OceanBights

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Contents

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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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We're Busy!

We have deviated from our usual *OceanBights* formula to accommodate busy volunteer schedules regarding collecting, analyzing, and presenting data as well as documenting results. However, our articles for this issue do form a coherent theme, namely describing the effects of climate change and specifically ocean acidification on our local shellfish.

To this end, Mary Ann Wilson continues her series on climate change, describing ocean measurement work at UCLA by our friend Dr. Leinweber. We also have adapted two articles written for other purposes to our acidification theme. The article on mussels was originally intended for my sister, who is unfamiliar with these bivalves. Another article describing, among other things, our trip to Avalon on the Rascal was derived from a tribute to the Swenssons, who provided seagoing services for our own ocean acidification measurements. Finally, a quest for local oysters produced the remaining major article for this issue. Oysters, too, are very vulnerable to changes in ocean waters.■

Mussels: Gastronomy and Science

Mussels have become a very popular food over the last several decades. What use to be considered a trash resource (bait) now has respectable representation on high-class restaurant menus. This is perhaps due to eating down the food chain, as scallops and oysters have become more precious. Mussels are common on both the East and West Coasts, although they are not on the Gulf Coast. However, if you order them in a Los Angeles restaurant, you will probably get New Zealand mussels or a product from Maine. Seems a waste to bring them from afar when *Mytilus californianus* are so plentiful in California. With climate change, will they always be here? The interactions of climate and mussels are complex, but they can be appreciated in a practical sense, that is, through the eyes of a hungry man.

Mussel-taking to satisfy that hunger is regulated by the California Department of Fish and Wildlife (limit is10 pounds a day). One can gather mussels in Los Angeles County though I know of no one, besides myself, who does. However, the need to regulate the harvest implies that others must take them, too. To bring home this wily game you must understand your prey's natural history so as better to position yourself for a successful hunt without getting hurt. Mussels are sessile filter feeders, taking water into their shell and across their gills to sieve out phytoplankton and bacteria. As such ➔ see **Mussels** page 6

California's Corrosive Ocean

By Mary Ann Wilson

The significance of our oceans' impact on greenhouse gases started four billion years ago, when atmospheric carbon was absorbed and allowed the earth to cool enough for life to begin. In our modern era, the ocean absorbs more carbon dioxide as atmospheric carbon dioxide levels increase. Currently the ocean is holding 50 times more carbon than the atmosphere and is slowing the rate of climate change by absorbing about 30 percent of carbon dioxide produced from industrial activities, including fossil-fuel burning, cement production and other activities.

But there's an important side effect. When carbon dioxide reacts with seawater, it creates more room for carbon dioxide by forming carbonic acid — the same weak acid found in soda. Carbonic acid releases negatively charged hydrogen ions, which lowers the pH level of seawater. Although ocean water is still alkaline, the term "acidification" refers to a gradual shift toward the acidic end of the scale. The pH scale ranges from 0 to 14; 7 is neutral, lower numbers are acidic and higher numbers are alkaline. Over the past 300 million years, ocean pH has averaged about 8.2, but since preindustrial times it has dropped 0.1 to a current average of 8.1. This may not sound like much, but the pH scale is logarithmic, so that a pH of 7 is about ten times more acidic than a pH of 8. Thus, this drop represents a 25-percent increase in acidity over the past two centuries.

Mary Ann Wilson

There are several reactions that occur between carbon dioxide (CO_2), water (H_2O), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}). But over the long term, ocean acidification leads to a decrease in the concentration of carbonate ions in seawater. Together with calcium ions they form the basic building blocks of calcium carbonate skeletons and shells. The decline of carbonate ions impacts the ability of many marine organisms such as corals, marine plankton, and shellfish to build or even maintain their shells.

There are two main forms of calcium carbonate used by marine creatures: calcite and aragonite. Calcite is used by phytoplankton, foraminifera, and coccolithophore algae. Aragonite is used by corals, shellfish, pteropods, and heteropods. When additional calcite and aragonite cannot be dissolved in water, that water is said to be supersaturated; when they can be dissolved, the water is said to be undersaturated for those minerals. Animals that need calcium carbonate can more easily obtain that mineral in supersaturated water. The saturation of these minerals in seawater decreases with depth, and the transition point between supersaturated and undersaturated conditions is referred to as the saturation horizon.

Currently, nearly all of the ocean surface waters are substantially supersaturated with regard to aragonite and calcite. However, more carbon dioxide dissolving in the ocean has caused the saturation horizon for these minerals to shift closer to the surface by 50-200 meters as compared to the 1800s. As the ocean becomes more acidic, the upper shell-friendly layer becomes thinner.

Aragonite dissolves more easily than calcite, so its saturation horizon is shallower and it will be first to be impacted by ocean acidification. For example, one might find the saturation horizon for calcite at 150 meters or even deeper, but for aragonite it may be at 100 meters.

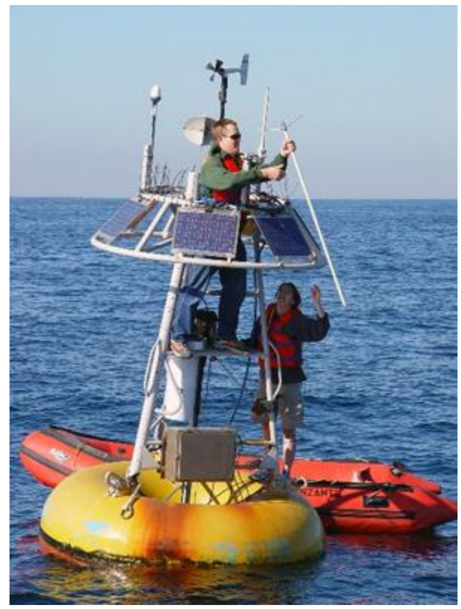
The saturation horizon is much closer to the surface in regions where upwelling occurs, such as along the West Coast from British Columbia to Mexico. That's because deep water in the North Pacific is naturally rich in CO_2, since the deep water has been out of contact with the surface for 1200 to 1500 years. As water travels along the oceanic conveyer belt, it accumulates CO_2 through natural respiration processes that break down sinking organic matter, generating CO_2 just as humans do when they breathe. Under normal conditions (and even more so under La Niña conditions), winds blow from north to south during spring and summer months along the West Coast. In conjunction with the rotating earth, this creates an effect known as Ekman Transport, which moves surface water away from the coastline, to be replaced by colder water upwelled from depths between 100 and 300 meters. This deep nutrient-rich water traditionally makes for robust fishery production. Now the naturally highly-acidic upwelled water is augmented with man-made atmospheric carbon dioxide, making this carbon-rich water even more acidic and bringing the saturation horizon closer to the surface.

In the Northeastern Pacific, corrosive waters are already shoaling into the euphotic zone during upwelling. In 2007 Richard Feely and a team of scientists found undersaturated seawater with respect to aragonite reaching depths of about 40 to 120 meters. In one transect near the California-Oregon border less than 20 miles from shore, the saturation horizon had shoaled all the way to the surface. Without the contribution of anthropogenic CO_2, the aragonite saturation horizon would be about 50 meters deeper.

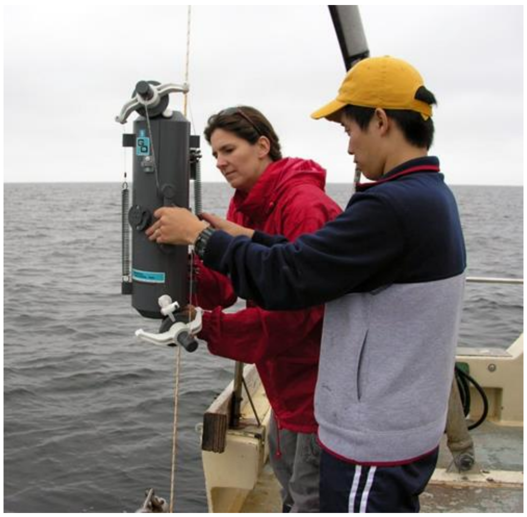
Because of this, the Pacific Northwest oyster-growing industry nearly collapsed before Feely and other scientists were able to help devise strategies and monitoring protocols. In 2007, the Whiskey Creek Shellfish Hatchery in Oregon lost millions of oyster larvae and later discovered that the larvae were being bathed in acidic waters drawn in by intake pipes. Oyster larvae are particularly sensitive in their first few days of life such that carbon dioxide alters shell formation rates, energy usage and, ultimately, their growth and survival. Now, the Whiskey Creek hatchery tries to neutralize the acidity of its waters by adding soda ash. Costs have increased and production has never fully recovered.

Island Scallops, a shellfish producer in the Georgia Straight near Vancouver, lost all its scallops over a 3-year period from 2010 to 2012, during which time pH levels had dipped to 7.3. CEO Rob Saunders said that this level of pH in the water was something he hadn't seen in his 35 years of shellfish farming. The loss amounted to 10 million dollars and reduced their workforce by a third (20 people).

No less troubling is the impact of acidification on the food chain. This year, a NOAA-led research team found evidence that acidity off the West Coast has been dissolving the shells of pteropods at an increasing rate since the pre-



Servicing the Santa Monica Bay Observatory mooring's antenna industrial era. These tiny free-swimming marine snails make up 45 percent of the diet of pink salmon and are also a food source for herring and mackerel. The highest percentage of sampled pteropods with dissolving shells were found from northern Washington to central California, where 53 percent had severely dissolved shells.



Dr. Leinweber and Takeyoshi Nagai attaching water-sampling bottle

Upwelling qualities differ between Northern and Southern California with Pt. Conception being the boundary. North of Point Conception upwelling is stronger and lasts longer (from spring to fall), bringing water from deeper depths up to the surface. Because the direction of the coastline changes from north-south to east-west, south of Point Conception, forming the Southern California Bight and sheltering it from strong winds, a weaker upwelling occurs in Southern California from February to May. The same NOAA-led research team found evidence of corrosive waters shoaling to depths of about 20-50 meters in the coastal waters off Washington, Oregon, and northern California, and to depths of 60-120 meters off southern California.

This has been the pattern for at least the past ten years, according to Dr. Anita Leinweber, a researcher at UCLA who has been measuring acidification levels in Santa Monica Bay for more than a decade. In a 2013 study, Leinweber and co-author Nicolas Gruber published trends for pH and the aragonite saturation state in the Santa Monica Bay from 2003 to 2008. They found that the saturation horizon there reaches 130 meters on average. As the aragonite saturation state changes, this shoaling is exacerbated and the horizon could climb 20 meters by 2050 to reach an average depth of 110 meters.

Median values for pH are also decreasing by an average of about 0.004 per year between 100 and 250 meters. These trends in Santa Monica Bay are larger in magnitude than most of those reported elsewhere — for example, in Monterey Bay the trend is about 0.003 pH units per year. They are also slightly larger than those expected on the basis of the recent trends in atmospheric CO_2. The study also noted that the saturation horizon reached its highest point—the top 30 meters—during the height of the upwelling season in April and May. Lower pH and aragonite saturation states were observed during winters when La Niña conditions prevailed, which makes sense given that La Niña conditions intensify upwelling conditions.

But this past April, Leinweber saw a statistically significant trend in surface pH, calculated from additional data which extended to 2013. The pH values in the top meter had been decreasing by about 0.003 per year.

"We have evidence already that ocean acidification is happening," Leinweber said. "It's not something that we're making up or something that we know has to come at some point. We actually see it."

As described above, the effects of ocean acidification will vary with location. Of interest to the Catalina Marine Society is upwelling produced by the presence of Santa Catalina Island in the Bight. Does this upwelling bring increased acidity to island waters? To understand this issue CMS is acquiring pH and other ocean chemistry data with its depth-profiling program. In addition to measuring acidity, these data will enable us to determine where the water comes from, where the phytoplankton resides, and how much oxygen is available to marine fauna. The goal is to obtain sufficiently dense records to compare to similar data collected in Los Angeles Harbor (by the Southern California Marine Institute), Point Loma (Scripps Institution of Oceanography), Santa Monica Bay, and off the Santa Barbara coast (University of California, Santa Barbara), as well as understand the physical processes operating around the island and develop expectations for what climate change and ocean acidification will bring.

The new data will supplement what was previously collected at a single depth (18 m) near Two Harbors, Catalina. Those data, which include pH levels from May 19, 2012 through November 17, 2013, are available to researchers and students at http://www.catalinamarinesociety.org/Scientificmooring.html■

Mussels ➔ they concentrate poisons that are in the water. To that end they are studied to quantify the amount of contaminants in a specific location. In the last issue of *OceanBights* we mentioned results from the NOAA Mussel Watch program regarding DDT levels on Santa Catalina Island.

Another poison is domoic acid, produced by some species of algae in unhealthful amounts during harmful algal blooms (HAB). To minimize people ingesting this toxin, the California Department of Public Heath (CDPH) maintains a hot line (800-553-4133) from which the latest warnings and closures of mussel beds can be heard and tainted mussels avoided. And, there is an annual quarantine starting on May 1 and lasting through October 31, during which mussels may not be taken in Southern California. During this time, harmful algal blooms are common.

A mussel bed and 3-ft wave

Gathering local mussels is fun, though it takes a little planning and work. Mussels inhabit the intertidal zone, meaning they may be exposed during low tide but are submerged during high tide. In the mussel bed that I harvest, I find that mussels live in a narrow vertical band perhaps less than 3-ft high. Somewhat counterintuitively, *M. californianus* only live where there is surf. Therefore the first thing to do when planning a mussel outing is to schedule a time when the tide is low, really low, exposing the mussels and protecting the gatherer from waves. This tidal requirement greatly thins out the available times for gathering mussels, because it has to be coordinated with the gatherer's availability and daylight hours. In addition to the time, the location must be considered. Mussels grow on hard substrate, i.e., rocks, and rocks in the intertidal are familiar though not the most common type of shore. Mussels are also prolific on pilings, but most places with pilings are not places where you wish to take mussels. When the scheduled day for gathering draws near, call the CDPH to get the all-clear regarding healthy game at the planned location. Oh, you also need a fishing license, though this is not what I consider fishing.

Mussel catching equipment is fairly rudimentary. I carry a bucket, an ice chest, dive boots and a knife, as well as coffee. The first act after donning my booties is, using the bucket, to fill the ice chest in my truck with sufficient sea water to cover my intended catch. I like to let my mussels rest in undisturbed clean, seawater for a spell, hoping that they will expel sand and dirt within their shells. Hence, I decant the sea water from the bucket into the ice chest. The chest should have a strong lid or cover that will not spill sea water during the ride home.

A thousand mussels

Next, I go to the mussel beds and carefully choose the mussels I want, placing them in the bucket. There are several considerations when choosing a mussel: size, ancillary growth, and shell appearance. None of these bear on taste. Large mussels yield a nice dollop of meat; however, their shells often show the appearance of age with their periostracum usually abraded. The periostracum is the covering over the shell which was employed in the shell growth process. Larger, and by implication older, mussels will have more other-life growth, including algae, chitons, limpids, anemones, etc., all of which should be removed before cooking. Smaller mussels usually have prettier shells and make a better presentation for dinner guests. They may also fit on the plate better.

When you see a mussel you want, you can either pull it directly out, or leverage and cut it out with a knife. This is not difficult unless you are holding your coffee. The mussel is held in place with byssal thread (a defining feature of musseldom) placed by its foot onto the substrate and the thread has to be detached. It can be strong as it must anchor the mussel against large surf. The freed mussel is tossed into the bucket. This procedure is repeated until you have enough mussels or the legal limit is reached.

The mussels are hauled to the ice chest and brought home where the real work begins. The work to be performed depends on how you plan to eat your mussels. If you like to have them steamed in the shell and in a bowl with yummy drippings to dip bread with, then you will want to clean the mussel shells thoroughly, with a brush. The byssal thread should be removed, perhaps by grabbing it with pliers and pulling it toward the end (opposite the hinge) until it comes out. This technique is not always successful. A steaming source of onions, garlic, white wine, olive oil, etc can be concocted and heated and then the mussels placed in a steamer and done in. They do not scream during the process. Cooking time is 10 to 12 minutes. When finished, I grab each mussel with tongs and shake the juice into the pot for dipping. If the shell isn't open discard the mussel as it was dead prior to cooking. I have never discarded a mussel that I collected on the day I cooked it. You can remove the meat from the shell, wash it and cut any remaining byssal thread out, and replace it in the shell for presentation. Or you can collect

Catch of the day

Steaming, almost ready

the meat into a container, fill it with the steaming fluid, and freeze it for use on another day.

So, the natural history of the mussel is curious, and of some interest to the hungry man. How come they live in such a small vertical range in places? Certainly the water's nutrients do not change significantly in the surf zone, which is very well mixed. The suggestion is that this location inhibits predation. A major predator is the ochre sea star *Pisaster ochraceus,* with other predators being birds and predatory snails such as oyster drills. Perhaps their marine predators must retreat when the mussels are exposed, or their aerial predators cannot tolerate the surf when the mussels are submerged. Or the damage produced by territorial predators may be limited by the short tidal exposure. There must be a masters' thesis in there somewhere.

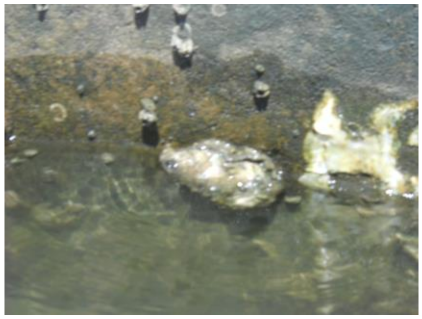
One last task

How will future mussel harvests be? Our ocean is changing. It is warming, becoming more acidic, more stratified, and may suffer more storms, as well as getting higher. These changes may reduce the mussel population, force the population to migrate, or be conducive to larger mussel populations (see Mary Ann's article in our last issue).

With sea level increases, the small vertical band of mussels will probably migrate up the shore until the rocky substrate ends, so I will not have to walk as far to get at them.

We do expect ocean temperatures to increase which may result in greater stratification. Higher temperatures may directly affect where mussels live. They do not appear in the Gulf of Mexico because the water is too warm for them there. The population of blue mussels (*Mytilus edulis, edulis* =delicious) on the East Coast, a close relative of our mussel has been migrating northward, according to a study by the University of South Carolina. The movement north over the last 60 years is a whopping 300 miles, from South Carolina to Delaware. That's further than I want to travel. However, a corresponding West Coast migration has not been directly observed, but a thinning of the population has been noted.

The increasing stratification will inhibit the transport of nutrients to surface waters. Because mussels live essentially at the surface, perhaps there will be less food for them to filter out in the future. This lack of nutrients at the surface is expected to be a widespread problem for marine life.


Oysters on sea wall, Upper Newport Bay

Ocean acidification is expected to inhibit the ability of shellfish to form their calcium carbonate shells (see Mary Ann's article in this issue). Experiments performed measuring mussel growth in water with various pH values have not shown deleterious effects on mussel growth; however, the end of the byssal thread which the mussel uses for attachment is known to fail under lower pH (greater acidification) conditions, suggesting that future generations of mussels in acidified oceans will be less able to withstand the increasing wave shock.

Finally, since mussels are correlated with surf, increasing wave shock may be helpful for mussel populations. The ultimate fate of the mussel beds is not clear; however, the distribution of mussels is sure to change, probably for the worst for this mussel hunter.■

Oysters in SoCal

Yes, I admit it. I'm a shellfish man. Lay out abs, shrimp, crawfish, crabs, clams, scallops, whelks or mussels, and I'm there. Unfortunately, this bounty does not exist much locally (with the exception of mussels, see the accompanying article). Sure we have good stuff, but not in prodigious quantities such that a poor man can eat well. But maybe things are changing.

I always have been partial to oysters. There is a rock offshore Malibu, whose 7-ft height is totally exposed during extreme low tides. During these times, I can inspect the rock to see what grows on it. To my surprise one day I found some bivalves and that got me interested in local oysters. The bivalves were actually jewel boxes, which when opened, look similar to tiny oysters, and finding them kept me thinking about oysters over the years.

Then, kayaking in upper Newport Bay, I found a large oyster shell near the Aquatic Center. Jackpot! There are local oysters. My appetite was whetted.

Perhaps because I spend more time in my dotage in estuaries or became sensitive to the presence of oysters, I began to see live ones with increasing frequency. But it is not only me who notices the increasing number of oysters, as there are recent reports of non-native oysters appearing in San Diego Bay and other southern parts of the state.

There used to be significant beds of the native oyster, *Ostrea lurida*, commonly known as the Olympia oyster, in California, especially the San Francisco Bay area. But these little animals, no larger than 3 inches, were quickly wiped out when the Forty-Niners needed food. This is a common story. For instance, oysters (*Crassostrea virginica*) used to be plentiful around New York City, but are rare there now, having been harvested to provide food and


Oysters in Grand Canal, Balboa Island

(aghast!) concrete from their calcium carbonate shells! The story is similar for the famed oyster beds of Chesapeake Bay, with the standard anecdote that oysters were so plentiful there that they filtered the entire bay every 4 days. An oyster can process more than 10 gallons of water a day and, in sufficient numbers, can improve water quality and clarity. Historically, oysters have been an ecological foundation, especially on the East and Gulf Coasts. They modify the environment by building reefs, and somewhat provide the ecological niche that coral reefs do. Alas, our native California oysters were never very plentiful and were soon reduced to commercial extirpation when the human population exploded during the gold rush.

To satisfy the demand for oysters, Japanese oysters (*Crassostrea gigas*, aka giant hard shells, perhaps 5 inches in length, and known as Pacific oysters or Miyagi as well as *C. Sikamea* or the Kumamoto), were imported and farmed. These are grown principally in the Pacific Northwest. Although oysters have always been popular, they are now joining the artisanal trend and qualify as foodie food. Local conditions can subtly modify the taste of an oyster, providing a terrior and branding the oyster as from a place rather than of a species (similar to what is done for food, like wine, in France). Now the Northwest, including Tomales Bay, is getting a reputation for terrior-influenced oysters. This latest trend may save and propagate our only native oyster for *O. lurida* is reported to have excellent flavor and it is farmed up north. Now there is a move afoot to increase its population locally.

Volunteers build oyster bed in Los Alamitos Bay (from web site)

Our native oyster is reported to exist in semi-enclosed bodies of water in the southland, although in small numbers. Oysters require less salinity than the ocean provides as indicated by their locations in estuaries. We certainly see oysters in Huntington Harbour and Newport Harbor, and they are almost abundant at the northern end of the Grand Canal splitting Balboa Island. These oysters are large and are probably not *O. lurida* but escaped *C. gigas*.

There is discussion on whether the imported oysters are outcompeting our native boys, based on their natural histories. *O. lurida* is closely related to the European flat oyster *O. edulis* (advice: if *edulis* is part of the name, eat it!) and the Chilean oyster *O. chilensis*. *O. lurida* spawns when the water temperature warms to about 16 °C and alternates sex between spawning. The *Ostrea* genus is marked by brooding its young within the mantle cavity. The males release sperm balls that contain approximately 1000 sperm into its mantle cavity. Shell contractions then expel the balls which dissolve into sperm. These are planktonic and may be swept into the mantle cavity of the female where the eggs are fertilized, perhaps 100,000's of them. They are kept within the cavity until they become free-swimming larvae. The larvae swim with their foot on top, making it more probably that they attach to underside surfaces. They glue themselves to the surface and become sessile. Unlike mussels, they cannot detach their foot and relocate.

In contrast, *C gigas* releases both eggs and sperm into the ocean where they meet, fertilize and form larvae which then seek a place to settle. This method of propagation has advantages over that used by *O. lurida*, perhaps helping the imported oyster out compete the local guy.

However, help is on the way. Prof. Danielle Zacherl, a biology professor at California State University Fullerton, is working to increase the presence of native oysters in southern California. Prof. Zacherl has performed experiments in Newport Bay regarding increasing recruitment of naturally occurring oysters. Her volunteer team has laid clutch of various materials to encourage and enable oyster larvae to settle. After a 2-year study, they found significantly increased recruitment in the materials she provided. These findings suggest that the local native-oyster numbers can be increased by providing suitable habitat. She is also involved in a project in Los Alamitos to encourage oyster growth there. See her website http://www.restore-olys.org/Restore-Olys/WELCOME.html

I chatted with Prof. Zacherl regarding her goals for oyster restoration. We know that oyster reefs provide habitat diversity, water clarity and near-shore stabilization. But some species do it better than others. Why did she choose the native oyster to restore?

She noted that the fossil record indicates native oysters have been in the area for hundreds of thousands of years. Other historical records imply a much more substantial presence of oysters at the turn of the 20th century in both Alamitos Bay and Newport Bay than exist now. Their diminishment indicates a changed ecology over that time as oysters are a foundation species, providing habitat to many other species.

Prof. Zacherl said that she wanted to restore the ecosystem to a character more appropriate to recent historical times. Although oysters do improve water quality, she noted that the small body mass and numbers of *O.lurida* did not make them a good candidate for large-scale estuary filtration. Even though much larger Pacific oysters may do a better cleaning job and they appear to be rather benign in terms of their impact on the local environment, she did not want to chance unforeseen consequences of promoting a non-native species. Other organizations agree as there are now substantial efforts by federal and state agencies to re-establish *O. lurida* in Puget Sound and the Bay area.

How will the native oyster fare with climate change? In some respects, the adult oyster may not notice. Generations will retreat upward with rising sea levels, their estuary locations may be impervious to higher storm activity and greater stratification. However, the life cycle has a weak point: the larval stage. As described in an adjacent article, oyster larvae die in acidic waters. And the ocean is becoming more acidic. Oyster growers in the Pacific Northwest know this too well. Occasionally, acidic water upwells in the area and is unintentionally pumped into oyster hatcheries. These low pH waters reduce the ability of the larvae to extract carbonate from the water to construct calcium carbonate shells. The result is no baby oysters. In the case of limited volumes of sea water, the acidity can be reduced by adding chemicals, but that solution is impractical for large estuaries. Hence, climate change may be a substantial threat to our local oysters.

Some say the oyster is the analogue of the canary in the coal mine and is warning us of the dangers we face with increasing carbon dioxide in the atmosphere. This is one of the reasons CMS is measuring pH off Santa Catalina Island. Such measurements may give us knowledge required to adjust or confront growing ocean acidification in the local area.■

Society News

The CMS Board had previously voted to expand to 9 members from 7. Applications for the position were requested, applicants vetted, and one position filled. Our new board member is Shawn Broes, who brings a lifetime of experience regarding Santa Catalina Island.

CMS held its 2014 annual meeting at the Aquarium of the Pacific on April 6th.

Annual meeting attendees discuss issues.

Progress and issues were discussed at length. Also, awards were given to Mary Ann Wilson for her contributions to *OceanBights*, and to Jim Updike, for service beyond the call of duty regarding the new depth-profiling program. Jim was also elected as president for the coming year. ■

The Rascal Expedition

This is the true tale of a weekend trip to profile ocean characteristics off Avalon, California. The Swenssons were amply gracious to provide transportation to Santa Catalina in support of our project. Their vessel, a 38' classic Catalina sailboat, is named Rascal and is treated as a member of the family. Catalina Marine Society staff, Ted Sharshan and Craig Gelpi, and the leader of the CMS Depth Profiling program, Jim Updike, met Erica Swensson at Dana Point Harbor. Erica would skipper, Ted provide mooring and instrument assistance, Craig would supervise the scientific instrumentation, while Jim oversaw port preparations, secretly knowing the maritime limitations of the CMS scientific observer, and buffering the skipper from a bad experience.

Depth profiles of ocean water adjacent to Santa Catalina Island are surprisingly rare. We know of only two other ongoing efforts to get depth profiles near the island. One uses an autonomous submarine glider which constantly glides between pre-programmed depths around the island (see Vol. 3 No. 1). The other is the California Cooperative Oceanic Fisheries Investigation program, which quarterly occupies a deep-water station off the southeastern end of the island. The former program is brand new, employing the latest in technology, while the latter was established to understand the collapse of the sardine fishery in the 1940s.

We set out to measure temperature, electrical conductivity, pH, dissolved oxygen and chlorophyll.

Temperature, the easiest parameter to measure, may be the most important, as its distribution determines so much of what happens in the ocean. Water has the property that a lot of energy must be transferred to change its temperature. Or, in other words, water tends to maintain its temperature and

CMS crew with Skipper

observed temperature changes are often indicative of water movement or long-term warming or cooling. Rising temperatures often signify hotter water moving over the thermometer. Temperature is also used to correct measurements taken by other sensors as their sensitivities are temperature dependent.

Conductivity is measured primarily to compute the salinity of the water. A remarkable property of seawater is that it contains the same proportions of various salts virtually everywhere. Therefore its ability to conduct electricity reflects the amount of salt within it, rather than the composition of the salts. Together, the amount of salt and the temperature determines the density of the water, which, in turn, influences its motion.

The acidity of the water is measured with a pH sensor. Ocean water is not an acid; rather it is a base, with properties akin to laundry detergent. However, carbon dioxide diffuses into the ocean from the atmosphere and undergoes chemical reactions that produce carbolic acid, pushing the pH toward acidity (pH <7). As the amount of carbon dioxide in the atmosphere increases, we expect the ocean to acidify, affecting all marine life, and therefore we monitor pH. (See Mary Ann's article this issue.)

Oxygen in the air also dissolves into the ocean at the surface. Additionally, dissolved oxygen is produced by plants, primarily phytoplankton within the ocean, increasing oxygen at depth. Animals need oxygen and there is much less of it in the ocean than in the atmosphere, and the amount is much more variable. Regions of low oxygen in the ocean are becoming more common and understanding this phenomenon is a major concern of ecologists planet-wide.

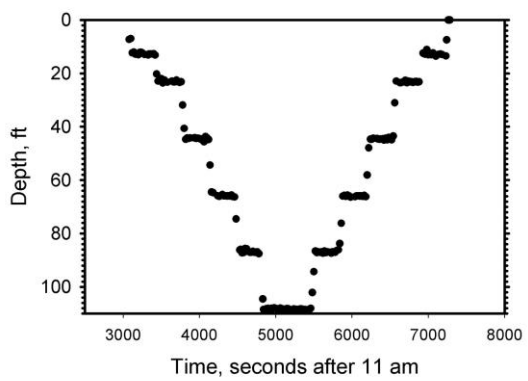
Finally, we measure chlorophyll. All plants use chlorophyll to convert sunlight, water and carbon dioxide into food and oxygen. The ocean is a biological system and the phytoplankton are major drivers of that system, forming the base of the food chain. The behavior of phytoplankton, their concentration, seasonal migration and growth, have an extremely large impact on the (larger) marine fauna we see.

We departed Dana Pt. about 9:45 a.m. and began our sail toward Avalon. With little wind, the main sail was unfurled to slight advantage and we motored to Avalon at nearly 6 kts, arriving about 3:30 in the afternoon. The traverse was punctuated by "man overboard" drills, with the man played by floating balloons, chanced across our path that the skipper was determined to rid the ocean of. We also checked out a floating refrigerator that amazingly would not sink. Once at Avalon, we were greeted by Harbor Patrol from whom we requested a mooring near Descanso Beach. Ted gamely grabbed the mooring wand and we were quickly moored. The dingy was inflated and launched, its outboard engine attached. Then we snorkeled and swam a tour of the Avalon Dive Park, noting 50 ft of visibility. Afterwards we took a quick trip into Avalon in the dingy. Upon return to the Rascal, we supped and chatted, then sacked out for the night.

Sounding

Erica's father, Rick, ferried out to Avalon on Saturday morning. We picked him up via dingy and then readied Rascal to the purpose of the expedition. We motored past the near moorings out to a depth of 100 ft, anchored and then started gathering data at 11:53 a.m.

The profile of measurements is made by lowering a sonde (the instrument that supports the sensors) into the water by hand. At predetermined depths, marked on the line, the sonde is held steady so as to accumulate a number of samples (one every 20 seconds) at that depth. We employed a timer so as to enjoy a beer rather than concentrate on a watch when station-keeping. A diver's depth recorder is attached to the sonde housing so that the actual depth and time are electronically recorded. An example of its output is shown in the figure and indicates that the crew did its job well, recording data to 33 m (100 ft). We repeated the stations on the upward retrieval as that is another opportunity for verifying the measurements. A couple of hours later, we wanted to iterate the procedure; however, we dragged anchor into shallower water,

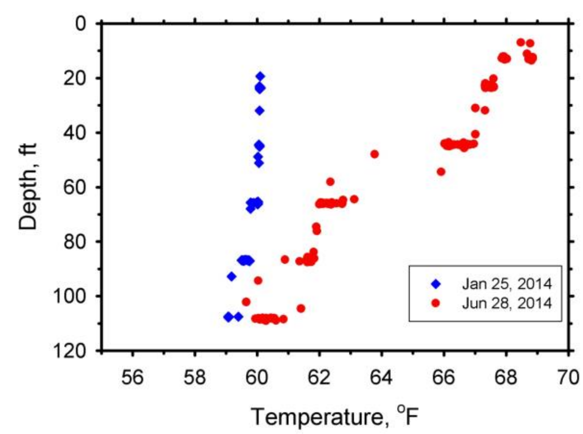


Crew's sounding verified

necessitating a move. With great difficulty, primarily due to snagging by an unseen kelp forest, the anchor was recovered by Rick and Ted. The Harbor Patrol came to investigate so Erica asked them if we could use an empty deep-water mooring to help with our measurements. Sure, they answered, and Ted did the mooring exercise again. Now, without worry, we repeated our second sounding.

This June trip complements a cruise in January to Two Harbors on the Honi, captained by Jim. Data from the two expeditions provide an illustration of how the ocean changes seasonally. We expect to see big differences in the values of the parameters measured, as seasonal effects become apparent after 5 months.

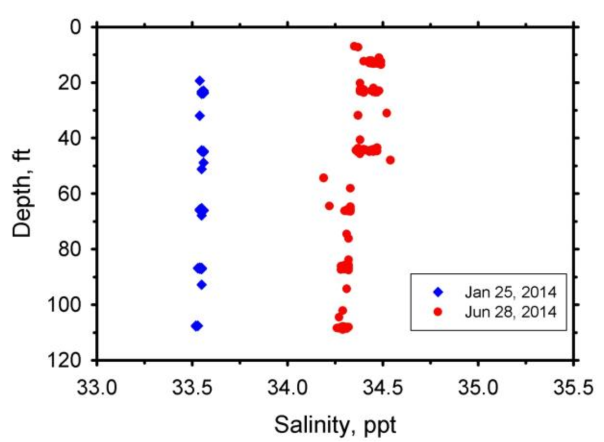
Temperature profiles for the first deployments of each trip are shown in the figure at right. The winter data, drawn in blue, indicate a nearly constant temperature with depth of about 60 ^{o}F with a small thermocline below 80 ft. In contrast, the summer data indicate much warmer water at the surface with a large thermocline between 40 and 60 ft. and with 69 ^{o}F water at 10 ft. These numbers are consistent with surface measurements made from Rascal's instrumentation as well as with personal experience obtained by free diving the afternoon before. This surface warming (at the top of the water column) distinguishes ocean from land, where the warming is at the bottom of the air column. Warm surface air is less dense and moves upward. Warm surface water is less dense and floats on the denser layers below, in a stable configuration. This has extraordinary effects on nutrients because mixing in the ocean is not by molecular diffusion but rather by water-parcel mixing. Globs of water at all scale sizes interchange, diluting their properties. However, a strong temperature



Summer and winter temperature profiles

gradient lessens the vertical interchange of water and reduces the flow of nutrients from depth to the surface. As the plankton graze down the nutrient supply, there is less growth and the little animals and kelp begin to diminish, increasing visibility.

The next data comparison is the salinity, shown below. We calculate the salinity using the measured conductivity and temperature. Salinity is used to identify masses of water. For instance, the California Current carries cold and relatively fresh



Salinity

water from Alaska past the Southern California Bight towards Mexico and the equator. Southern water, lounging in the sun all day, suffers evaporation which increases the proportion of salt. Hence, salinity can differentiate water originating between north and south. We see a large difference in the salinity between the January and June data, with the water being saltier in the summer. Also, there is a vertical salinity gradient; the water becomes saltier near the surface. These are clues to the ocean dynamics around Santa Catalina.

The pH values we measured showed no significant changes between the two expeditions but did indicate the ocean tended to greater acidity nearer the surface, somewhat surprisingly.

Finally, the chlorophyll readings indicated very little chlorophyll, as we suspected from the great visibility we found in the Dive Park. However, we did find that the chlorophyll concentration increased with depth. The probable reason is that these small ocean plants sought an optimal balance between sunlight and nutrients and had to go deep to achieve it.

We finished sounding and returned to our original mooring near Descanso Beach. Snacks and another afternoon swim were in order, followed by a visit with a kayaking friend, then dinner in town and a wonderful evening.

On Sunday morning, we breakfasted on the Rascal, took a short excursion into town, then began our cruise back to Dana Point practicing our man overboard drills. We made it to the slip without incident, but with many great memories and good data.

More information on our depth-profiling program is on our web site.■

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

Meetings

CalCOFI 8-10 December 2014, La Jolla

Southern California Academy of Sciences Annual Meeting, 15-16 May 2015, Loyola Marymount University

Ocean Sciences Meeting 21-26, February, 2016, New Orleans

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 $20); 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