensity (a measure of sound energy reflected from the sea floor that contains clues about sea-floor composition),
- classify and map surface-sediment facies (for example, rock, sand, or mud) at 8-m/pixel resolution, and
- use the facies data to quantitatively map the complexity of marine communities and benthic habitats of the San Pedro shelf.



*WCMG personnel **Kevin O'Toole** (top) and **Hank Chezar** (wearing hat) recover the camera sled onboard the research vessel* Ocean Sentinel. *Attached to the camera sled were two video cameras, one oriented obliquely and the other vertically, and one 6-megapixel digital camera. The sled was navigated by using a shipboard differential geographic positioning system (GPS) and LACSD's trackpoint system. Photograph by **Tom Parker** (LACSD).*



Shaded-relief bathymetry of the San Pedro shelf, showing the extent of the study area (outlined in red). Water depths within the study area range from about 10 m near the shore to about 100 m at the shelf break. Blue lines show sea-floor video/photography transects; yellow triangles show locations of sea-floor samples recently collected from the research vessel Early Bird II.

The study is a cooperative effort between USGS scientists and personnel from the Los Angeles County and Orange County Sanitation Districts (LACSD and OCSD). The USGS is providing expertise in geology and marine mapping, and the sanitation districts are providing funding, biological expertise, and ship time. Project scientists are also working closely with the California Geological Survey to identify possible sources of offshore sand for beach replenishment.

The San Pedro shelf is one of the broadest mainland continental shelf segments between Monterey, CA, and the United States-Mexican border. Approximately 75 to 80 percent of this shelf segment is composed of low-relief, sediment-covered sea floor, and the remaining 20 to 25 percent is composed of rock outcrop interspersed with boulders and cobbles.

The multibeam base map used in the study was developed from Kongsberg Simrad EM300 and EM3000 multibeam bathymetric and acoustic-backscatter data collected in the 1990s (see URL **http://walrus.wr.usgs.gov/pacmaps/la-index.html**). The science team conducted two cruises in 2004 to refine and ground-truth the base map and to help identify and map the distribution of benthic fauna (living on the sea floor) and demersal fish (living on and just above the sea floor). The first cruise (October 7-21) collected sea-floor video along more than 365 km of trackline and shot more than 13,000 high-quality still photographs, using WCMG's midsize camera sled (designed by **Hank Chezar**) and LACSD's 63-ft-long research vessel *Ocean Sentinel*. The WCMG science team

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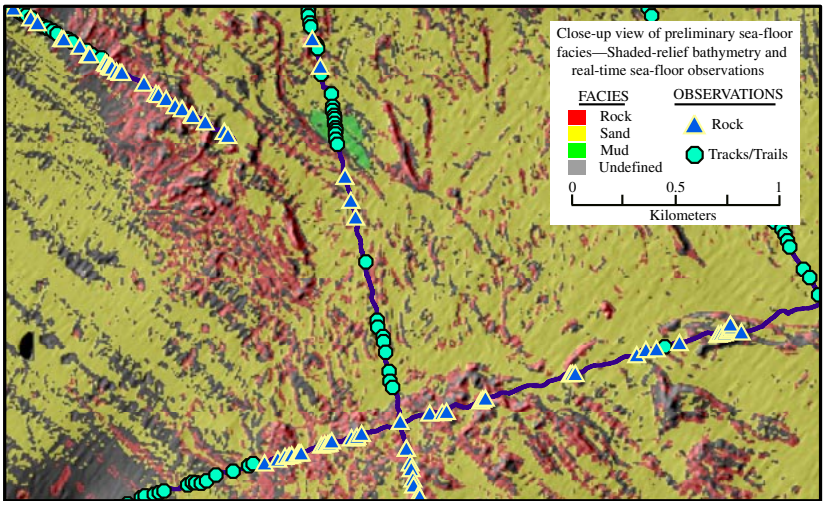
included **Brian Edwards**, **Pete Dartnell**, **Eleyne Phillips**, **Hank Chezar**, and **Kevin O'Toole**, with mobilization help from **John Gann** and **Gerry Hatcher**. Eleven biologists, database specialists, and managers from LACSD provided additional support during the 12-day cruise. Real-time sea-floor observations were recorded every minute, using programmable keypads and **Gerry Hatcher's** GNAV software. More than 120 potential geologic and biologic attributes (such as sea-floor composition, abiotic complexity, biotic complexity, biologic modifiers of the sea floor, and number of benthic fauna and demersal fish) were keyed during each 20- to 30-second observation window. These attributes were quickly incorporated into a geographic information system (GIS) for comparison with the multibeam bathymetry and backscatter and associated facies map. The second cruise (November 29-December 10) was dedicated to sea-floor sampling conducted aboard the 42-ft research vessel *Early Bird II*, contracted by the OCSD. The WCMG scientists on that cruise were **Brian Edwards** and **Pete Dartnell**. Five OCSD scientists and one California Geological Survey scientist provided additional support. During the 10-day cruise, the team collected sea-floor samples from 181 sites, using a grab sampler designed by MEC Analytical Systems, Inc.

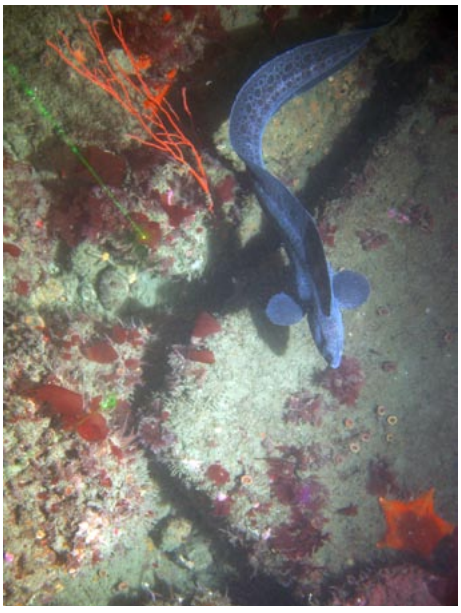
To date, the science team has produced a preliminary facies map, using an empirical technique developed in central Santa Monica Bay by **Pete Dartnell** and **Jim Gardner** (U.S. Geological Survey Open-File Report 2004-1081; see summary and link to full report at URL **http://walrus.wr.usgs.gov/reports/ofr2004-1081.html**). The map, based on the multibeam bathymetry and acoustic-backscatter data, as well as historical textural data from usSEABED and hardground observations, shows the distribution of exposed hardground (including rock outcrops and artificial reefs) and sedimented regions composed of sand and mud.

Work is progressing on two fronts. First, the surficial-facies maps will be refined and ground-truthed, using sea-floor video (for example, see video clip of sand waves at URL **http://soundwaves.usgs.gov/2005/02/fieldwork2.html**), photography, realtime observations, and sediment texture. Second, WCMG geologists and LACSD biologists are collaborating to identify and map the distribution of benthic organisms, using sea-floor video and photography (for example, see video clip of rocky sea floor at URL **http://soundwaves.usgs.gov/2005/02/fieldwork2.html**). Once the maps of surficial facies and benthic organisms are completed, sea-floor geology and benthic faunal relationships will be integrated to develop species-specific suitability maps and more general habitat maps designed to support California Fish and Game Marine Protected Area (MPA) work and demersal-fisheries management. Final products from this project can also be used to study shelf-sediment processes, offshore hazards, marine resources, and anthropogenic impacts on the sea floor.❁

Orange County Sanitation District personnel ***George Robertson*** *(left) and* ***Mike McCarthy*** *recover their "box/grab" sampler onboard the research vessel* Early Bird II. *Photograph by* ***Brian Edwards****.*



Closeup of a preliminary sea-floor-facies map of part of the San Pedro shelf, overlaid by realtime sea-floor observations recorded during the video/photography cruise. The facies map was generated from multibeam and other data before both the video/photography and sediment-sampling cruises. Rock observations are regions where both the major (more than 50 percent) and minor (less than 20 percent) sea-floor attributes include exposed rock. Track/trail observations include regions where benthic organisms left relatively long impressions in the finer-grained sediment.



Sea-floor photograph taken during the October 2004 video/photography cruise onboard the research vessel Ocean Sentinel, *showing a rocky region with coral, erect gorgonia, drift weed, a sea star, white anenomes, and a wolf eel. Such photographs are used to refine and ground-truth the surficial-facies map and to identify and map the distribution of benthic fauna and demersal fish.*

Dam Removal on the Elwha River in Washington—Nearshore Impacts of Released Sediment

By Jonathan Warrick

The Elwha River drains the rugged Olympic Mountains of Washington, flowing northward to the Strait of Juan de Fuca. Construction of two hydroelectric dams in the early 1900s resulted in the loss of approximately 95 percent of the anadromous salmon spawning habitat on the river. In 1992, the Elwha River Ecosystem and Fisheries Restoration Act was enacted by Congress to authorize removal of the dams in order to restore the once-plentiful salmon runs in the river. Dam removal is currently slated to begin in early 2008.

As well as restoring salmon runs, dam removal on the Elwha River will expose more than 14 million m^3 of sediment deposited in the deltas within the two reservoirs. The sediment-management strategy is to allow the material to be naturally eroded and transported to the Strait of Juan de Fuca, acknowledging that some sediment will remain in place and be deposited in the river channel and flood plain. Contributions of sediment to the strait may end or even reverse the current trend of coastal erosion near the river mouth. Sediment contributions may also bury or alter nearshore habitats (including kelp beds and geoduck clam burrows) offshore of the river mouth.

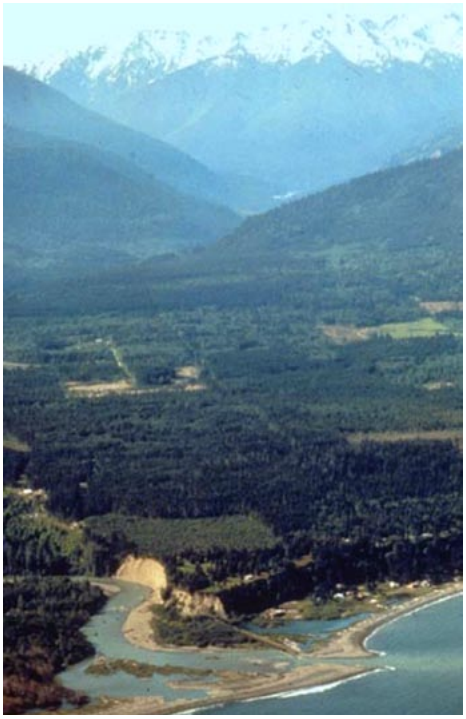
Map of the Elwha River region.

U.S. Geological Survey (USGS) scientists have begun research to characterize the nearshore impacts of the Elwha River dam removals as part of the USGS Coastal Habitats in Puget Sound project. Project scientists have been working closely with local, tribal, State, and Federal parties to develop coordinated monitoring and modeling plans. Within the USGS, scientists from the Coastal and Marine Geology Program, which is funding the project, are working with hydrologist **Chris Konrad**, biologist **Jeff Duda**, and geographer **Harvey Case** to develop a coordinated Elwha River science plan that links fluvial, ecological, and coastal research.

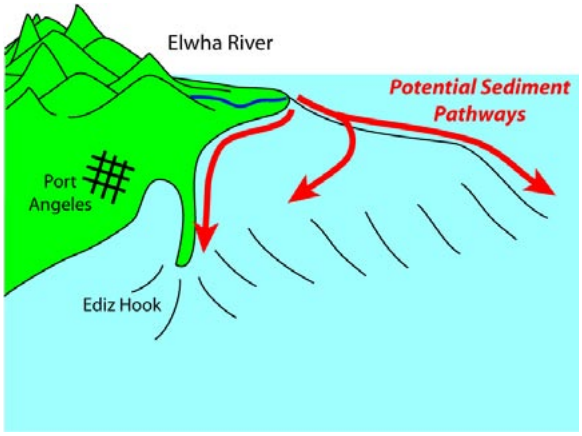
As part of this coordination, USGS geologist **Jon Warrick** participated in the "Technical Workshop on Nearshore Restoration in the Central Strait of Juan de Fuca" held March 2004 in Port Angeles, WA, where ecologists, fishery scientists, engineers, and geomorphologists agreed on the high-priority need for a conceptual model of sediment transport and deposition off the Elwha River. Since this workshop was held, the USGS has led efforts to develop both a simple conceptual model of sediment transport and a research plan for quantifying sediment-transport rates and pathways.

The USGS Coastal Habitats in Puget Sound Project will employ three major techniques to evaluate dam-removal impacts: mapping, monitoring, and modeling. The mapping work will focus on collecting baseline bathymetric and seabed information from which changes can be tracked through the dam-removal process. Two mapping techniques are being used. In March 2004, **Guy Cochrane**, **Jon Warrick**, **Jodi Harney**, **Andy Stevenson**, **Larry Kooker**, **Mike Boyle** (all of the USGS), and **Tina Blewett** (Washington Department of Fish and Wildlife) used combined swath-sonar, seabed video, and seabed grain-size sampling techniques from the research vessel *Karluk* to map the nearshore region off the Elwha River mouth. Preliminary results show that the substrate from the river mouth out to approximately 30-m water depth consists of mixed sand and gravel, with areas of large sand waves (approx 10 m high) and some boulder fields.

(Elwha Dam Removal continued on page 8)



The Elwha River (mouth in foreground) flows into the Strait of Juan de Fuca from Washington's Olympic Mountains (background).



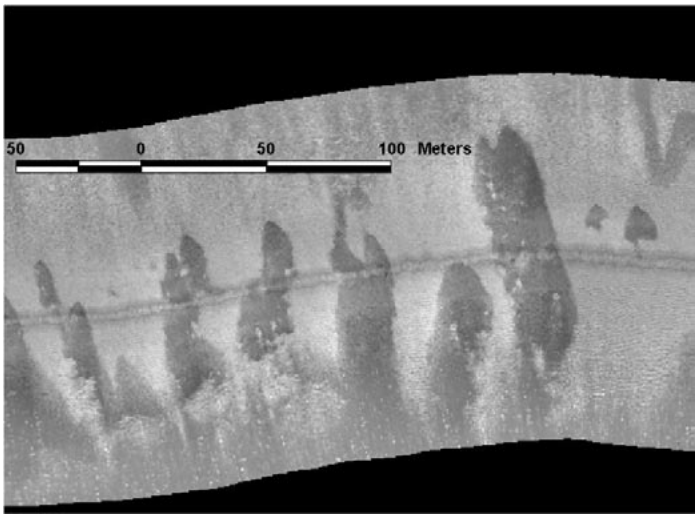
Simple conceptual model of sediment transport offshore of the Elwha River. Potential pathways of sediment (arrows) may be along the shore or cross-shore down the submarine delta.

(*Elwha Dam Removal continued from page 7*)

In September 2004, **Guy Gelfenbaum**, **Peter Ruggiero**, **Jodi Eshleman** (all USGS), and **Etienne Kingsley** (Washington Department of Ecology) conducted bathymetric and topographic mapping, using a second mapping technique that relies on satellite-based global-positioning-system (GPS) units on land and in watercraft. More than 100 shoreline cross sections were obtained in the September mapping exercises, which will be repeated twice per year through the dam removal. These measurements—along with beach surveys by the Lower Elwha Klallam Tribe at seven sites and aerial photography by the Surfrider Foundation—will be the primary method of tracking changes offshore of the Elwha River mouth.

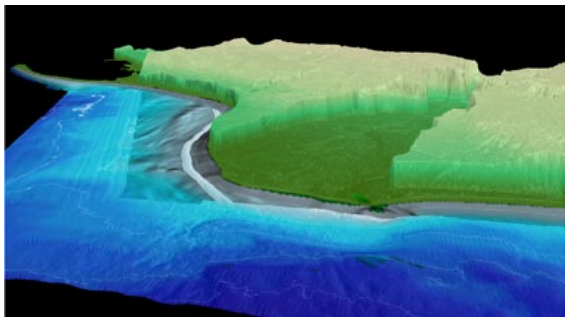
Because oceanographic information about the strait is very limited, the USGS research project will also monitor and numerically model waves and currents in the region offshore of the river mouth. Oceanographic monitoring will begin during spring 2005 with deployments of acoustic Doppler current profilers (ADCPs) and directional wave gauges, which will be used to develop an understanding of waves, tides, and currents that may affect the sediment released by dam removal.

Observations of physical conditions off the river mouth will be used to calibrate and validate a three-dimensional hydrodynamic model of the Elwha River area of the strait currently being developed by **Guy Gelfenbaum** and **Giles Lesser** with Delft3D modeling software (see URL **http://www.wldelft.nl/soft/d3d/intro/**). Modeling is an important part of the research plan because wave and current conditions along the river-mouth delta are expected to vary widely, owing to the complex bathymetry of the submarine delta offshore of the present river mouth. Preliminary results of the circulation modeling show strong eddies offshore of the river mouth, features that are commonly encountered by local fishermen.



Preliminary results of the swath-sonar backscatter mapping (which records the intensity of sound energy reflected from features on the sea floor), showing large sand waves (dark color) over a region of mixed gravel and sand (bright colors). Water depth of observations is approximately 5 m.

The planned mapping, monitoring, and modeling will help characterize the pathways and fate of sediment released from behind the dams of the Elwha River. This information will be crucial in evaluating the impacts of dam removal on the substrate and habitats of the beaches and the nearshore.❁



Combined bathymetric and topographic data for the area of the Elwha River mouth. Bathymetry of the delta is from swath-sonar and GPS measurements. Topography of the land surface is from lidar (light detection and ranging) measurements provided by the Lower Elwha Klallam Tribe. View southeastward. Image created by ***Peter Dartnell*** *(USGS).*

Coral Reef Off Florida Determined to be Deepest Known on U.S. Continental Shelf

By Jennifer Leigh Oates

Consultation with colleagues at numerous national meetings has helped a team of scientists determine that a coral reef off the southwest coast of Florida is the deepest ever found on the U.S. continental shelf. Scientists and graduate students from the University of South Florida (USF) and the U.S. Geological Survey (USGS) discovered the deep coral reef and diverse fish populations while conducting collaborative research west of the Dry Tortugas in 1999. USGS marine geologist **Robert Halley** was on the team that made the discovery.

"Although deeper-water corals form reefs in the dark of ocean depths, [the reef at] Pulley Ridge is the deepest photosynthetic coral reef that we know of today," said **Halley**. The reef lies in approximately 250 ft of water off the coast of southwest Florida on a series of drowned barrier islands collectively named Pulley Ridge. A long, north-trending feature, Pulley Ridge was originally discovered in 1950 when an academic group from Texas conducted dredging and hauled in mollusks. The ridge

(Deepest Reef continued on page 9)

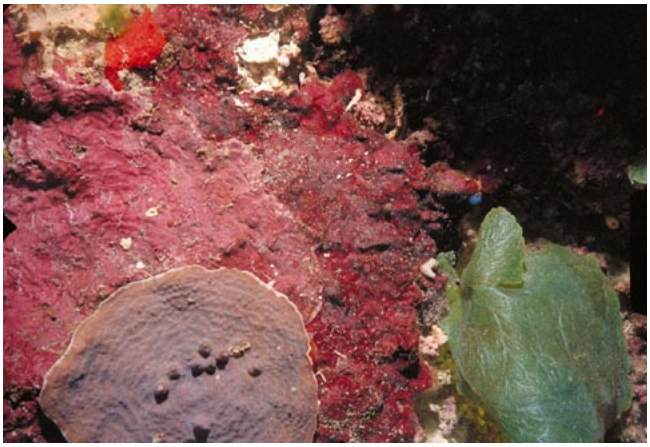
Coral reefs at Pulley Ridge are of particular environmental concern because of their depth, unusual benthic community, and fragility. SEABOSS photograph of sponges and the green leafy alga Anadyomene menzeisii. *Photograph courtesy of* ***Bob Halley*** *and* ***Dann Blackwood****.*

(*Deepest Reef continued from page 8*)

hosts the unusually deep photosynthetic-coral reef on its southern section. The deep coral reef is 20 mi long and 3 mi across at its widest point and covers an island that was submerged 13,000 years ago. It is a significant discovery that may be unique.

The southern Pulley Ridge coral reef has been the subject of several research cruises since its discovery in 1999. In June 2001, for example, **Halley** and USGS research assistant **Kate Ciembronowicz** took part in a National Geographic Sustainable Seas Expedition to the reef during which they collected bottom-sediment samples and used a one-person submersible to shoot video footage (see article in *Sound Waves*, August 2001, at URL **http://soundwaves.usgs.gov/2001/08/**). In spring 2003, USGS and USF researchers used the USGS SEABOSS (Sea Bottom Observation and Sampling System) to collect video transects, still photographs, and coral and algae samples from along the ridge (see article in *Sound Waves*, July 2003, at URL **http://soundwaves.usgs.gov/2003/07/**). The SEABOSS—a modified van Veen grab sampler in a stainless-steel frame with integrated still photography and video systems—is the source of the photographs that accompany this article. Another Pulley Ridge research cruise will take place this year, with USGS scientists joining colleagues from the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University, Corpus Christi, and from the Florida Department of Environmental Protection.

The corals on Pulley Ridge are considerably healthier than those from shallow-water reefs nearly worldwide, including those in the Florida Keys. Corals are normally found in shallower water because they require large amounts of sunlight, but research shows that shallow corals are stressed and vulnerable to disease, global climate change, loss of habitat, and human activity. The Pulley Ridge reef provides pristine habitat for giant red grouper, bass, scamp, damselfish, angelfish, rock beauty, and hogfish. Remote-sensing images, video clips, and numerous color photographs of the area's sea floor, fish, and corals are available online at URL **http://coastal.er.usgs.gov/pulley-ridge/**.



SEABOSS photograph of brown coral, red coralline algae, and the green leafy alga Anadyomene menzeisii. *Photograph courtesy of* ***Bob Halley*** *and* ***Dann Blackwood****.*

Because many of Florida's coral reefs are in decline, the Gulf of Mexico Fisheries Management Council (URL **http://www.gulfcouncil.org/**) has taken steps to protect Pulley Ridge. On January 13, 2005, at a meeting in Baton Rouge, LA, the council voted to make a 100-mi^2 area centered around Pulley Ridge a Coral Essential Fish Habitat. This designation carries with it a set of regulations that prohibit such fishing activities as anchoring, long-line fishing, trawling, and use of buoyed traps or pots. Various activities that do not disturb the bottom, such as drifting over the site and suspending a fishing line in the water, are still allowed.

Red grouper, from underwater video around Pulley Ridge.

Raising Crane at Patuxent Wildlife Research Center

By Tania Larson

Imagine spending your time feeding, nurturing, and teaching the daily tasks of survival to a baby who could never know your true identity. At the U.S. Geological Survey (USGS) Patuxent Wildlife Research Center, employees wear disguises, never use their real voices, and use puppets to deliver food to the baby whooping cranes they care for—all so that these little ones can be released to the wild never knowing they were raised by humans.

The whooping crane is the most endangered crane in the world. In the 1940s, these majestic creatures, which stand 5 ft tall and have a wingspan of 7 to 8 ft, were estimated to have a population of fewer than 20 birds, all part of a single flock. The USGS and its many partners are working to protect wild whooping cranes and their habitat, as well as to es-

(*Raising Crane continued on page 10*)

A three-day-old whooper chick is taught to forage outdoors by a costumed technician using a whooper puppet head. A pocket in the costume holds a recorder playing whooping-crane brood calls. Photograph by ***Kathleen O'Malley****, USGS.*

(Raising Crane continued from page 9)

tablish additional self-sustaining flocks. Current restoration efforts are attempting to establish a new nonmigratory flock in central Florida and an additional migratory flock that will breed at Necedah National Wildlife Refuge in Wisconsin and winter at Chassahowitzka National Wildlife Refuge along the gulf coast of Florida. To tackle the challenges of establishing an additional migratory flock, the USGS Patuxent Wildlife Research Center joined forces with Operation Migration, the International Crane Foundation, and other nonprofit organizations and government agencies to found the Whooping Crane Eastern Partnership (see URL **http://www.bringbackthecranes.org/**).

*A six-day-old whooper chick explores on his own in the safe environment of his pen. Photograph by **Kathleen O'Malley**, USGS.*

At Patuxent, whooping cranes, or "whoopers," are hatched and raised in a carefully controlled environment designed to prepare them for their release into the wild. Employees wearing costumes to mask their human form use a whooper puppet head to teach the chicks to eat and swim, take them for walks, and introduce them to an ultralight aircraft, which will serve as a mechanical parent for their migration. Just before the chicks are ready to fledge—get off the ground on their own and fly—they are transferred to Necedah National Wildlife Refuge in Wisconsin. Fledging there causes the cranes to remember the refuge as their breeding territory. After completing their training in Wisconsin, the cranes are ready for the ultralight-guided migration to their winter grounds. By guiding juvenile cranes on their first migration and showing them the way from Wisconsin to Florida, the ultralight-aircraft pilots teach the cranes a new, safe migration route and reintroduce them to the core section of their historical breeding range.

*A mixed-age group of young whoopers attend Patuxent's "ground school," where they first learn to follow the ultralight aircraft. A costumed technician uses the "robo-crane" head to feed mealworms to the chicks as a reward. Photograph by **Kathleen O'Malley**, USGS.*

On December 12, 2004, costumed pilots in three ultralight aircraft arrived at Chassahowitzka National Wildlife Refuge, leading 13 juvenile whooping cranes to the completion of their first migration. The 1,200-mi trek over seven States took 64 days and turned out to be quite an adventure, marked by battles against bad weather, mountains, eagles, rogue cranes, infection, and other obstacles. In addition to the three ultralight aircraft, the cranes traveled with an entourage of five recreational vehicles (RVs), five trucks, a Cessna 182 aircraft, and a 32-ft equipment trailer. During the expedition, one aircraft is used to lead the flock, while the other two fly behind it, picking up and guiding any divergent groups or stragglers; meanwhile, personnel on the ground stay ready to follow stray whoopers all over the countryside, if necessary—all to ensure that not even the youngest, weakest, or most rebellious juveniles are left behind.

Unfortunately, things don't always go as planned. The cranes training for this year's flight class once numbered 15. Sadly, one crane became sick during the trip, and despite the best efforts of the team and veterinarians at the University of Florida's College of Veterinary Medicine, she was euthanized to prevent further suffering. Another crane was dropped from the ultralight flight class because of developmental and behavorial problems; nevertheless, he made a successful migration later in the season.

The 2004 migration was the fourth annual ultralight-led migration of young cranes. As proof of the program's success, birds from earlier years are migrating north and south on their own. This year, in a preliminary supplemental release study, the juvenile crane deemed unfit for ultralight-flight school was released with some of the adult cranes at Necedah National Wildlife Refuge in Wisconsin to see whether he would make his way south by

(Raising Crane continued on page 9)

*A young whooper raised at Patuxent exercises his wings. Photograph by **Kathleen O'Malley**, USGS.*

(Raising Crane continued from page 10)

following some of the older birds. The juvenile arrived in Madison County, FL, on December 19, becoming the first crane in the new migratory flock to make his first journey south on the tails of older whooping cranes, rather than ultralight aircraft.

Read more about this year's migration, the supplemental release, and the current status of both the juvenile and adult cranes by visiting the Whooping Crane Eastern Partnership Web site at URL **http://www.bringbackthecranes.org/** and following the site's links to Operation Migration and the International Crane Foundation.

For many, the whooping crane is the international symbol of conservation, and the story of this species' recovery from near-extinction is a powerful reminder that, despite numerous obstacles, through partnership and dedication we can make a difference. The Patuxent Whooping Crane project, as part of the Whooping Crane Eastern Partnership, works with individuals, nonprofit organizations, and government agencies from here to Canada to conserve the wild flock and reintroduce new thriving flocks of this stunning bird to the world—and their efforts have had great success. As of December 2004, the last remaining wild flock, which migrates from Wood Buffalo National Park in Canada to Aransas National Wildlife Refuge in Texas, had grown to at least 213 birds, as reported by U.S. Fish and Wildlife Service Whooping Crane Coordinator **Tom Stehn**; the nonmigratory flock in Florida had grown to about 90 birds; and the new migratory flock had 35 adults, soon to be joined by 14 juveniles.

*Juvenile whooping cranes follow an ultralight aircraft piloted by **Brooke Pennypacker** during their 2004 migration from Wisconsin to Florida. This image was captured in Boone County, Indiana, on November 6. Photograph courtesy of **H. Ray** of Operation Migration, Inc.*

For more information on USGS work with whooping cranes, visit the Whooping Crane Reports Page at URL **http://whoopers.usgs.gov/**.

USGS Scientist Studies Causes of Anomalous U.S. Hurricane Landfall Count in 2004

By Jennifer Leigh Oates

A U.S. Geological Survey (USGS) scientist at the Center for Coastal and Watershed Studies in St. Petersburg, FL, has examined climate features likely to have influenced this year's record number of U.S. hurricane landfalls. In an article published as the cover story in the December 14, 2004, issue of *Eos (American Geophysical Union Transactions*, v. 85, no. 50), **Brian Bossak**, a USGS Mendenhall Postdoctoral Fellow, concluded that overall North Atlantic tropical cyclone activity in 2004 was not excessively high. He found that multiple climate features were juxtaposed in such a way as to encourage both hurricane intensification and a track bringing hurricanes ashore south of the North Carolina State line. The state of the El Niño-Southern Oscillation (ENSO) and Atlantic sea-surface temperatures (SSTs) supported an active season in terms of the formation of North Atlantic tropical cyclones. In particular, a climate feature known as the North Atlantic Oscillation (NAO) was implicated in influencing the position of the Bermuda High Pressure system, thereby steering hurricanes on a more southerly track toward the Southeastern United States instead of a track curving out to sea, as has been the case in the past several years. Furthermore, climate features affecting vertical wind shear over tropical regions were favorable for hurricane intensification, explaining the abnormal number of major hurricanes that made landfall in 2004.

*The tracks of Hurricanes Charley, Frances, and Jeanne across central Florida. Lines represent tracks, and point symbols represent eye positions as reported by the National Hurricane Center (of the National Oceanic and Atmospheric Administration's National Weather Service, URL **http://www.nhc.noaa.gov/**).*

Bossak is currently completing work on his pilot project at the USGS, the Coastal Impact Assessment Tool (CIAT), and conducting a statistical verification of observed climate influences on U.S. hurricanes. Stay tuned for further updates on these topics!

2004 Holiday Season—USGS Employees Donate Toys

By Jennifer Leigh Oates

Thank you to everyone at the U.S. Geological Survey (USGS) Center for Coastal and Watershed Studies in St. Petersburg, FL, who donated new unwrapped toys for Christmas gifts! Florida Congressman **C.W. "Bill" Young** was happy that we had collected a large box of toys to be part of a distribution to needy children on his behalf in celebration of his birthday, a yearly custom of the congressman's (see article in *Sound Waves*, March 2004, at **http://soundwaves.usgs.gov/2004/03/staff.html**). **Congressman Young** asked his DC staffer, **Harry Glenn**, to visit the center on December 16 to retrieve the toys.

Harry Glenn *holds a box of donated presents for needy children. Pictured with him are* ***Lisa Robbins****, center director, and* ***Jack Kindinger****, deputy director.*

Carl Goodwin Honored Upon His Retirement from USGS

By Hannah Hamilton

A fond farewell was bid to **Carl R. Goodwin** on December 6 at the National Ecosystem Restoration Conference in Orlando, FL, in recognition of **Carl's** retirement from the U.S. Geological Survey (USGS) after 38 years of service. USGS Director **Chip Groat** and the Florida Integrated Science Center (FISC) Board of Directors paid tribute to **Carl's** decades of USGS work, honoring and thanking **Carl** for his dedicated and enthusiastic service to the USGS, his innovative hydrologic model of Tampa Bay estuary, and his pioneering efforts as a member of the FISC Board of Directors.

Director Groat also honored **G. Ronnie Best** for his efforts in organizing the first National Ecosystem Restoration Conference (NERC). Speakers, poster presenters, and participants from across the country and around the globe attended the meeting, including many USGS scientists and managers.

FISC Board of Directors with USGS Director ***Chip Groat*** *and members of the Eastern Region Leadership Team (left to right):* ***Carl Goodwin*** *(chief, Florida Water District),* ***Lisa Robbins*** *(chief, Center for Coastal and Watershed Studies, St. Petersburg, FL),* ***Chip Groat****,* ***Russ Hall*** *(chief, Center for Aquatic Resource Studies, Gainesville, FL),* ***Pam Malam*** *(Regional Executive for Geospatial Information and the Florida Integrated Science Center), and* ***Suzette Kimball*** *(Eastern Regional Director).*

Oceanographer Joins the Western Coastal and Marine Geology Team

By Curt Storlazzi

Kathy Presto has recently joined the U.S. Geological Survey (USGS) Western Coastal and Marine Geology Team as an oceanographer.

Kathy received her B.S. degree in geology from Boston College and recently completed an M.S. degree in geological oceanography at the University of Washington (UW). While working on her Master's research, she participated in five USGS/UW cooperative field experiments investigating sediment dynamics on Hawaiian coral reefs, and three cruises as part of the National Science Foundation (NSF)-funded MARGINS source-to-sink project off Papua New Guinea (see URL **http://www.margins.wustl.edu/**). **Kathy** gained valuable field experience with hydrodynamics and sediment-transport instrumentation during her work on these projects, and this experience will be beneficial at the USGS, where **Kathy** will be working with **Curt Storlazzi**, **Mike Field,** and others in the Coral Reef Project looking at oceanographic and geologic controls (including terrestrial-sediment runoff) on coral-reef ecosystems in the United States and U.S. Trust Territories.

Kathy's efforts will focus on all aspects of the project, from data collection in the field to processing, analyzing, compiling, and presenting the results of the study.

Those of you on the Menlo Park, CA,

(Oceanographer continued on page 13)

(Oceanographer continued from page 12)

campus might remember that **Kathy** was an ECO (Environmental Careers Organization) intern for the USGS from 1999 to 2001, working with **Mike Torresan** in the Sedimentological Laboratory and with **Monty Hampton** on studies of coastal-cliff retreat as part of the 1997-98 El Niño project. **Kathy** left the USGS in 2001 to head up to Seattle to work on her Master's degree at UW under the guidance of **Andrea Ogston**, whom **Kathy** met at the USGS when **Andrea** was a postdoctoral researcher working with **Dave Cacchione**.

Please come by cubical C-22 in the Pacific Science Center in Santa Cruz, CA, and welcome **Kathy** back to the USGS.❁

***Kathy Presto** uses the "backpack," a mobile benthic/boundary-layer instrument package, to make spatial measurements of flow and terrestrial-sediment resuspension on South Moloka'i's (Hawai'i) shallow fringing-reef flat.*

Birthday Blood Donor in Gainesville, FL

By San Juana Burns

Patricia Burns, daughter of ETI Professionals contractor **San Juana Burns** at the U.S. Geological Survey (USGS), celebrated her 17th birthday by donating a pint of blood at a Life South Community Blood Drive held at the USGS Center for Aquatic Resource Studies (CARS) in Gainesville, FL. Among others donating blood this day were proud mom, **San Juana**, along with USGS employees **Carla Wieser**, **Ron Hill**, and **Hannah Hamilton**, and University of Florida Department of Fisheries employees **Patrick Baker** and **Carla Beals**.

CARS hosts the Life South Blood Mobile every two months, the suggested donating schedule. Donors must be at least 17 years old and weigh at least 110 pounds. On this day, **Patricia** met both criteria.❁

***Patricia Burns** celebrates her 17th birthday by donating blood. Photograph courtesy of USGS-ASCI contractor **Buck Albert**, Florida Integrated Science Center (FISC) Web Administrator.*

Students from the Netherlands Contributing to USGS Studies in Florida

By Tom Smith

Three more students from the Netherlands—**Theo Vlaar**, **Tom Basten**, and **Chris Duynhoven**—have joined the U.S. Geological Survey (USGS)'s Dynamics of Land-Margin Ecosystems project and are working with **Gordon Anderson** in the Florida Everglades. All three are enrolled at Larenstein University of Professional Education in Velp, the Netherlands. Over the years, we have had many fine interns from Laurenstein (for example, see article in *Sound Waves*, November 2004, at URL **http://soundwaves.usgs.gov/2004/11/staff2.html**). **Tom** and **Chris** will be with us through March; **Theo**, who is doing research for his Master's degree, will be here through May.❁

*(Left to right) Dutch students **Chris van Duynhoven**, **Tom Basten**, and **Theo Vlaar** sitting on the pontoon of the helicopter that carries them from site to site during fieldwork.*

Sights and Sounds of Nature at the Florida Integrated Science Center, Gainesville, FL

By Hannah Hamilton

The Florida Integrated Science Center (FISC) facility in northwestern Gainesville, FL, is located on 28 acres of University of Florida research lands away from the bustle of town and campus. Reaching the center requires traveling along Millhopper Road, an Alachua County Scenic Roadway. If you approach the center from the east on Millhopper Road, you can stop at Devil's Millhopper Geological State Park before you arrive; if you approach from the west, you can visit San Felasco Hammock Preserve State Park, which borders FISC lands on the north and west.

Completed in 1984, FISC Gainesville-West has 20 research ponds, five freshwater wells, and the uncommon and invaluable features of two 4,000-ft^2-area wet labs for controlled indoor aquatic experiments. The facility is used for research on estuarine and freshwater fishes, mussels, and other benthic invertebrates, amphibians, reptiles, and birds.

Birdwatchers at the center are often rewarded not only with bald eagles but also with other daytime hunters, such as red-tailed hawks, red-shouldered hawks, and ospreys. There are resident purple martins and bluebirds. Kestrels, egrets, anhinga, grackles, and blue herons are common sights. Wild turkeys are seen passing through. Depending on the time of year, visitors and employees may see sandhill cranes at the ponds, a welcome sight, heralding the change of season.

On warm sunny days, a walk around the ponds may yield the sight of turtles, including Florida cooters and Florida red-bellied turtles, taking in the sun or plunging below the surface for cover. A look in another pond may allow you to glimpse a young alligator diving to avoid detection, so that it can continue enjoying the free and easy meals to be had in research ponds full of fish. In the summer, black-bellied whistling ducks raise ducklings in the ponds. In the winter, hooded mergansers take a break at the ponds, and on any given day you may see five, or 25, gathering. Other migrating visitors include wood storks, blue-winged teal, and red-winged blackbirds.

*Bald eagle perching in a loblolly pine at the FISC facility in Gainesville, FL. Photograph by **Buck Albert**.*

*Purple coneflower at the FISC facility in Gainesville, FL. Photograph by **Shane Ruessler**.*

Water moccasins and banded water snakes keep to themselves around the ponds. Corn snakes, black racers, yellow rat snakes, five-lined skinks, and green anoles are found on the grounds and are sometimes feasted upon by the birds of prey.

Visiting the center is not only a visual experience but also an auditory one. Green treefrogs, squirrel treefrogs, spring peepers, American bullfrogs, and barred owls can be heard calling.

Deer are less frequent than in years past but can still be seen from time to time in front of the facility munching on anything edible. Some evenings a red fox may be sighted trotting across the property, or rarely, an alligator walking across the parking lot. They are perhaps seeking the other facility residents for dinner: rabbits, opossums, armadillos, and raccoons.

In an effort to be an unobtrusive part of the landscape and provide safe haven for native animals, employees at the center use only native plants to improve existing habitat and to create new habitat for native songbirds and butterflies. Under the direction of resident biologist **Shane Ruessler**, invasive plant species are being removed and replaced by natives. To date, 20 endangered native-plant species have been added to the landscape. The result is a visually and environmentally friendly place.

*Swallowtail larva on fennel at the FISC facility in Gainesville, FL. Photograph by **Shane Ruessler**.*

Building Bridges with Future Neighbors—National Marine Fisheries Service Regional Office

By Jennifer Leigh Oates

Two employees from the National Marine Fisheries Service (NMFS) Southeast Regional Office headquarters visited the U.S. Geological Survey (USGS) Center for Coastal and Watershed Studies in St. Petersburg, FL, on December 3. PowerPoint presentations explaining the roles and responsibilities of NMFS and its parent agency, the National Oceanic and Atmospheric Administration (NOAA), were given to increase the number of cooperative projects between the USGS and NMFS. The NMFS Southeast Regional Office headquarters plans to move to the University of South Florida (USF) campus in downtown St. Petersburg in 2005. Approximately 53 USGS employees attended the presentations. **Lisa Robbins** (USGS center director) had presented an overview of the USGS Florida Integrated Science Center (FISC) to a NMFS group in August 2004 (see article in *Sound Waves*, October 2004, at URL **http://soundwaves.usgs.gov/2004/10/staff.html**). To reciprocate the favor, **Buck Sutter** (Deputy Regional Administrator of the NMFS Southeast Regional Office) and **Michael Henderson** (NMFS Regional Coordinator) spoke to USGS employees.

(Left to right) ***Michael Henderson, Lisa Robbins, Buck Sutter,*** *and* ***Jack Kindinger*** *(USGS center deputy director).*

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