OceanBights

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Contents

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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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This Issue

In this issue of *OceanBights* we have an interview with Dr. Yi Chao of the Jet Propulsion Laboratory, describing the new Aquarius mission designed to measure ocean salinity from space. We suspect that many readers do not realize what a powerhouse in physical oceanography JPL is. As humanity begins the holistic study of our planet, long-term satellite observations of our ocean become more important, both to establish baselines and observe global dynamics. And JPL is at the forefront of this effort. The Yi interview is our first experience with this type of presentation. Please let us know what you think of it.

An interest in metagenomics led to discussions with Dr. Karla Heidelberg at USC Wrigley Institute of Environmental Studies, which in turn, led to Karla providing our researcher's article describing exciting concepts and work on ocean acidification and genomic studies. Little known is that this work is actually performed on Catalina Island.

Straddling the San Pedro Channel is California's coastal radar constellation. We describe how this array is employed in various marine studies and alert you to their appearance so you can recognize one if you happen upon it.

Our spotlight columns illuminate the large Southwest Fisheries Science Center and the much smaller Algalita Marine Research Foundation. Algalita has gone through amazing efforts to document and study waste plastics in the ocean. For SWFSC, we do a case description of their turtle studies to describe the type of work performed in La Jolla.

Interspersed among the articles are notes on Society activities. We hope you enjoy the articles and consider joining in on the fun. ■

Spotlight on: Algalita Marine Research Foundation

When we hear the name "Algalita" we immediately think of plastic junk fouling our ocean. That is because the Algalita Marine Research Foundation, located in Long Beach, is dedicated to protecting the marine environment through conducting research and collaborative studies concentrating on plastics in the ocean, including its distribution, sources and effects.

The basic story is well known. The Algalita Foundation was started by Captain Charles Moore to help restore giant kelp off the California Coast. Algalita means little kelp plant in

►*continued on page 5*

Octocorals and Ocean Acidification Studies at Catalina

By Karla Heidelberg

The California coast in general, and the Southern California Bight (SCB) in particular, have the dubious distinction of being the first areas of the world ocean where upwelling of acidified seawater has been strongly demonstrated. Increasing atmospheric carbon dioxide (CO_2) resulting from burning fossil fuels and other human-related activities is making the world's ocean more acidic. An estimated 25-30% of the atmospheric CO_2 is absorbed by the oceans, therefore as atmospheric CO_2 levels increase from human activities, so do the levels in the ocean. This has resulted in a measured decrease in seawater pH, carbonate ion concentration and calcium carbonate ($CaCO_3$) saturation state. Together these changes are referred to as "ocean acidification".

Ocean acidification is resulting in unquestioned negative biological consequences for marine calcifying (skeleton or shell producing) organisms, including corals, coralline algae, a variety of benthic invertebrates and even some high-latitude water column invertebrates. Ocean acidification affects different organisms in various ways, and these differential effects could greatly alter ecosystem structure, food webs, and biogeochemical processes in ways that are hard to predict. The effects of ocean acidification paired with other changes, such as rising temperature, may threaten the persistence of marine ecosystems as they are today and their dependant human communities. The Los Angeles Basin and the greater SCB have been suggested as likely to be among the first regions in the world to experience the direct economic impacts of ocean acidification. For this reason, members in my lab at the USC Wrigley Institute of Marine Science on Catalina Island are studying the potential effects of ocean change on several types of marine organisms, including tropical and temperate corals.

Dr. Karla Heidelberg

Corals are a common marine organism to evaluate effects of ocean acidification. However studies to date have all focused on scleractinian 'reef building' corals of the tropics. While California does not have scleractinian corals, we have abundant temperate octocoral species, such as sea pens and gorgonians. Octocorals commonly occur in reef and hard bottom communities worldwide in habitats of varying temperatures and depths. Although less-well-studied than the scleractinian corals, octocorals can be highly abundant and important in structuring ecosystems and providing critical fish and invertebrate habitat in coastal waters of southern California.

We are studying the ecology of the Golden Gorgonian (or California Golden Coral), *Muricea californica*, including potential effects of ocean acidification. This striking gorgonian is a filter-feeding temperate colonial species that lives on the rocky bottom at depths between 50 to 200 feet deep from Point Conception in California down through Central America, including dense assemblages found throughout the Channel Islands. Golden Gorgonian skeletons are composed of proteinaceous gorgonin and amorphous carbonate spicules for support. The coral holdfasts, or structures that attach the organisms to the bottom, are composed mostly of aragonite, a crystal form of calcium carbonate that is more soluble than the common form, calcite. Due to their aragonite composition, these species are potentially very vulnerable to changes in pH. However, because Catalina Island is separated from the mainland by a deep channel, the effects of deep water upwelling of more acidic waters is thought to be less of a threat. Catalina Island, therefore represents an ideal location to learn more about the baseline ecology of the Golden Coral that might be more related to preindustrial conditions and to then learn through experimental manipulations what the likely effects of changing ocean conditions could be on this species. Our early studies are focusing on corals found in areas adjacent to the USC Wrigley Marine Science Center, near Two Harbors. This area allows us to benefit from a new partnership with the Catalina Marine Society to obtain scientific mooring data in Big Fisherman's Cove adjacent to the lab. Data from this effort provides part of the necessary information on long-term environmental parameters (temperature, conductivity, dissolved oxygen and chlorophyll) near our field study site so we can determine environmental parameters to mimic (or manipulate) in laboratory experiments.

Johanna Holm with Golden Coral, *Muricea Californica, courtesy of K. Heidelberg*

In addition to evaluating the direct effects of changing pH and other ocean parameters on coral growth and health, we are interested in the important mutualistic relationship between the corals and microbial communities. Corals and other benthic invertebrates form close and unique relationships with assemblages of diverse microbes that are distinct from free-living microbial communities in the overlying water. The microbial assemblages are thought to confer critically important benefits to the host. For example, a number of different bacterial types known to fix both nitrogen and carbon have been observed in other coral-associated communities. It is also possible that coral-associated bacteria scavenge limiting nutrients (e.g., iron, vitamins) that are then harvested by the coral. In a similar study with a cold-water sponge found off the coast of Sydney, Australia, we found that the host-associated microbial communities help defend the sponge community against the introduction of foreign DNA (and hence contribute to its genetic resilience), prevent biofouling on animal surfaces and provide essential vitamins and nutrients to the host. Long-term environmental changes, such as decreased pH, may alter the host-specific microbial communities maintained by the coral and adversely affect coral health. Microbial communities may shift from a mutualistic (positive) relationship to more pathogenic communities, resulting in greater coral disease.

To better describe the microbial communities, we are studying the microbial communities in both the water overlying octocoral communities and collected directly from samples of coral tissue. This helps us determine what kind of species-specific communities the corals maintain on their surfaces. Once the microbes have been isolated through filtration, we break open the cells and extract their genetic material (DNA and RNA), and the samples are sequenced in the lab using similar methods that were used to sequence the human genome. The sequence information allows us to evaluate the genetic makeup of the microbial communities, which provides a picture of who's there (based on key genes of certain families of organisms), what microbes have the potential to do (for example, a gene that controls the production of an antifouling compound) and what they are actually doing in the environment. This type of information is also valuable in biodiscovery research, as microbes provide a rich source of discovery for novel genes, enzymes and metabolic pathways. The following brief video provides additional information on sequencing marine microbes http://college.usc.edu/news/stories/537/the-machine-that-goes-ping/.

Later results from our studies on corals found adjacent to Catalina Island can be compared to corals living in more vulnerable and compromised marine habitats located along the coast of the mainland. We expect these new data on effects of CO_2 on coral-microbe interactions and coral health will add to a rapidly expanding insight into the vulnerability or the resilience of marine organisms along the coast of Southern California. When paired with information on physical ocean parameters, results will be helpful for modelers predicting ocean acidification impacts in the Southern California region. ■

►Algalita *continued*

Spanish.

However, after completing a yacht race near Hawaii, Captain Moore took the long way home to California, sailing through the Northern Pacific Gyre. From his boat he spotted an unusual amount of flotsam. The gyre is an oceanic convergence zone and objects that are deposited in the North Pacific and float long enough, such as plastics, have a good probability of drifting into this zone. The presence of this trash so far from shore made a strong impression on Captain Moore and he redirected the organization that he started toward understanding and reducing the amount of plastics discarded into the ocean.

Of course, the first step to understanding the significance of plastics in the ocean is to measure how much is there, where it is and what it is. Determining how much plastic is out there is difficult because the North Pacific Gyre is not an easy place to survey, being about 2000 km from San Francisco and Los Angeles. And the gyre is large with an area of many hundreds of thousands of square kilometers within an amorphous boundary. Remarkably, Algalita has mounted several expeditions to the gyre to trawl for debris and measure it characteristics.

Special trawls are used to retrieve plastics. For floating stuff, a manta trawl is employed. It has a large mouth and wings that can position it at the surface and away from the trawling boat's wake, capturing undisturbed plastics, plankton and fish that are in its path and then sending them into its trailing net. For sampling the water column, bongo nets are deployed at depth. They resemble bongo drums in that they have circular openings and are usually paired. Each net of the pair is designed to catch a particular size range of plankton or plastic particle. Knowing the dimensions of the trawl net opening, the length of time it is deployed and the speed of the boat enables the computation of the surface area or volume sampled. A count of the plastics captured can then be used to determine its areal density in the sampling region.

The captured plastics are sorted according to size, color and type. An expedition may sample many areas in the gyre and the amount of plastics encountered per trawl can then be mapped to build an understanding of the distribution of plastics within the gyre.

Algalita staff deploying bongo nets. Courtesy of Algalita MRF

Fish and larvae caught in the trawl are repositories of information. Hundreds of fish were caught in the 2008 expedition, frozen onboard and brought to a laboratory in

Southern California for analysis. The fish are counted, classified and dissected to determine if they had fed on plastics. Thirty-five percent of the fish had. Plastics retrieved from the fish gut are in turn sized and categorized.

Work supported by Algalita was the first to indicate that small fish are affected by plastics, too. The effects of marine debris on larger marine animals have been well documented but its effect on lower trophic levels had not until Algalita commenced its studies. Much work remains to be done, however. We do not know how long the plastic particles are resident within the gut or the health consequences for the organisms and the food chain.

Although plastics are made from petroleum, marine plastics do not break down into simpler components and evaporate or decompose in the same manner that petroleum from marine oil does (see *OceanBights* summer 2011 issue). Marine plastics include the synthetic polymers polyethylene and polypropylene which are used for packaging because they are flexible, strong, light and resistant to chemical degradation, making them long lived. However, under wave action they do break into smaller pieces, eventually becoming the size of large zooplankton and easily mistaken for food.

One would think that swallowing plastic particles is deleterious to health but the situation is worse. Contaminants that are in the air can be absorbed into the water and attach to particulate materials, including floating plastics. Algalita-sponsored studies have found that floating plastics attract pollutants and carcinogens, concentrating these on their surfaces. The bad chemicals include persistent organic pollutants (POPs), including polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) all of which are considered endocrine-disrupting chemicals (EDCs). The use of chemical nomenclature and abbreviations is to emphasize that these are really bad substances.

Plastics found in dissected fish. Courtesy AMRF

Then there is the study of the source of the plastics. Of course, being man-made, we know the ultimate source of this pollution, but where do the plastics enter the ocean? Images of trash in the Los Angeles River at its mouth in Long Beach are well known. Again, Algalita has sponsored studies of this trash to quantify the amount and type of plastics entering the ocean through the Los Angeles Basin's two largest rivers, the Los Angeles and the San Gabriel. The river flows were sampled with hand nets, manta trawls and streambed samplers, with the latter two being lowered by crane. Of course, most trash enters the ocean in episodic events, that is, during rain storms. Algalita extrapolated measurements of plastic runoff for a 72-hour period weighted as 24 hours each of heavy rain, moderate rain and no rain. Their estimate for this period was 2.3 billion pieces and fragments of plastic, 71% being polystyrene (plastic insulating foam) 10% being pre-production resin pellets and the remaining being miscellaneous pieces.

Algalita is clearly committed to hard science in its investigation of ocean plastics. The above studies have been published in the Marine Pollution Bulletin, the Journal of Environmental Monitoring, and the Journal of Integrated Coastal Zone Management. In addition to its quantitative work with marine plastics Algalita continues its kelp reforestation studies and has an outreach program for the public.■

California's Coastal Radars

By C. Gelpi

One of the difficulties of ocean science is obtaining data over large sections of the ocean at a single instance. However, various remote sensing programs are now underway that permit us to get a more regional and even a global view of our ocean's properties (see the Aquarius article, this issue). One such program is now making continuous large-scale ocean current measurements off the coast of California. To see the latest coastal current measurements go to www.SCCOOS.org/data/hfrnet.

HF radar at Corral Creek, Malibu. Photo by C. Gelpi

The Southern California coastal currents are measured by a chain of 32 simple radars arrayed along our coast and on some offshore islands. The radars operate in the HF (High Frequency) band, between 3 and 30 MHz, or stated another way, between the AM and FM bands on your car radio, if you remember those. The coastal current project interests me for several reasons besides making large-scale measurements. First, I have an interest in HF radar from its interactions with the ionosphere, and second, I seriously dislike diving in regions of large currents. If we could check a web site to determine the direction of currents before we drove to a dive site, we may make other plans. Anyone caught in the Pt. Dume current lately?

Historically, some of the largest radars ever built were HF radars, designed to detect ballistic missile launches located thousands of kilometers away from the transmitter using reflections of radio energy off the ionosphere. These radars are often referred to as over-the-horizon radars for their ability to probe beyond the line of sight. Our coastal radars do not use ionospheric reflections but they do probe quite a long distance offshore.

How do these radars work? At its simplest, a radar (RAdio Detection And Ranging) transmits a radio signal, part of which is reflected by an object, and returned to the receiver. By measuring the time from transmit to receive, we know the distance to the object since radio waves travel at the speed of light. Knowledge of the direction of transmission permits a bearing to the object. In the coastal radar case, the objects are sections of ocean, and we want to know the ocean's velocity at all locations. There is some complication to determining the bearing to specific sections of ocean, but that task has been accomplished satisfactorily using fancy mathematics. After processing, the ocean-surface resolution is on the order of 5 to 10 km. These sections can be repeatedly revisited to determine their gross surface currents as measured via the Doppler shift, or the minute change in frequency of the radio waves reflected by the ocean waves transported by the current.

Of course, knowing the direction of currents is very useful, permitting better management response to hazardous conditions and disasters, assisting coastal resource management, and enabling better scientific understanding of coastal processes. Chief proposed uses include the prediction and tracking of where bad water is heading. Bad water includes that contaminated by oil and sewage spills or river discharges. Although sometimes the bad water signal is readily apparent (for example, the slick produced by surface oil), in other cases the signal may not be discernible (at night or for other reasons) and its propagation must be inferred from currents. The currents can be integrated over time to determine the likely location of transported objects or contaminants, or used to predict their future locations.

Other proposed uses are to predict storm surges, study climate change, mitigate coastal erosion and improve weather forecasts. Yet another use is to modify maritime routes in order to avoid opposing currents or get an assist from supporting currents. This is a modern day implementation of Ben Franklin's analysis of the Gulf Stream to achieve the same goals.

To further understand the utility of this radar chain, I contacted an old acquaintance who works with these radars, Prof. Libe Washburn, from University of California, Santa Barbara. UCSB operates 10 radars and Prof. Washburn is intimately familiar with them. He sent me information and papers on several studies described below.

The continual measurement of surface currents provides a mechanism to address many questions in marine biology and marine resource management. For example, fishermen and divers know well that offshore oil platforms are rich in marine life, but as we consider whether to remove decommissioned platforms or leave them as artificial reefs, questions arise about the relation of the platforms to marine life: do they enhance it or attract it from more natural habitats? One factor is recruitment. Are young that appear at the platform at greater densities than at nearby natural reefs the result of attracting fish from those reefs or the result of the platform being a suitable habitat? Some fish have a larval stage that is particularly influenced by surface currents (called ichthyoplankton, see SWFCS article, this issue), and the analysis of surface currents bears on our understanding of their recruitment. For example, if current flows pass a platform to non-suitable habitats, then the young fish that arrive at the platform would perish if they did not recruit there. That is, prevailing currents are such that young-of-year would not survive if not for the platform. An analysis of currents derived from HF-coastal-radar data indicates that for the species of fish studied, the platforms did indeed increase the opportunities for fish recruitment.

We generally think of currents off our coast as those that bring very cold water from Alaska that makes our play in the SoCal ocean less fun. Many of us are aware of the recirculation eddy in the Southern California Bight that keeps Catalina water a tad warmer than that off San Diego. However, the HF radar constellation provides much more detail on surface flows. The California currents flowing toward the south can be thought of as being pushed by the winds. When these winds stop, or relax, the current usually reverses and heads north. This happens on average about once every one to two weeks. Disturbances, such as eddies, that are associated with these changing currents, can be followed and measured and compared to predictions from theory. The result of such analyses has been a much better understanding of the current dynamics in the Santa Barbara Channel.

Although these radars cannot find currents close to shore due to the interference of the land with radar returns, we suspect that currents offshore are closely correlated with those that are nearshore and can be estimated with models. We look forward to the time when we can use real-time current information to plan dives and boat trips and avoid those infamous and nasty against-the-current swims at Point Dume. This sounds like a ripe topic for volunteer researchers.

Northrop Grumman awards CMS Community Service Grants

The HF-radar effort is a part of the Coastal Ocean Current Monitoring Program (COCMP) and a component of Southern California Coastal Ocean Observing System (SCCOOS). Paid for by the public, these data are freely available to all.■

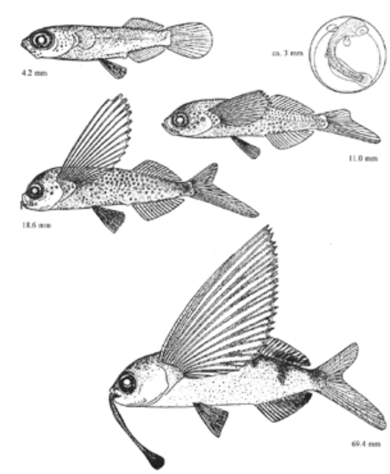
Spotlight on: Southwest Fisheries Science Center

The Southwest Fisheries Science Center (SWFSC) conducts science research for the National Oceanic and Atmospheric Administration especially in regards to the National Marine Fisheries Service in California. In other words, they conduct federal research so the U.S. can do its job, such as managing fisheries and protecting endanger species. SWFSC has 5 five divisions, three of which are located in a primo location, next to Scripps Institution of Oceanography, in La Jolla, while the other two are relegated to those hard-luck towns of Pacific Grove and Santa Cruz. The lucky divisions are Protected Resources, Fisheries Resources and, go figure, Antarctic Ecosystem Research.

A lot of SWFSC work involves assessing and understanding marine life in support of fisheries management for economic sustainment or to support federal law. The latter includes the Marine Mammal Protection Act (MMPA) and the Endangered Species Act. Understanding marine life begins with the basics, such as estimating population size and determining trends in abundance. It then progresses to identifying evolutionary significant units, determining and mitigating threats to the population and designating critical habitat. The latter requires understanding the life history of a species, how it interacts with the environment and understanding the state of the ecosystem. Although the work of SWFSC is vast, we will try to give a coherent picture of it by outlining some specific research, particularly as it pertains to Southern California.

Of course, the most basic metric for understanding a population is the number of individuals of a particular species. One can imagine the difficulty in obtaining this number or even estimating it. Measuring the basics often entails much primal excitement as the researcher often must go to the ocean to witness the population. Hence, SWFSC employs research-vessel surveys, aerial surveys, shore-based surveys and small-boat-based research. However, estimating species numbers is a task begging for automation, and SWFSC is researching and developing sophisticated methods to locate populations and estimate their sizes.

The Fisheries Resources Division concentrates on species with economic value, especially those that are managed by the Federal government. SWFSC conducts assessments of anchovy, sardines, Pacific mackerel, market squid, and krill. (As we write this, krill are being gobbled up in unfathomable quantities by Blue whales off Palos Verdes.) If you have ever tried to count the number of sardines in a bait ball, then you can appreciate the task of assessing these fish and invertebrates. One technique is to sample the ichthyoplankton (planktonic fish eggs and larvae). SWFSC is very proud of its ichthyoplankton identification work. The ichthyoplankton contain a bewildering array of fish eggs and larvae advected by the prevailing currents. They are scooped out the ocean and then sorted, identified and counted. Ichthyoplankton have been



Ichthyoplankton to adult, Flying Fish, CalCOFI atlas collected and organized from the CalCOFI cruises (see last issue of *OceanBights*) providing a time series over 60 years long of fish measurements. Identification is the trick as the larvae and eggs do not look like their parents. However, the ichthyoplankton are much easier to catch than their parents and much can be inferred about the state of the parent population from an analysis of their eggs and larvae. SWFSC is world renowned for their ichthyoplankton studies and archive. If you are interested in the identification characteristics of larvae, download the CalCOFI atlas number 33, "The Early Stages of fishes in the California Current". In addition to visual identification of larvae, the institution is working on the automation of fish egg identification using DNA markers. If the ichthyoplankton DNA can be extracted, analyzed and associated with particular species automatically, then much more data could be obtained easily for the fisheries.

In addition to assessing fish stocks, the Fisheries Resources Division monitors the ecosystem, researches fish ecology, analyzes the numbers and puts the results in context. Monitoring the ecosystem consists of collecting, processing and archiving observations such as those made by the CalCOFI program and also catch-data from fisheries. Such observations include movement patterns, stock structure and food-web dynamics. The Analysis and Synthesis Group refines the data and develops databases and algorithms for statistical studies. It also conducts studies pertaining to management options and strategies.

The Protected Resources Division conducts Federal research supporting the Marine Mammal Protection Act and the Endangered Species Act. The marine mammals associated with the MMPA are cetaceans and pinnipeds. For the MMPA this division develops the understanding to maintain elements of these mammals' ecosystem. They compute population size, estimate human-caused mortality, and determine stock structure using some of the survey techniques described earlier.

Leatherback turtle with tracking device, from SWFSC archive

The National Marine Fisheries Service has the responsibility for implementing the Endangered Species Act for marine species on the endangered list, currently 82 species, including all marine turtles. Turtles are particularly interesting to us given recent sightings at Santa Catalina (thought to be a green turtle, *Chelonia mydas*) and Malibu (leatherback, *Dermochelys coriacea*), as well as the growing non-nesting colonies of green turtles in the Los Angeles area. Both species have been declining precipitously globally and are being studied by SWFSC. The Endangered Species Act directs the fisheries service to designate critical habitats and to make recovery plans. Although sounding bureaucratic, the recovery plans have direct bearing on SWFSC work. For the turtles, identifying stocks sometimes means tracking turtles to their breeding grounds. And for some turtles that appear in our local waters, those breeding grounds are far away. Hence advanced survey techniques are developed, one being a leatherback-turtle harness that holds tracking gear without harming the softer-shelled turtle. The gear includes a transmitter and a GPS receiver that telemeters the turtle's location when the turtle is at the surface. Tracked turtles provide information on migratory routes, foraging and nesting areas. For example, leatherback turtles found along our central coast (and occasionally off Malibu) are foraging but may migrate to Papua New Guinea for nesting. In the same manner, green turtles found at Catalina may just be passing through or be residents in the Bight, either near LA (San Gabriel River) or San Diego Bay.

SWFSC's collection of turtle tissues and DNA samples is one of the largest in the world. The samples can be used for behavioral, ecological, and phylogenetic studies, including simple tasks such as sex determination, pregnancy status and age. More complex interpretation is required to retrieve information on foraging and trophic level. This is performed through stable-isotope analysis techniques. Chemical isotopes, that is, elements with the same number of electrons and protons but that differ in atomic weight because of varying number of neutrons, engage in the same chemical reactions, but their concentrations differ due to nuances regarding their mass (e.g., faster evaporation of the lighter isotopes or differing rates of chemical reactions). The concentration ratio of chemical isotopes, for example C^{13} to C^{12} within a tissue sample depends on the particular tissue as well as the tissues that the animal ate, and the food that that prey fed on, etc. Hence the trophic level (position within the food web) of the animal can be inferred, as well as the type of food the animal consumed. Phylogenetic studies bear on the relationship of regional populations. These are determined based on the similarity of haplotypes, i.e., DNA sequences that are adjacent on a chromosome and are transmitted together.

Understanding the life cycle of endangered turtles enables the SWFCS to propose viable solutions and regulations in the recovery plans for the turtles. These include identification of needed habitat for feeding and nesting and the recommendation of mechanical devices to mitigate turtle by-catch.

Finally, the Antarctic Ecosytem Division executes a national program providing information on the marine living resources in the ocean areas surrounding Antarctica. These data are needed for the development and support of U.S. policies regarding the conservation and management of these animals. Although the Antarctic is beyond the charter of the Catalina Marine Society, work at the bottom of the planet certainly sounds cool.■

CMS presented to the Whalers, Antelope Valley Desert Divers and the Southern California Dive Club of the Inland Empire.

David Bentley and David Tsao, the D&D team on deployment. Photo by K. Norris

CMS deployments and retrievals

Late summer and early fall were busy periods for CMS field work. Successful instrument deployments and retrievals were executed off White Point in Palos Verdes, Leo Carrillo in Malibu, and at Wrigley Institute of Environmental Studies on Catalina Island.

The White Point dive replaced a thermograph deployed in January 2011 by Merry Passage and Phil Garner. They graciously set the instrument at one of their frequented sites and retrieved it ten months later. The temperature data revealed the site to be an internal-wave hot spot; in one twelve-hour period we found the temperature change by nearly 6°C (~11°F).

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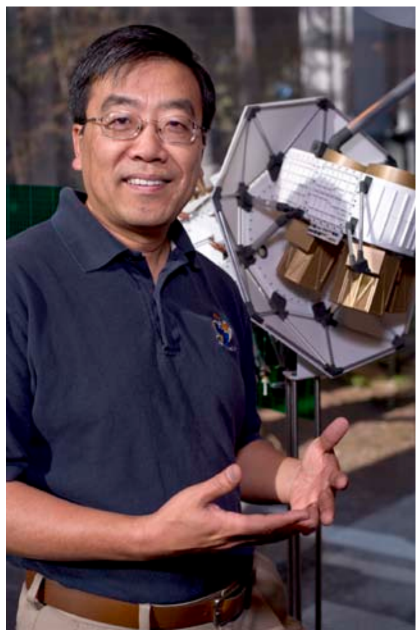
Aquarius, A Missing Piece of the Climate Puzzle

By Chris Howell

On June 10, 2011, NASA's Jet Propulsion Laboratory, Pasadena, California, successfully launched the Aquarius/SAC-D observatory from Vandenberg Air Force Base near Lompoc, California. Joining a family of 16 NASA Earth Science satellites now in orbit, Aquarius' mission over the coming years will complete a once-missing component in our study of global climate variability. Its data will increase our ability to understand and predict major ocean events such as El Niño and La Niña and how atmospheric conditions, such as the accelerated rise in greenhouse gases, affect Earth's climate.

Riding atop a Delta II 7320 launch vehicle, Aquarius/SAC-D made its way into what is known as a "terminator" orbit. Flying more than 400 miles above the planet, Aquarius follows a polar route, staying just inside the shadow line of our rotating Earth. Three passive microwave radiometers aboard the Aquarius instrument read a path on the planet's surface 300 kilometers wide as it travels above. Sharing the same antennae, a second instrument, an active radar developed by JPL called a scatterometer, paints the 300-kilometer wide path with a radar pulse to measure the surface roughness, or reflectance, of the water. The combined data from these two instruments are used to create a global map of our ocean's surface salinity, refreshed each week and accurate to two parts per ten thousand.

Why is this information so vital to understanding our changing global climate? The complex salt within Earth's oceans is the very medium that moves heat throughout our planet's water column. With saltwater having a greater specific gravity than freshwater, two fundamental principles, gravity and heat convection, work together to shape sub-tidal currents. Heavier, saline-rich water will sink beneath the newly arriving freshwater from rainfall, glacial melt, rivers and streams. As it descends, it carries with it solar heat, creating convection currents in the depths below. By measuring the density, variability and circulation of salt within the ocean, we begin to know more about how our planet's changing climate and the global water cycle are linked.



Dr. Yi Chao
Photo by C. Howell

Catalina Marine Society interviewed JPL's Aquarius Project Scientist Yi Chao, whose work has helped shape Aquarius through the last ten years from proof of concept, to the fully functional, first-of-its-kind instrument orbiting our planet today.

CMS: How did the Aquarius mission begin?
Yi: The mission officially started about ten years ago. The P.I. (Principle Investigator) has been working on Aquarius for about twenty years. I got involved in the late nineties. A lot of us have been working on Aquarius for a long time. Officially, the mission started in 2002. The aircraft program (to develop the instruments) began well before the satellite program in the late '90's.

CMS: How did you become involved with the mission?
Yi: I received my Bachelor's degree from China in atmospheric physics and came to the United States for graduate school in 1985. I went to Princeton to study atmosphere/ocean sciences. After two years, having

received my master's degree, I became more and more interested in the ocean, so I switched from atmospheric science to ocean science, which is very similar. They're both in the Earth/science, geo/science category. I got my Ph.D. in Oceanography, and then I came to UCLA as a post-doc, and began to interact with the people at JPL. I became fascinated with remote sensing techniques from aircraft and space, and after three years, I moved to JPL. I started my first job here in '93.

My main interest is studying ocean processes and phenomena. I try to ask the question why does the ocean do this, how does ocean health affect the ecosystem, atmospheric processes and climate? JPL is working with a lot of engineers who try to think about future ways of measuring the ocean from space. It evolved from sea-level measurements in the nineties, wind-level measurements in the late nineties, and then ocean salinity being the natural course of study.

Salt controls the weight of the water. More importantly, the temperature and the salinity determine the weight of the seawater, the density. The weight of the water determines how the ocean flows, how it overturns. So, heavy water sinks. It's like the atmosphere where light air rises and that drives the convection. The vertical motion of the atmosphere affects the rainfall, the circulation. It's the same thing for the ocean. It's the heavier water that's important. That weight, with heat convection, drives the three-dimensional flow. By knowing the surface salinity you can condition this kind of flow. Without knowing the salinity information, you only have partial information.

Scientists have been dreaming about remote salinity sensing for decades. The first paper on it came out in the seventies exploring a theory on how we might use microwaves to measure salinity. So the theoretical work was done thirty years ago. Because the signal is very small, it's very challenging and took about twenty years for the community to sort out how to make all those little corrections and extract a small fraction of the signal being measured. The frequency we use is 1.413 gigahertz in the microwave band. We chose that frequency because it gives us the biggest response to salinity. So, in other words, we found that this is the frequency where a slight change of salinity corresponds to the biggest changes in the microwave signal the Aquarius radiometers can detect.

CMS: In the on-line graphic representing Aquarius, it depicts the three radiometers as red, green and blue, looking something like an early video projector. How did that come to be?

Yi: (laughter) Each radiometer is identical. We don't have to fly three. We can fly one. It would just take three times as long to cover the globe. So, think about it. We line up the

Adopt-A-Thermograph

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.

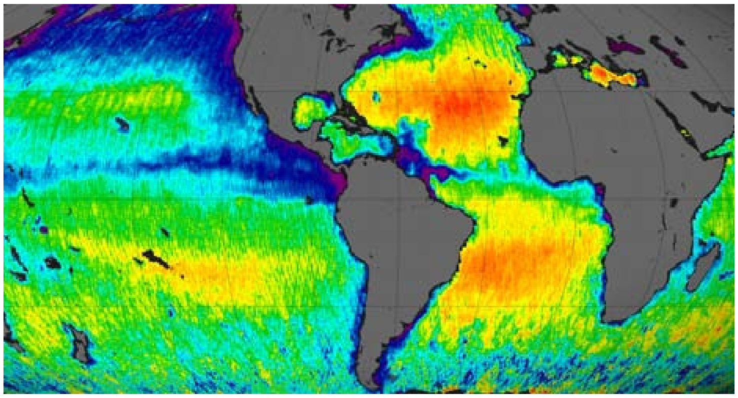
The Adopt-A-Thermograph is directed by David Tsao. For more details, contact David at david@catalinamarinesociety.org or Craig at craig@catalinamarinesociety.org .

three footprints, first one, then the second, then the third in a nice configuration. They line up horizontally. So rather than cover a hundred kilometers, now we can cover three hundred, and within a week, we can cover the whole globe. If we were to fly only one, it would take three weeks to cover the whole globe. Three is a nice configuration.
We could fly more, but mechanically, it's difficult to arrange. How do you fly five? With three, you optimize the coverage while giving the mechanical engineer less of a headache to configure. The original concept was to rotate the dish. Rather than have a mechanical dish with three radiometers, we would have had one radiometer in constant rotation. That option proved not to be very practical. It would have cost a lot of money, and would have presented a lot of risk. Eventually, we decided to take a more conservative course, utilizing three radiometers for the configuration. That was optimal. These studies took a few years before we were ready to begin the project.

CMS: Can you say more about the spacecraft's orbit tracking just inside the nightline of our planet as it spins on its axis?
Yi: We fly a so-called "terminator" orbit. Basically, we follow the sun by flying the boundary between day and night. This way, the spacecraft can collect solar energy while the instrument looks at the dark side of the planet, allowing us to minimize the "noise" caused by sunlight reflecting off the water. On the night side, the only thing reflecting off the water is the light from stars and galaxies, making it much easier to work with.

CMS: How does the scatterometer work?
Yi: The radiometer is a passive instrument collecting radiation emitted from the planet's surface. The scatterometer, on the other hand, is an active radar that measures the "roughness" of the water caused by waves and swells. It sends a pulse to the ocean's surface to measure the reflectance. If it's a perfect mirror, you get a perfect reflection. The spacecraft uses the same dish antenna for both instruments, combining the two separate signals from the radiometer and the scatterometer to produce an accurate measurement.

CMS: Can you tell us about the instrument-calibration process once the craft reached its designated orbit?
Yi: Once you start turning on the instruments, there are a number of different calibration processes to complete. There are the orbital parameters and the pointing of the instrument. You want to make sure you're pointing in the right direction, and to calibrate the antenna patterns and the antenna temperatures. All of this is first tested on the ground and in the lab. Then, in space, we have to make sure everything functions the way it was designed to. So, calibrating the stability of the radiometer is still ongoing at this point with less than a month of the data sets in. The first of the data sets began to come in almost a month into flight, around 21 July 2011. Now, we want to take a little more time and better understand how the instrument works. Once we



First surface-salinity map.
Courtesy of JPL

finish the calibration, then we start the validation.
We have many independent surface measurement sources to verify calibration. Salinity readings taken by ships, buoys, robotic vehicles, and drifting vehicles in the ocean are vital to the process. With their conductivity sensors, they measure salinity at the surface, and then we compare the two. One is touching the water and one is four hundred miles in space. We are still in this calibration phase and working out some issues. Yesterday was our "first light" (Aquarius completed its first global mapping on Sept. 23, 2011,). There are still some issues we need to work out. We need to understand the scatterometer data better. In first light, we only used the information from the radiometer. We're still working to calibrate the scatterometer so we can better utilize all the information. There's a variety of information you can feed into the retrieval program. So right now, we call it quick-look processing.

CMS: How high is the bird flying?
Yi: The Aquarius satellite is flying at 657 kilometers, or 408 miles.

CMS: Touching on the practical implications of the mission, how will the information from this and related projects help us to understand the effects of global climate change in both our ocean and atmosphere?
Yi: If you go to the NASA Website, you will see 15 or 16 satellites already flying which measure different aspects of the Earth's systems: atmospheric, land processes, ice, snow and the ocean. Aquarius is one of the many, yet we are providing this very important piece of information, this missing piece of the puzzle. I couldn't say this is going to be the silver bullet that's going to change everything, right? But this is certainly one of the key pieces of missing information to be added to our database of all known knowledge and to monitor the global changes. The capability of the satellites is global coverage. You don't have to send a thousand ships and all their technicians to the ocean, because every week, the satellite will cover every part of the planet. Salinity is affected by precipitation, evaporation, river runoff, ice melting; so anything related to salt and freshwater will give you a signature in salinity. This is part of the water cycle. In other words, if you are melting more of the snow pack in California, where does the snow go? You can't store it in your backyard; it eventually has to go back to the ocean. When the water goes back to the ocean, you will see the salinity becomes fresher. If the ice is melting, you're going to see salinity changes. Salinity is really an indicator of many of these processes. Aquarius will provide information about the global water cycle, and more importantly, will quantify the change. You can use the salinity changes to infer how much the source is changing. In that way, it's a very powerful data set to be added to the so-called knowledge database.

CMS: Do you think this data will influence industrial behavior?
Yi: I wouldn't expect immediate changes. All of these climate data sets need a long record. You can't use something changing from today to next year, or even two years from now, to infer something magically is evolving, right? I hope Aquarius' data sets eventually will have a strong impact on policy. An example would be the famous Keeling Curve where we've seen how atmospheric CO_2 is changing in Hawaii over a period of fifty years. When started in the '50's, the scientist from San Diego (David Keeling of the Scripps Institution of Oceanography) never thought "that's a powerful curve," that it would be named after him, and the enormous impact it would have on policy. It may take a decade or more to accumulate enough accurate data, then to understand the trend and eventually influence the policy makers.

CMS: How will the (Aquarius) information be released?
Yi: Once we are through the calibration/validation phase, the data will be released and made available to the public. JPL's

data center, known as PODAAC, Physical Oceanography Distributed Active Archive Center, <http://podaac.jpl.nasa.gov> is responsible for gathering the data and publishing it on the website. The digital data, the images, the graphs, everything is public access. It's open to everybody on the globe without restriction. Before releasing the data to public domain, the science team makes sure the instrument is working properly and the information is accurate. That's the calibration/validation phase. Our goal is to release accurate data within a year of the launch. Coming up in the next few months, in early 2012, there'll be a major meeting with all of the science team members presenting their findings. Hopefully, we'll conclude that the data are accurate, then, release it so that everybody can do their own research. Then, the public can then go to the website and access ocean salinity information in their region of interest.

CMS: Part of the Aquarius project calls for a 2012 deep water project in the Atlantic using ships, smaller craft, buoys and submersibles.
Yi: There's a dedicated website describing this as well called SPURS (Salinity Processes in the Upper Ocean Regional Study http://spurs.jpl.nasa.gov). That experiment will have two goals. One is to provide more in situ data to help us to compare with Aquarius and more importantly, to collect three-dimensional information at various depths. We have five cruises planned. Each cruise will be thirty days long and will take place in the North Atlantic about 28 degrees north, away from the coast, where maximum salinity in the Atlantic is present. We'll deploy a number of different vehicles, including robotic vehicles, to measure saline concentration in the three-dimensional water column, and then try to understand what controls the change at the surface. Aquarius measures only surface salinity. By knowing the surface changes, we hope to use this field campaign to understand the processes that take place within the water column. So, if we see some changes at the surface, we can anticipate what may be happening at depth.

CMS: What depths will the study gather information from?
Yi: Some of the robotic vehicles go down to two thousand meters; some of them go down to a few hundred meters.

CMS: Will this research be conducted only in the North Atlantic?
Yi: Yes, for the first series. There will be five cruises at the same spot at different seasons. Each cruise is thirty days long. The first cruise will take place in the fall of 2012, with the first series concluding in the summer of 2013. All will take place in the same North Atlantic location. We call it sub-tropical: 28 degrees north, 38 degrees west. You can go to the website for a detailed description. Each cruise will occupy an area a few hundred kilometers by a few hundred kilometers, so we'll have a view of Aquarius' footprint. A lot of information will be collected in that footprint. And even within this designated portion of Aquarius' path, a lot of changes occur such as microclimates and even micro-oceans. We chose that area because it's very salty, around 38psu's (practical salinity units). We want to understand what maintains the salty water. That's a simple question.

CMS: In the global water cycle, is salty good?
Yi: There's no such thing as absolute good or bad right? In certain areas, you want to monitor the change, that's really the key. You want to see whether the area's freshwater gets fresher, you know, and if the salty water gets saltier. That represents the speeding up or slowing down of the water cycle. So you ask the questions: do we have more evaporation as we change the climate? Do we have more freshwater melting? All these questions are related.

CMS: Speaking of climate, I've read that ocean events known as El Niño and La Niña actually begin in the region of Indonesia during monsoon season.
Yi: El Niño begins in the western Pacific where major

rainfall changes occur. That, presumably, will have a salinity signal. One of our science questions is to quantify this. We anticipate that Aquarius will be able to see El Niño/La Niña signals, but we'll need several years time to compare our data.

CMS: How long will Aquarius' mission run?
Yi: The nominal, or baseline mission, is like the warranty on your car. The engineer can't promise the longevity of the craft beyond a certain period. So, as for reliability, they say the baseline is three years. The team is very confident that most, if not all, of the parts, are going to work for at least three years in space. But, nobody is going to throw away a car when the warranty is up. Some NASA satellites last ten, twelve years or more.

CMS: Yi, thank you very much for meeting with us.
Yi: Sure! Thanks for your interest!■

►Deployments *continued*

David Bentley and David Tsao, deployed a two-thermograph array from Leo Carrillo Beach. They sponsored the thermographs within the "Adopt-A-Thermograph" program (see insert on page 13) designed to support the Continental Array Project. The deployment entailed a significant 300-m swim to reach the depth necessary for the deep site. Mike and Cole Bushell accompanied them with a recreational dive. D&D used GPS gear and bearings to measure the site well for a successful retrieval.

CMS Board member Mike Doran led deployment activities at WIES with the Catalina Conservancy Divers Tom Turney and Tom Luce. The WIES deployment supports our pilot program to maintain a scientific mooring at Catalina. The instrumentation measures conductivity and temperature (used to compute salinity), dissolved oxygen and chlorophyll. Because the CMS has only one sensor suite, we need to turn around the instrument very quickly to avoid large gaps in the time series. Thanks go to Kellie Spafford, the lab technician at WIES, for data downloading, maintenance and calibration, which permitted Mike to redeploy the suite one week after retrieval.■

D&D team timing the sets
Photo by K. Norris

Upcoming Meetings

CalCOFI Conference 12-14 December 2011 at Scripps in La Jolla, "Integrated Ecosystem Assessment and Ecosystem Modeling of the California Current"

Ocean Sciences Meeting 2012, 20-24 February 2012, in Salt Lake City

Southern California Academy of Sciences annual meeting, 4-5 May 2012, Occidental College, Eagle Rock

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) submit an application that is approved by the board; and, 3) pay the annual dues (currently $100). 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
19872 Collins Road
Canyon Country CA 91351

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	**Field**	**Office**
Data analysis	Boating	Web design/programming
GIS	Diving	Graphics
Programming	Instrument calibration	Photography/Videography
	Hardware/Equipment fabrication and mounting	

Magazine/newsletter	**Fund raising**	**Press/publicity**
Reporting	Event planning	Public speaking
Publishing	Event volunteer	Newspaper articles
Editing	Grant writing	
Departments		