OceanBights

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The Catalina Marine Society is a nonprofit membership corporation founded in 2009 in Los Angeles to marshal volunteer resources to study the marine environment of Santa Catalina Island and the Southern California Bight.

Submissions. The magazine may publish submitted articles that pertain to our mission statement. Contact the e-mail address below for more information.

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Editorial: Terraforming 'Bu Lagoon

If you travel across Malibu on Pacific Coast Highway, you may not notice Malibu Lagoon. It is a mere 13 acres between the terminus of Malibu Creek, whose headwaters are 25 miles upstream, and the landward side of the famous Surfrider beach, which can be seen from the mountain pass through which Malibu Canyon Road is built. That such a small estuary is now considered an important component of our coastal wetlands is a sad commentary on our times. The lagoon was recently reconfigured after much legal wrangling that perhaps foreshadows much future debate on larger projects.

As near as I can figure, there are 3 categories of interested parties; there are those who wish to restore native habitat; there are those are wish to maintain the ecological status quo; and, there are the historical recreational users (surfers). The arguments put forth by the various parties are reminiscent of those I heard a decade ago regarding the disposition of offshore oil platforms at the end of their service life.

The Lagoon began evolving away from being a "natural" estuary about 200 years ago, when the area was used to run cattle, an industry that substantially changes the native flora and fauna. The Creek was dammed in 1925, which both limited the salmon run to the downstream edge of Rindge Dam as well as reduced the flow of the creek. Additionally, the lagoon was reduced in size when construction materials were dumped there, forming a base for recreational ball fields.

The mouths of small rivers and creeks are often closed naturally by the alongshore transport of sand by ocean waves. They are opened by sufficient water flow which, in Southern California, occurs seasonally during the rainy months.➔*Continued page 5*

Spotlight on: Malacology at Museum of Natural History

Researching our Los Angeles County Natural History Museum (NHM) in Exposition Park, I was struck by superlatives: the **second largest collection of marine mammal specimens in the world; the fourth largest collection of crustacea in the world; outstanding collections for Ichthyology, Malacology, Polychaetous Annelids, invertebrate paleontology and echinoderms**, plus a Marine Biodiversity Center. The museum achieved this status in just 100 years. Comparable institutions, such as the British Museum, founded in

1753, and the American Museum of Natural History in New York, founded in 1869, had a considerable lead time in building their collections. However, our museum was given a head start with contributions from four local organizations, including the Southern California Academy of Sciences, Historical Society of Southern California, the Cooper Ornithological Club and the Fine Arts League. The NHM now consists of 3 separate museums: William S. Hart Park in Santa Clarita, the Page on Wilshire and the Natural History Museum across from the Coliseum. With so much material I decided to focus on just one section, Malacology, or the study of shells.

Lindsey Groves (Malacology) and Dr. Jody Martin (Crustacea) were kind enough to invite me to come to the museum and chat with them. I thoroughly enjoyed the visit. Without knowing much about museums, I can sense that they are special places by the excitement found in their staff regarding their work and the mission of the museum. Walking into the staff entrance and proceeding up the elevator to the third floor, one gets that old timey museum feel, though without the musty smell. That is, it felt like a museum of natural history is expected to feel like.

Lindsey heads the Malacology Department which, as described by the museum "…promotes the scientific study, conservation, and acquisition of extant mollusk species including gastropods (marine, terrestrial, and freshwater snails and slugs), bivalves (marine and freshwater clams), cephalopods (octopus, squid, cuttlefish, and nautilus), polyplacophorans (chitons), scaphopods (tusk shells), aplacophorans (wormlike mollusks), and monoplacophorans ('primitive' limpetlike snails). The collection is worldwide in scope with an emphasis on the eastern Pacific Ocean (arctic Alaska to southern Chile) and includes an estimated 500,000 lots containing approximately 4.5 million specimens." That's a lot of specimens.

Lindsey Groves searching the collections.

Being out in the malacology collection is when the immensity of the number of specimens is felt. A portion of the collection is moving to another location and some of it currently resides in the hallways, emphasizing the impression that the museum is stuffed with material.

I always like to get a feel for an institution, so I asked questions about the organization, funding, and working conditions. As typical for county entities, the museum is strapped for money and many positions go unfilled. This is especially the case for curators, who produce original research, often based on the museum specimens. Curators are not to be confused with the collection managers, who take physical care of the museum's specimens. This staffing shortage provides lots of opportunities for volunteers, and while I was in the office, so was a volunteer, Janice Lipeles, examining a box of material though a dissecting microscope and separating shells from debris. The box was sent to the museum by U.S Geological Survey colleague Daniel R. Muhs. The museum gets much of its material this way, by researchers on collecting trips, providing material that would perhaps be too expensive to acquire in a non-incidental matter.

Of course, I asked to see the malacology collections and was treated to view hundreds, if not thousands, of shallow sliding drawers holding boxes (of varying sizes but just a few inches deep) containing the specimens. Each box had a typewritten or computer-generated label describing the specimens in the little box, locality data and the origin of the specimens and the donated collection, if applicable. From one of the first drawers opened, I spied a fossil mollusk marked as being from Elsmere Canyon. Elsmere Canyon is a small canyon within May Mountain, the westernmost mountain of the San Gabriel's, and a mountain that I have hiked hundreds of times, always with an eye for fossils. I have only found them in Elsmere Canyon and apparently these fossiliferous strata are of geologic interest (and informed it was Miocene, much older than I had guessed).

Mr. Groves is an expert in Cypraeidae (cowries and kin) and clearly a busy guy as I read of several new species he worked up. It can take weeks of dedicated effort to determine whether a specimen is a new species. To physical scientists like myself, finding and naming a new species (even if it has been extinct for millions of years) epitomizes a level of achievement we cannot hope to reach, and so we remain in awe of our fellow life (and past-life) scientists.

I focused on a specific issue to get a better feeling for research enabled by the museum and with the goal that context and details would be recognizable to our readers. Lindsey directed me to a study of historic ocean temperatures as determined by analysis of fossil orange cup coral (*Balanophyllia elegans*). These solitary corals and others closely related to them (e.g., the brown cup coral) are the only corals found off Southern California. Understanding the effects of global warming on our local ocean is a grand contemporary issue as discussed in an adjacent article. We can get some handle on the effects of ocean temperatures by understanding the zoogeography. An assemblage of animals is slanted toward warm water species where the water is warm and colder-water species where the water is cool. This phenomenon is well known in the Southern California Bight as it has a large temperature gradient between Orange County and Point Conception (where are your spiny lobsters?).

Visitors Charles Drost (L) and Sky Bischoff-Mattson (R) [USGS] examining land snails from San Clemente and San Nicolas islands.

The same principle probably held in the past so if an assemblage of species from a particular time period can be discerned, we can estimate the relative ocean temperature for that period. Fossil assemblages are conveniently found in marine terraces. Marine terraces, or benches, are produced by wave action on the coast. Waves pound the shoreline, forming a relatively flat regions just off the coast, that are subsequently exposed or submerged by changing sea levels and tectonic movements. One can see a bench forming under the cliffs of Point Fermin, and recognize others as coastal landforms, including Pacific Coast Highway, particularly in Malibu. Of course San Clemente Island is noted for a series of such benches, observed with fondness by the diver's eye as he approaches by boat. But perhaps less well known are the terraces on Palos Verdes, of which there are 13 described.

Coral specimens found in marine terraces are used to date the terrace. Each terrace also will contain an assemblage of marine fossils laid down when the terrace was underwater. The interval when the terrace was underwater can be determined from isotopic analysis of the coral found in the shelf. The coral skeleton contains trace amounts of radioactive uranium whose decay products can be used to date the time when the animal was alive. If the fossils are related to present-day species whose territorial limits are known, i.e., northern cold-water species or southern warm-water species, the relative ocean temperature when and where the bench was formed can be deduced. This information is used to understand some of the local effects of climate change. Indeed, such analysis has indicated that the eastern Pacific was cool at the end of the last interglacial period, some 80,000 years ago.

To do this analysis, large numbers of specimens from marine terraces must be analyzed, and these large numbers are only found in museums with extensive collections. Such studies indicate the utility of deep collections held by the museum as well as the efforts of the curators to analyze and understand their specimens.■

➔*Editorial, continued*

Upstream, there are nutrient inputs from local agriculture and water treatment plants. These are monitored by Heal The Bay's Stream team as discussed in an earlier issue of *OceanBights*. When these nutrients reach the lagoon, they feed large algal mats and contribute to eutrophication, producing water with low oxygen content, as there is no tidal flushing when the mouth is obstructed, nor large surface areas available for the wind to mix the water by generating surface waves. As a result, the lagoon presented nasty water that contrasted with its historical composition. An argument is made to restore the lagoon to be similar to past conditions.

In spite of the unappealing water, a survey several years ago with seine nets turned up several kinds of fish, including endangered tidewater gobies (*Eucyclogobius newberryi*), topsmelt (*Atherinops affinis*), opaleye (*Girella nigricans*), shrimp (*Palaemon macrodactulus*) and some freshwater species. In addition, a small population of reproducing steelhead trout was known to exist upstream. Arguments were made that the lagoon was a functional ecosystem, consistent with its latitudinal location and size, and that re-engineering it would destroy endangered species that were apparently thriving in

Re-configured Malibu Lagoon at low tide.

Malibu.

Finally, some surfers were concerned that changing the lagoon would affect the nearby undersea topography and endanger or modify the "wave" that attracts surfers. The sand disposition depends on where the berm is breached and has significant impact on the quality of the surf. Other surfers thought that the quality of the "wave" has decreased over the decades perhaps because there was little sand deposition from the dammed creek.

Similar arguments were put forth regarding the deposition of end-of-life oil platforms. Should they stay or should they go? They are apparently beneficial to fish, as discussed in previous *OceanBights* articles, a great boon to SCUBA diving, but clearly are unnatural. The decision is the rigs-to-reef program, where the underwater components of the decommissioned rigs are permitted to remain.

The 'bu lagoon has been remodeled before, apparently unsuccessfully. And, the sand berm has been intentionally (and illegally) breached, which is thought to contribute to urchin die offs as described in a recent article published by the Southern California Academy of Sciences. Hence, how successful a new effort will be is not evident.

Recently, the lagoon was reengineered. Besides the cabanas and educational outreach signage, the major change was the increased surface area of the lagoon. A recent late-night personal survey did not find grunions running according to schedule but did find shorebirds on the lagoon side of the sand spit – a good sign.

I put the question to our readership, how do you feel about modifying the local environment? The issue really pertains to the larger environment. We have been effectively terraforming the earth for centuries. With climate change becoming more evident, more schemes are being studied to reduce global warming, including tampering with the primary production of the oceans, adding reflective aerosols to our atmosphere, etc. How do you feel about these issues? Send us a note or longer piece describing your thoughts and reasoning.■

Adopt-A-Thermograph Program

The CMS is seeking donors and site managers for its Adopt-A-Thermograph program. These sponsors will extend and complete the Continental Thermograph Array that is currently under development.

Participants will donate the minimum cost for a single thermograph setup, currently totaling $150. The Catalina Marine Society will supply the sensors and associated mounting hardware and will perform QA and calibration procedures on the sensors before they are deployed and when they are retrieved. The sponsors, if they desire, may also be the site manager, providing the resources for deploying and retrieving the thermograph, or have the CMS arrange for the diving.

The Adopt-A-Thermograph is directed by David Tsao. For more details, contact David at david@catalinamarinesociety.org or Craig at craig@catalinamarinesociety.org.

Bobby Meistrell Passes

We are saddened by the news that Bobby Meistrell died on Father's Day on his boat offshore Santa Catalina. Bobby was well known to the Southern California Diving and Boating community.

We remember Bobby as a generous soul who both encouraged our work and opened his house for non-profit group meetings. Along with his house came a viewing of his extensive shell collection and sampling of his bourbon. I'm having one now, thinking of him.■

Leopard Sharks in La Jolla

By Andrew Nosal

Reflecting on the recent completion of my doctoral dissertation at Scripps Institution of Oceanography, I appreciate how much of my success I owe not only to my mentors, friends, and family, but also to the lowly leopard shark, which, prior to 2006, I had never even heard of.

While an undergraduate at the University of Virginia, I did a summer internship at the University of Southern California in 2006. My summer project involved sequencing amino-acid transporter genes and assessing density-dependent stress in oyster and sea urchin larvae, which necessitated a 5-week stay at the Wrigley Institute for Environmental Studies (WIES) on Santa Catalina Island. I am deeply grateful for the invaluable genetics and laboratory training I received during this internship (and sea urchin larvae were especially interesting to study—they look like swimming Apollo lunar modules); however, I could not envision a lifelong career studying these microscopic critters. I yearned for something more.

After a week or two on the island, I learned that a group of leopard sharks routinely gathered in the shallows along a cobble beach just south of the WIES pier. I had never seen or even heard of a leopard shark. What came to mind initially was the epic jaguar shark from the *Life Aquatic with Steve Zissou* (Google "jaguar shark" if you have not seen this quirky Wes Anderson film). Unlike the fictional jaguar shark, which ate Zissou's best friend, the real-life leopard shark was apparently harmless, having only been implicated in one "attack" on a human in the 1950s, which was hardly unprovoked. A spear fisher cornered a leopard shark and, in a panicked attempt to flee, the fish bumped the fisher and gave him a bloody nose. I cannot say I blame the shark. Fearing at worst a bloody nose, I decided to venture into the water to share the company of these sharks, somehow hoping to be mystified like Steve Zissou in the final scene of *Life Aquatic*. I was not disappointed.

Dr. Andrew Nosal

One afternoon in July I donned a mask, snorkel, and fins and jumped into the chilly water from the WIES pier, accompanied by another intern. As we started to make the 100-foot swim south to the cobble beach, the visibility declined to about 15 feet and I grew a bit weary, scanning my surroundings in all directions. Then, I saw my first shark! At first it was just a split-second glimpse of a silhouette that could not be mistaken for any other animal. As I drew nearer to the beach, a shadow materialized into a leopard shark—spots and all! **One shark became two and then three**. A few seconds later I heard the other intern scream through her snorkel. The muffled sound of terror made me laugh, which caused water to rush into my mask. Pulling my head out of the water to drain it I noticed my snorkeling buddy was 30 feet behind me and had just seen her first shark. When I put my head back into the water, 50 leopard sharks surrounded me, each 4 – 6 feet long, in only chest-deep water.

At first I was giddy with excitement, but I soon relaxed and soaked in this amazing sight. I watched as the sunlight filtered through the water and glistened over the leopard sharks' writhing bodies. The combination of mulberry saddles and spots of its namesake appeared unique to each shark, like a fingerprint.

The sharks glided smoothly through the water, maneuvering around each other like little fighter jets, less than one inch off the bottom. I found the large fish to be surprisingly skittish and difficult to approach, but when I floated motionless on the surface the sharks came to me and did not appear threatened by my presence. The best word to describe my encounter with these sharks is sublime—the feeling that transpires upon entering a majestic architectural wonder, viewing a space shuttle launch, or listening to Beethoven. It is a feeling that manages to unify humility and exaltation in the heart and mind of a human being. Steve Zissou, eat your heart out!

After an hour of admiring these fish I became cold and swam back to the WIES pier to sit on the warm deck. I lowered my mask around my neck and peered back toward the cobble beach, exhaled and reflected on my newfound love and appreciation for sharks. Little did I know as I returned to the laboratory up the hill to resume counting oyster larvae, that in the near future I would be studying this very species and trying to understand why they form these groups, or aggregations, in shallow water.

Leopard Sharks gathering in La Jolla. Courtesy of the author.

Fast-forward one year and I am on a 17-foot skiff off La Jolla with my lab mate waiting for a thresher shark to bite our baited line. This was an unremarkable, dinky little boat that needed more than a fresh coat of paint (I had yet to learn the challenge of getting research money to fund things like boat upkeep.) A few weeks earlier I started my Ph.D. at Scripps Institution of Oceanography and was helping my lab mate catch and acoustically track juvenile threshers. I knew I also wanted to study sharks but needed to pick my own project. My lab mate mentioned that **tons of leopard sharks came every summer to the southern end of La Jolla Shores Beach**, in front of the historic Marine Room restaurant, and that there might be an interesting dissertation subject there.

After my experience on Catalina Island, I did some digging and learned that leopard shark aggregations were actually quite common, but seemed to be limited to sheltered bays and coves, such as Humboldt Bay, San Francisco Bay, Elkhorn Slough, and of course Big Fisherman's Cove near WIES. This discovery made the aggregation in La Jolla seem peculiar because it did not occur in a sheltered bay or cove, but rather along the open coast in the surf. Why were the leopard sharks attracted to the La Jolla site where the only remarkable feature was an offshore submarine canyon? Could the canyon have something to do with the sharks' presence? Could studying this anomalous leopard shark aggregation actually reveal commonalities among all aggregations to explain why they occur? I posed these questions to my dissertation advisor and piqued his interest; he gave me the green light to proceed with the project, which would take the next five years to complete.

First, who were these leopard sharks, demographically speaking? What percentage was male and female? Were they mature or immature? From my observations snorkeling with the sharks in La Jolla, as well as on Catalina Island, they appeared to be adults, but the only way to determine sex would be to catch them and check for finger-like claspers on the underside, which are unique to males. The next few summers I fished for leopard sharks at this site, which required special permission from the California Department of Fish and Wildlife, because the site is located within a no-take marine reserve. Fishing at this site was tricky for a number of reasons. The sharks were often swimming in 2 – 4 feet of water, which meant they were often at or inside the surf line, where we needed to cast our lines. Maneuvering a 17-foot boat near the surf was a delicate task that required careful and unceasing vigilance of our fishing lines, the incoming swell (which varied as the tide moved in and out), and the hoards of snorkelers and kayakers that were there to enjoy the sharks, but were often oblivious to our presence and operation. If a shark became hooked and started swimming circles around the boat, the monofilament line cutting through the water would have mowed down anything in its path, including tourists. Oh yeah, and we had to always be polite and assure the locals we were not poachers. To be less conspicuous and not to draw unwanted attention we fished with hand spools (a plastic ring wound with line) instead of a pole and reel.

Tagging sharks. Courtesy of the author.

For every shark captured, the length and sex were determined, and just prior to release it was tagged with a spaghetti identification tag with contact information in case someone else captured it in the future. Between 2007 and 2011 I captured 140 leopard sharks in La Jolla. All were sexually mature (more than 110 cm, or about 3 feet, long) and 97% were female. Thus, contrary to popular belief, these leopard sharks are not here to mate, otherwise we would have caught more than just 3% males. The lack of juveniles also suggested the sharks were likely not here to give birth. I should mention at this point we conducted ultrasounds on a number of these females and all were found to be pregnant. So what then were these mostly pregnant females doing in La Jolla, if not to give birth?

I approached this question by using active acoustic tracking to elucidate fine-scale movement patterns on the sharks in and around La Jolla. I attached an acoustic transmitter tag (or pinger) to the base of the dorsal fin of eight leopard sharks. Each transmitter had a depth sensor and emitted a continuous pinging sound underwater at a frequency inaudible to sharks, but audible to a properly tuned hydrophone and acoustic receiver mounted to our 17-foot rinky-dink boat. Sharks were tracked one at a time; I followed each shark for 48 hours by following the sound of the pings and every five minutes recorded the GPS position and the depth of the shark.

The tracked sharks remained in very shallow water during the day (2 – 4 ft), in front of the Marine Room restaurant, but at night dispersed away from the aggregation site to deeper (up to 150 ft) and colder water, particularly in and around the offshore submarine canyon. I suspected they were feeding during these roundtrip nocturnal excursions, most likely on small squid, which spawn in the canyon at night. To test this, we conducted **a diet analysis on the La Jolla leopard sharks using a non-lethal method called gastric lavage**. This involves inserting a PVC tube into the shark's stomach, flushing it with seawater, and then inverting the shark to allow the stomach contents to flow out of the tube and into a strainer. After 70 sharks, the dominant food item was clearly squid (along with a smattering of fish parts, octopus, and various crustaceans). One of the reasons for the leopard sharks aggregating in La Jolla was becoming clear. There was a rich and predictable food source nearby in the form of squid spanning grounds in the canyon. However, I soon discovered the submarine canyon was even more important.

Because of the shape and orientation of the canyon, **wave energy is refracted (diverted) away from the canyon head, where the leopard sharks aggregate**, producing there an area of exceptionally low wave height called a divergence, or "shadow," zone. Except at night, the tracked sharks did not venture outside of this zone. I believe these calm conditions (the calmest along the immediate coastline) allow the sharks to more easily enter the warm shallows near the surf; at other locations they would be pummeled by large waves if they dared to approach the shore. These findings are consistent with the widely held belief that pregnant female sharks are attracted to warm water because the resulting increase in their body temperature (leopard sharks are ectothermic, or "cold-blooded") may accelerate embryonic development and thus minimize the gestation period (already 10-11 months).

In addition to the fine-scale movement patterns ascertained by actively following sharks tagged with transmitters, I also wanted to know about the seasonal patterns of aggregation behavior and whether the same individuals returned year after year. This information was ascertained by passive acoustic tracking, in which 22 females were surgically implanted with coded transmitters; stationary (moored) underwater acoustic receivers "listened" for surgically implanted sharks that swam within detection range (about 1000 ft) and automatically recorded the time, date, and code for any shark swimming by. Receivers were deployed from the Mexican border to Los Angeles including of course the La Jolla aggregation site. In this case, transmitters were surgically implanted because the sharks would be monitored for over three years and any external tag would almost certainly become tangled in kelp or sea grass or otherwise be scraped off on a rock. Sharks were caught and placed on their backs to induce tonic immobility, a natural state of relaxation we used for anesthesia. The transmitters were inserted into the shark's body cavity through a small incision and then stitched close with dissolvable sutures.

Consistent with the hypothesis that these females are attracted to warm water, the sharks were most abundant in La Jolla in late afternoon when water temperature was highest. This pattern also persisted on a seasonal scale, with shark abundance being highest in late June – early December, peaking in August and September when water temperature was highest. The "high" aggregation season also coincided with seasonally low swell height and southwesterly swell, from which the Point La Jolla promontory shields the aggregation site.

As for where the sharks go during the winter, about half of the surgically implanted sharks remained near La Jolla and were detected year-round, albeit more sporadically during the "low" season of late December – early June. The other half swam north along the coast and was detected south of Los Angeles along the mainland, except for two sharks that were detected by a receiver in Big Fisherman's Cove on Catalina Island. This was an interesting observation that demonstrates the mainland and island populations are not isolated and provided an interesting contrast with the general supposition that leopard sharks are "nearshore benthic"; that is, the leopard shark occasionally behaves as pelagic species swimming amongst the likes of mako and blue sharks in the open ocean between the island and mainland. Despite these winter departures from La Jolla, most sharks returned the following year. In fact, over the three-year monitoring period, at least 50% of the surgically implanted females returned annually and continue to be detected today.

Apparently, the two most important factors explaining leopard shark aggregations in La Jolla and elsewhere are having easy access to feeding grounds and calm warm water. Although the La Jolla site is not a sheltered bay or cove, it mimics environments such as Big Fisherman's Cove, due to the anomalously calm conditions created by the offshore submarine canyon. Lastly, from a conservation perspective, the La Jolla and WIES aggregation sites clearly benefit as no-take reserves; this will ensure these pregnant females are protected during this vulnerable time and allow snorkelers and kayakers to enjoy these animals.

The past five years have been the most fun and interesting of my life. The most important lesson I took away is exemplified by the old adage, "hope for the best and prepare for the worst." Conducting fieldwork is very complicated and never goes as planned, especially with our beloved piece-of-junk boat. The engine stalled numerous times leaving us stranded and needing a tow back to Scripps pier. Once, during a track the engine cut out and we had to continue the track by rowing, while on another occasion the steering got jammed in the full-over position causing us to buzz around in circles and lose the shark. But that little boat, although the bane of my existence, carried me through my dissertation. I just had to be realistic, so that I would be pleasantly surprised if nothing went horribly wrong. In the end, if the boat did not sink, explode, and no one got hurt, *that* was a good day. ■

SLUGS!

The Society is proud to host a free lecture on Opisthobranchs (nudibranchs) given by our local expert Kevin Lee. Enjoy Kevin's fabulous images of the critters as the renowned photographer and adventurer discusses local nudibranchs, including details of their diet, camouflage and other elements of their natural history. Light refreshments will be served.

Saturday, 2 pm, August 24 at Cabrillo Aquarium Auditorium in San Pedro

Sea-Level Rise and Coastal Erosion in the Southern California Bight

By Mary Ann Wilson & D. Gordon Kelly

Climate change, specifically global warming, is producing rising sea levels worldwide. But how rapidly is sea level increasing off southern California and how will it affect us? Global sea levels are projected to rise as much as nine inches by 2030, one and a half feet by 2050 and four and a half feet by 2100. Most of this rise is expected to result from the melting of the Greenland and Antarctic Ice Sheets, which store the equivalent of nearly 200 feet of sea level. The onset of deglaciation which began 20,000 years ago slowed to a stop 2000 years ago, then resumed at modern rates sometime between 1840 and 1920. Since 2006, that rate has accelerated.

So far, sea level in Southern California has risen at a slower pace than the global level. However local sea-level increases are expected to surpass the global mean rise, increasing by one foot in 20 years, two feet by 2050 and as much as five and a half feet by the end of the century.

That's because much of California is sinking from the effects of an ice sheet that has long since disappeared. During the last ice age, an ice sheet depressed northernmost Washington, creating uplift around it. Since the ice melted, the flexure in the continental plate began to slowly release, causing uplift in northernmost Washington and subsidence in the rest of Washington, Oregon and California.

Mary Ann Wilson and D. Gordon Kelly

For the coast north of Cape Mendocino, tectonics offset that subsidence. Ocean plates are descending below North America at the Cascadia Subduction Zone, causing regional uplift along much of the Washington, Oregon, and northernmost California coast. Global Positioning System (GPS) measurements show this area is rising about 1.5–3.0 mm per year (or 5.9–11.8 inches each century).

However, south of Cape Mendocino in the San Andreas Fault Zone, tectonic plates move horizontally, creating little vertical motion. GPS measurements (which also measure compaction of wetland sediments, and/or fluid withdrawal or recharge), indicate this area is sinking at an average rate of about 1 mm per year (or 3.9 inches each century), though GPS-measured rates vary widely across locations. Records from 12 West Coast tide gauges concur — most gauges north of Cape Mendocino show that relative sea level has been falling over the past 6–10 decades, and most of the gauges to the south show that relative sea level has been rising.

Regional sea-level rise also varies due to local factors affecting the dynamic height of the sea, such as wind, air pressure, and surface-heating influence of climate patterns such as the El Niño/La Niña–Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). These result in changes in ocean circulation on seasonal and multidecadal timescales that involve redistributing mass by altering the temperature and salinity of the upper ocean.

These climate patterns may also explain why California has not yet experienced the same sea-level rise as measured around the globe. Satellite altimetry, tide gauge, and ocean temperature measurements show a long-term increase in sea level off the U.S. west coast. According to Dr. Peter Bromirski's 2011 study, trends along the West Coast — estimated from tide gauge measurements and confirmed by satellite altimetry since 1992 – signify relatively flat sea levels since about 1980. The study points to the Pacific Decadal Oscillation (PDO), which alternates between positive and negative phases. Presently in the positive phase, wind-driven ocean currents draw water away from the west coast and pull colder, denser water up from the depths (upwelling), depressing the sea level for the eastern Pacific. If the PDO shifts, as Bromirski suggests it may be doing, the associated wind patterns would shift, reducing upwelling, which could accelerate sea-level rise back to global rates or beyond.

Satellite altimetry records assessed by the Intergovernmental Panel on Climate Change (IPCC) also showed that sea level fell about 0–6 mm each year from 1993 to 2003 along the west coast. The IPCC suggested that the largest fraction of this short-term variation was caused by ENSO. But note that ENSO and the PDO do not act independently of each other. ENSO may play a significant role in decadal and longer sea-level variability. While ENSO can influence the PDO, the PDO can modulate tropical Pacific circulation as well as ENSO.

Higher baseline sea levels could add to storm levels, making extremes more common, leading to more coastal flooding and erosion, inundation, wetland loss, structural damage, and salinity intrusion into coastal aquifers. Add a large El Niño event, and coastal sea levels could rise an additional four to 12 inches for several winter months.

Coastal erosion hits home.

The largest waves have been getting higher and winds have been getting stronger in the northeastern Pacific, according to several observational studies. But wave and wind records go back only about 35 years, and to some extent reflect large El Niños and PDO fluctuations. If proven to be a long-term trend, the frequency and magnitude of extremely high coastal wave events will increase. But if not, sea-level rise will still magnify the impact of storm surges and high waves on the coast. What is currently defined as a 100-year flood today will occur much more frequently as sea level rises and the number of people exposed to risks from 100-year floods will increase substantially. We do have evidence from tidal gauges that tidal ranges are trending up in Southern California, mostly in La Jolla. Coincidentally, the occurrence of high sea-level storm extremes has increased at La Jolla 30-fold since 1933.

To some extent, marshes and mudflats protect our inland areas from storms by storing flood waters and damping wave height and energy. They also offer refuge and forage for wildlife, fishes, invertebrates, and millions of migratory waterfowl. Wetlands also help absorb nutrients and reduce loading to the coastal ocean. To continue doing this **as sea levels climb, marshes must rise**, too, which requires a sufficient supply of sediment and accumulation of organic material. But for urbanized wetlands such as Ballona Creek, the sediment supply may be too low, and accretion could very well trail sea-level rise. Habitats, often hemmed in by development, would have to retreat landward to survive, with few places to go.

Cliffs and bluffs, the dominant feature of the west coast, have been slowly retreating for thousands of years. Their rate of erosion depends on what they are made of as well as external forces. Cliff and bluff retreat happens periodically and suddenly from a variety of forces. Large blocks fail under heavy rainfall, large waves, or earthquakes. In steep, mountainous areas, failure is often through large landslides or rock falls, usually driven by excess or prolonged rainfall during the winter months. One example is the slide that occurred in November of 2012. A 600-foot section of Paseo Del Mar in San Pedro below the White Point Nature Preserve suddenly dropped down the cliffside. It was the most damaging landslide on the Palos Verdes Peninsula since the 17th and 18th holes fell to the beach in 1999 from what's now Trump National Golf Club.

A rising sea level would cause waves to break closer to the coastline and reach the bases of cliffs or bluffs more frequently, thereby increasing the rate of cliff retreat. According to one recent study, a 40" sea-level rise would accelerate erosion rates for southern California by 20 percent. The California Coastal Commission states that for gently sloping beaches, the general rule of thumb is that 50 to 100 feet of beach width is lost for every foot of sea-level rise.

Cliff and bluff erosion is irreversible. The most common response has been to armor the cliff base with rock revetments or seawalls. Ten percent (110 miles) of the California coastline is armored, including 33 percent of the coastline of the four most developed southern California counties: Ventura, Los Angeles, Orange, and San Diego. Despite this protection, coastal storm damage has increased over the past several decades because of intense development and several severe El Niño events. In addition, armored coastline ultimately reduces beach size.

"An armored coast blocks the natural sediment transport from the shore, and in California much of the sand on our beaches comes from creeks," said Dana Murray, Heal the Bay's Marine and Coastal Scientist. Thus, beaches cannot migrate landward, and continued flooding of the seaward beach results in a reduction in beach width, and its eventual loss entirely. This also spells trouble for California grunions, which migrate to Pacific beaches, mostly from Punta Abreojos Mexico, to Santa Barbara, California every spring and summer. The walls can diminish or even eliminate grunion spawning grounds.

"Waves hit the wall and scour the sand, exacerbating coastal erosion," Murray said. "As waves keep hitting the wall, the beach sand is eroded more and more. A rock revetment just makes the problem worse. Beach residents are stopping the natural wave action from potentially coming on their property, but in front of the wall they're losing the beach."

Shore armament.

A case in point: **Broad Beach residents want to replenish that lost sand, but these days they're having trouble finding suppliers of sand**. Manhattan Beach has denied them sand from South Bay, so proponents of the privately-funded Broad Beach project are hoping to dredge sand off Dockweiler Beach. However, the Los Angeles County Department of Beaches and Harbors has objected, saying that the Broad Beach project would deplete reserves that might be needed later to replenish other public beaches eroded by rising sea levels.

If sea level increases substantially and wave heights continue to increase, overtopping of walls will become more frequent. "Broad Beach's rock wall is not supposed to last," Murray said. "Even in their reports, they say they'll last no longer than 5 or 10 years anyway because the rocks fall apart. From an environmental standpoint, the most sustainable option is managed retreat, in which coastal structures are abandoned or taken down." She cited the city of Ventura, which has completed the first phase of a managed retreat at Surfer's Point, removing a sea-damaged parking lot and moving a bike trail 65 feet inland.

In a presentation at University of Southern California in October of 2011, Dr. Reinhard (Ron) Flick said that the coastal infrastructure is tuned to current extremes of total sea level, which includes storm surges, tides, and other fluctuations to about 4 meters. Though unlikely, an increase of 2 meters by 2100 would trigger extreme events of at least 6 meters, intensifying the effects of storms.

Currently, permits involving sea walls before the California Coastal Commission are decided on a case-by-case basis. But now the California Coastal Commission is developing specific guidelines for dealing with potential climate change impacts for coastal development applicants, which should include a suite of options that prioritizes better options for public access and the environment. They are expected mid-year and will be open to public comment.

Although Southern California so far has been spared a significant increase in sea level, **expectations are that sea level will rise faster here in the coming decades**. This increase will reduce our wetlands, diminish our beaches, erode our cliffs, and destroy coastal developments. Much of the uniqueness of the Southern California coast is at risk.■

First in series of articles describing effects of climate change on Southern California

Spotlight on: Southern California Academy of Sciences and its annual meeting

The Southern California Academy of Sciences held its 106th annual meeting in early May at California State University Long Beach. The presentations were eclectic, representing any and all science conducted in Southern California that the authors wish to present. That local flavor is what interests me and I happily skipped work to attend the two-day conference.

The Academy traces its origins to 1891, taking the name Southern California Academy of Sciences (aka SCAS) in 1896 and incorporating in 1907. In contrast the California Academy of Sciences, based in San Francisco, began in 1853, shortly after California became a state.

Members of the SCAS began fossil hunting in the La Brea Tar pits and eventually helped develop the Los Angeles Natural History Museum as a place to store the finds described in an accompanying article. The logo of the Academy is the Smilodon or saber-tooth cat, whose remains are well known from the tar pits.

SCAS logo

Today the work of the Academy is definitely slanted toward marine studies and student involvement, as it sponsors some student research. Four prizes were given to students for best papers and all four involved marine studies. Regarding marine studies, I heard talks ranging from fish to shorebirds and much in between. Below are small synopses of many of the presentations.

Of great interest to me was the news of a project to restore the native oyster to estuaries in Southern California, particularly Los Alamitos Bay and Upper Newport Bay. This news was attended by poster presentations on oyster DNA studies, planning for studies of water-clarity-improvements produced by new oyster beds, and the historical record on oysters in Newport Bay. I did get a researcher to spill the beans regarding the exact location of the planted oysters. Next time I kayak in Newport, I'll bring an oyster knife [editor's note: better not].

An interesting poster was on the identification of pipefish. Pipefish can be tricky to identify in the field and a student developed a series of physical length metrics to quickly identify various species of pipefish. She even found an unknown pipefish. Divers do not see pipefish very often, however we do see them routinely in the detritus in the submarine canyon off Veterans's Park in Redondo Beach and occasionally in La Jolla Cove. Surprisingly, using a beach seine on Cabrillo beach, she caught 52 pipefish in one pull (it was a large beach seine). The student won an award for this work.

Understanding the behavior of fish is difficult as they are always in stealth mode, operating underwater. However, advances in electronics are enabling the study of fish in new ways. One such study was to understand the movement of white croaker (*Genyonemus lineatus*) in Los Angeles and Long Beach harbors. White croakers eat invertebrates found in sediments. If the sediments are fouled with pollutants, so will be the croaker, resulting in their being banned from the local food supply. To learn more about their habitat selection and movement, 50 white croakers were caught with hook and line from 5 areas within the harbor complex (don't try this on your own). These were fitted with acoustic devices and released. Each device telemeters an unique code which identifies a specific fish. Hydrophones were placed at various choke points, or narrow channels, to listen for fish that swam by and therefore fish movements could be tracked within the harbor. Although there was some net movement of fish around the harbor, they tended to stay in the area where they were caught. Additionally, a directional hydrophone was hung from a boat and a specific fish was tracked for 24 hours. Of course, the fish would return to the most polluted areas to spend the night!

Somewhat similar studies were conducted with barred sand bass (*Paralabrax nebulifer*). The ocean off White Point (Palos Verdes) is known to be contaminated with PCBs and fish taken from this area should not be consumed. Barred sand bass taken off the Palos Verdes shelf were tagged and tracked with a large array of receivers. They were found to move from the contaminated regions off White Point to Huntington Flats for their spawning aggregations (tens of thousands of fish spawn there). An immediate issue was that the location where the fish were tagged is a no eat zone, and where they aggregate is not, but the fish do not seem to read much and those that frequented polluted-sediment areas migrated out of the area to be caught while spawning.

Less is known about grunion (*Leuresthes tenuis*) movements. Where do they go between spawning runs? How do they make a living? We did learned locations where grunion runs are very common (and we did go looking at the appointed hour but came up empty for grunion experiences). Apparently, normally diurnally-feeding birds do know where grunion are expected to make a dash for the beach as they are waiting for them there late at night. How the birds know this is still a mystery.

Unfortunately, if the birds don't get the grunion, beach grooming might. Many invertebrates (as well as grunion eggs) live in the beach, including the upper-intertidal zone. They are prey for other animals, including birds. Beach development, plowing and removing of wrack reduces the habitat of these animals. These processes, in turn, reduce the habitat for the shorebirds. Indeed, two small isopods (*Tylos punctatus* and *Alloniscus perconvexus*) have been extirpated over much of their historic range, especially in Los Angeles County. Although these isopods are anything but cute, the shorebirds that feed on them are poster children for ecological care.

Shorebirds include the western snowy plover (*Charadrius nivosus nivosus*) and the least tern (*Sterna antillarum browni*) and there were SCAS sessions on ongoing activities to preserve them. The snowy plover hangs out on the beach, eating invertebrates, and will even nest in depressions in the sand. With the urban development of the local beaches, this is not a safe procedure and there has not been a snowy plover nest documented in LA County since 1949, although birds annually return to a handful of roosting sites in the county, including Malibu Lagoon. Efforts to save the plover include fencing portions of beach to give the birds a respite from joggers, dogs, vehicles and beach plowing.

Another local breeder is the California least tern with two local colonies, one on Venice Beach and the other near Pier 400 in San Pedro. The reasons for the declines vary. At a site on Venice Beach, a scarcity of prey fish (anchovies and grunion are on the menu) has caused adult birds to spend more time foraging for food and less time guarding their clutches. Hence, eggs are vulnerable to hungry crows and other flying predators.

Finally, we heard of monitoring eelgrass and its invasive competitor, *Sargassum horneri sargassumg* in Big Fisherman Cove. This sargassum is a real pain in the Avalon dive park, growing thickly up to 6 feet above the seabed and obscuring the bottom. It is also more difficult to swim through than the native kelp. We have informed the principle investigator for the program of our data collection efforts nearby and offered our data to assist their studies.

Western Snowy Plover

California Least Tern

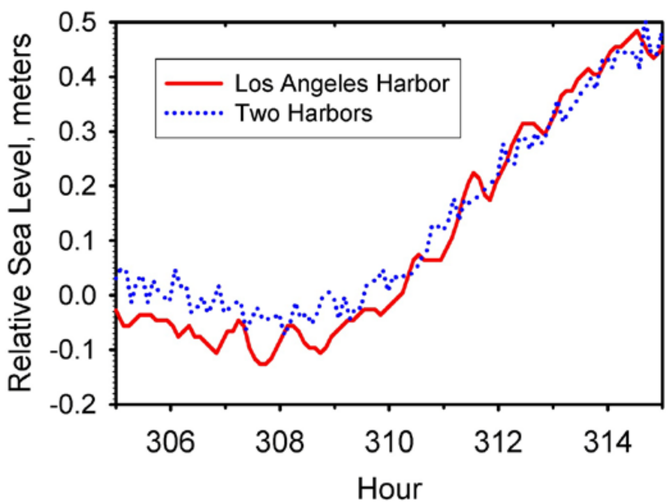
The SCAS annual meeting is a wonderful conference to learn about our SoCal environment and the studies. Next year, it will be held at Cal State Channel Islands.■

Seiches in Los Angeles Harbor

Recently, we placed an underwater pressure gauge near WIES at Two Harbors to measure the local tide. As described in the preceding issue of *OceanBights*, the tidal fluctuations measured at WIES were very similar to those measured in the harbor at Los Angeles. However, we noticed an additional water-level fluctuation in Los Angeles Harbor that was not present at Santa Catalina. It was a seiche (pronounced saysh).

Seiches can be thought of as water sloshing back and forth in an enclosed basin. Sometimes they are excited and easily observed in a 5-gallon Sparkletts water bottle when a cup of water is withdrawn from the bottom. The surface rises and falls alternatively between the center and perimeter. The frequency of the fluctuations depends on the size and depth of the basin, with larger and deeper basins having larger periods. The 5-gallon bottle has a fundamental period of less than one second. Well, the same phenomena can occur on a much larger scale. In the case of a semi-enclosed harbor, waves that impinge at the harbor's mouth can excite a seiche. The figure below shows a seiche we found in Los Angeles (the red line). The water level changes by only a few centimeters in the example and with a periodicity of about 1 hour. However, it is very noticeable in the recorded data.

With a little searching we found that seiches are well-known in the LA harbor. The NOAA nautical chart for the harbor describes the harbor seiche with "The most persistent and conspicuous oscillation has a period of approximately 1 hour." The concomitant surge may produce a current as large as a knot in the main channels and **1.5 knots in the back channel**. The NOAA booklet indicates that the half-hour flooding and draining of the harbor can cause rapid changes in height and that



Seiche observed in LA Harbor as the 5-cm amplitude modulation.

the velocity may endanger vessels docked at the piers!

We found an obscure legal action involving the LA Harbor seiche. The case revolved about the mean high tide above mean lower low water, which can be assumed to be particularly important to property owners in the harbor. A plaintiff argued that high tide was 5.1 feet while the defendant claimed it was 4.7 feet. The difference was attributed to the harbor seiche. (Mean lower low water, MLLW, is the average water height of the lowest tide for a recording period, usually the National Tidal Datum Epoch. The Epoch is 19 years and the last was 1983-2001. MLLW is the datum used for nautical depth charts and tides, explaining why the tide is usually positive.

Seiches can be found in other semi-enclosed locations that permit excitations by ocean phenomena. Locally, I measured one in the San Elijo Lagoon that was approximately a minute in period, too long in duration to be directly related to ocean waves, but comfortably short enough to be timed with a watch.■

Society News

The Society held its 2013 annual meeting on April 28 at the Aquarium of the Pacific. Board elections were held via e-mail and postal ballots during the previous month with the result that the existing slate of board members is returning. They are Jon Davies, Lauren Oudin, David Tsao, Karen Norris, Jim Updike, Mike Doran and Craig Gelpi. At the annual meeting the board elected its officers, who are: David Tsao, President; Karen Norris, Secretary; and, Craig Gelpi, Chief Financial Officer. Craig is also the Chief Scientist, a vice-president position.

Presentations were made regarding the Society's activities over the previous year. These included events such as Diver Day and the SCUBA Show, conferences attended, research papers written, outreach lectures given, proposals submitted, expenditures and revenues, and plans for next year. Of special interest were the two field projects undertaken by the Society. **These are: expanding**

and maintaining our scientific mooring at Two Harbors, and developing the Continental Thermograph Array.

Three award certificates were given to recognize exemplary service in support of these projects. The first was to Kellie Spafford, a member of the WIES staff. Kellie has performed the major work regarding the care, maintenance and calibration of the sonde on the mooring. She did so in an efficient manner, notifying us of problems, installing sensors and, when necessary personally diving the mooring.

Mike Doran received a certificate for organizing 20 dives over the last 2 years to service the mooring. These are not easy dives logistically, usually requiring a weekend stay in Two Harbors and securing a buddy diver. Mike has also put in additional sensors including the pressure gauge and thermograph string, which provide auxiliary data in support of the mooring.

David Tsao (R) presents Mike Doran an award for his organization of diving activities in support of the mooring. David was also awarded for his dedication to the CTA.

CMS SCUBA Show booth.

David Tsao received a certificate for extraordinary efforts to retrieve thermographs. Besides making herculean swims nearly out to the shipping lanes to deploy the instruments, he has also chartered a boat in an attempt to recover them. We also recognize David's successful efforts toward building the Continental Thermograph Array, which is nearing completion.

Final discussion topics at the meeting included how to expand the Society, particularly in regard to increasing the general-public membership.■

Upcoming Meetings

CalCOFI Conference December 9-11, 2013 in La Jolla.

AGU Fall Meeting December 9-13, 2013, San Francisco.

Southern California Academy of Sciences Annual meeting, May 2014, California State University, Channel Islands.

2014 Ocean Sciences Meeting February 23-28, Honolulu, HI.

Catalina Marine Society Membership

Catalina Marine Society Members support the goals of the Society through their dues and also elect the Society's directors. Membership is described in the bylaws and is granted to those who: 1) agree with the mission statement; 2) pay the annual dues (currently $100); and, 3) submit an application that is approved by the board. An e-application is available on

http://www.catalinamarinesociety.org/CMSMembership.html

Manual Membership Application

Please send the following required information to the Catalina Marine Society via e-mail or post to the address below.

Name, e-mail address, postal address, reason you wish to join the Society, and that you agree with our mission statement.

Dues can be paid through the "Donate" link or checks made payable to the "Catalina Marine Society" sent to the following address:

Catalina Marine Society
15954 Leadwell Street
Lake Balboa, CA 91406

If you are interested in contributing to the work of the Society in other ways, please let us know. Categories and examples of needed volunteer work are listed below.

Lab

Data analysis
GIS
Programming

Field

Boating
Diving
Instrument calibration
Hardware/Equipment fabrication and mounting

Office

Web design/programming
Graphics
Photography/Videography

Magazine/newsletter

Reporting
Publishing
Editing
Departments

Fund raising

Event planning
Event volunteer
Grant writing

Press/publicity

Public speaking
Newspaper articles