Marine Biological Laboratory | THE UNIVERSITY OF CHICAGO

The Ecosystems Center
Annual Report 2016-2017

About the MBL
The Marine Biological Laboratory (MBL) is dedicated to scientific discovery – exploring fundamental biology, understanding biodiversity an
d the environment, and informing the human condition through research and education. Founded in Woods Hole, Massachusetts in 1888, the MBL is a private, nonprofit institution. In July 2013, the MBL and the University of Chicago formed an affiliation that enhances both institutions' missions of leadership and innovation in scientific research and education.

About The Ecosystems Center
Established in 1975, the Ecosystems Center operates as a collegial association of scientists. Its mission is to investigate the structure and functioning of ecological systems and to predict their response to changing environmental conditions; to apply the resulting knowledge to the preservation and management of natural resources; and to educate both future scientists and concerned citizens.

Editors
Anne Giblin
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Front and back cover: Sunset over the MBL Rowley Field House and the Plum Island salt marshes (Credit: Jane Tucker)

This page: Aerial view of the Great Sippewissett Marsh (Drone photo: Rhys Probyn/Ivan Valiela/Javier Lloret)

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Using the basics

MESSAGE FROM THE DIRECTOR

By Anne Giblin

When I started graduate studies there was a debate about the relative merits of basic vs. applied research. "Basic" science was considered pure science while "applied" science was narrowly focused on local problems where results were not likely to be widely transferable. One rarely hears this debate anymore. Time has shown that some of the most complex challenges, such as addressing coastal eutrophication and climate change or restoring damaged ecosystems, may be "applied" problems, but solving them requires new and deep basic knowledge.

Since it was founded over 40 years ago, the Ecosystems Center has been involved in long-term studies and experiments on critical issues that intersect basic and applied science. We, and our colleagues, have looked not only at the immediate impacts of environmental changes but also at ecosystem feedbacks that will determine long-term responses. We have learned that very short-term responses of the arctic tundra to a fire, of a marsh to sea-level rise, or a forest to soil warming, do not tell the full story. Unless we follow these ecosystem responses over decades we may come to the wrong conclusion.

Long-term observations and experiments are most powerful when coupled with a deep mechanistic understanding of ecological and biogeochemical processes and with models to integrate and test our understanding of how the pieces fit together. In this issue we highlight some ways that a better understanding of plant physiology and plant-soil process, coupled with modeling have informed our understanding of large scale problems.

Increased nutrient loading to the coastal ocean has led to water quality problems across the globe. But while we know that nutrients increase algae growth, the processes that allow this growth to explode into a bloom are not understood. In this issue we report on new insights into algal physiology that might help predict when algae are likely to proliferate to form damaging green, red, and brown tides.

Salt marsh plants trap sediments that help marshes keep up with sea-level rise. Salt marsh plants are adapted to periodic tidal submergence, but species vary in their tolerance to inundation. Therefore, changes in abundance of different salt marsh species serves as an indicator of whether marshes are keeping up with sea level.

Unfortunately, an analysis of vegetation over the last several decades suggests that Cape Cod marshes might not survive into the next century with current rates of sea-level rise. Vegetation in arid lands faces the opposite problem, too little water. During dry periods some plants tap water deep in the soil but these deep soils contain few nutrients. So how do plants obtain nutrients during dry periods in arid ecosystems?

Experiments reveal that plants bring water up from depth and release it from near-surface roots. This release stimulates microbes in these richer shallow soils to release nutrients that plants can use.

Climate change impacts both plant growth and soil microbial processes. But the direct impacts of climate are likely to be far less than changes mediated by changes in nutrient availability. In most ecosystems, recycling nutrients from the soil supplies most of the requirements for plant growth. Therefore, the fate of nutrients released is a critical factor determining the long-term trajectory of ecosystem change over time and helps us predict how individual ecosystems will respond to climate change and disturbance.

These four projects represent just some of the exciting research taking place at the Ecosystems Center. Through our educational and outreach activities, we also work to make this knowledge available to solve "applied" problems and to inspire the next generation of scientists. There is little time to waste. Issues such as climate change and eutrophication are sometimes called "wicked problems" not simply because of their global impact and scientific complexity, but because social and political institutions are not well equipped to deal with them and seem paralyzed by them. Scientists have an important role to fill to break this deadlock. We need to continue to define, clarify, and diagnose problems but, perhaps most importantly, lead the search for new solutions.

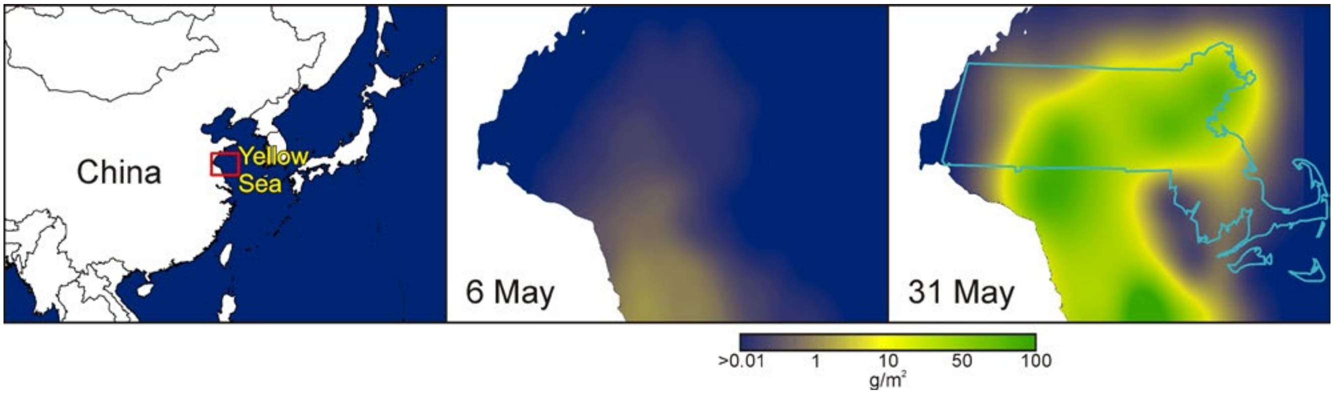
Novel insights from the largest green tides in the world

Expansive green tide in the Yellow Sea, China. Photo by Dongyan Liu.

Maps of the global distribution of human footprint on natural environments show highest potential impacts where densities and activities are most intense, usually along coastlines. Increasing intensive human activities in China release unusually large amounts of nitrogen to air, water, and watersheds. Although watersheds intercept quite large proportions of nitrogen inputs, considerable nitrogen loads from agricultural, wastewater, and atmospheric sources still manage to be discharged to receiving coastal marine waters of the Yellow Sea. Discharges from land have increased by about 6-fold during recent decades, with the result that recent concentrations of dissolved inorganic nitrogen in Yellow Sea surface waters range up to unusually high concentrations, reaching 72.2 μM, values much larger than the 0-3 μM that are typical of most seawater.

In general, nitrogen supply limits growth of algae and plants in coastal marine environments. It was not therefore surprising to find that certain opportunistic species, mainly green macroalgae in the genus *Ulva*, have recently proliferated in the Yellow Sea, with a rapid development of a macroalgal canopy - the green tide - across much of the sea surface (images across). The Yellow Sea green tides - the largest green tides in the world - grow quickly to cover a large expanse. Floating canopies of *Ulva prolifera* start expanding around river mouths and shallow water, and within a few weeks grow over much of the Yellow Sea, covering an area more than twice that of the State of Massachusetts (top image across).

Possible sources of nitrogen that support the Yellow Sea green tides likely include wastewater and fertilizer discharged from land. To understand the relative contributions of these sources of nitrogen to the explosive expansion of the green tides, the Valiela lab, in collaboration with Dongyan Liu and colleagues at State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, China, measured stable isotopic nitrogen and carbon signatures in samples of macroalgal biomass (figure across). Stable nitrogen isotopic values (the vertical axis in the figure

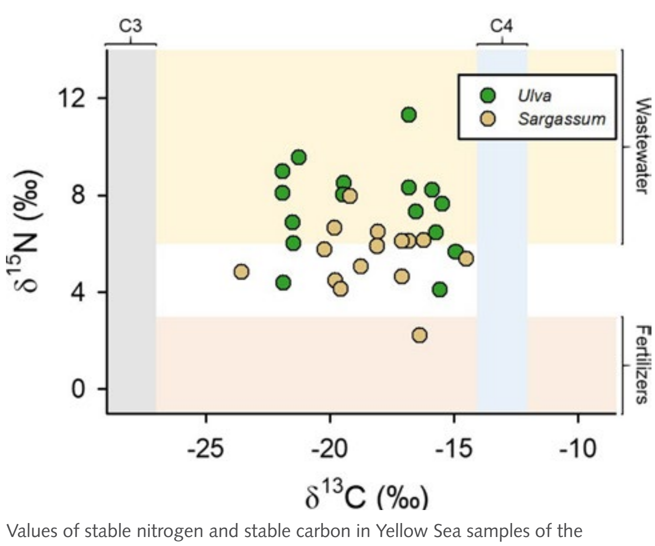


Location of the study area in Yellow Sea and distribution of Green Tide biomass during growth period. An outline of the State of Massachusetts is shown to provide a spatial comparison. Images by J. Lloret using data from Liu et al. 2015

below) measured in *Ulva* samples tend to fall toward ranges characteristic of wastewater, rather than fertilizers. This suggests that discharges of wastewater nitrogen might be mostly responsible for green tides. Measurements done on samples of *Sargassum*, a brown macroalga also present in the Yellow Sea, showed similar results. Other inputs of nitrogen to the Yellow Sea (atmospheric deposition, livestock manures, nitrogen fixation) are likely smaller, but merit future study. Stable carbon isotopic signatures measured in the macroalgae (the horizontal axis in the figure below) revealed another novel feature. Stable carbon isotopic values differ in photosynthetic organisms that have somewhat different metabolic pathways for fixing carbon from CO_2. These have been referred to as C3 and C4 plants. C4 plants generally show fast and productive growth, in part because they efficiently re-use CO_2 within internal air spaces, which, incidentally, leads to the isotopic fractionation that sets up contrasting carbon isotopic signatures in the two groups. Textbook-level understanding has been that C4 metabolism was restricted to certain fast-growing grasses that evolved during the early Tertiary. Previous work - by us at the MBL and others - with macroalgae in sites across temperate coasts of the Americas and Europe showed the puzzling result that stable carbon values in different species of *Ulva* approximated values characteristic of C4 metabolism. Recently, Jianfang Xu and colleagues at the First Institute of Oceanography, Qingdao, China reported a solution to the puzzle: transcriptome sequencing of *Ulva prolifera* revealed the presence of enzymes characteristic of C4 metabolism, and highly efficient carbon fixation. This new evidence showed that in this macroalga, C3 and C4 metabolisms co-occur, and that C4 processes may take over and may lead to rapid growth characteristic of the green tide explosions.

This novel development suggests not only that C4 metabolism is more widely distributed among producer taxa than thought, but that it has a far more ancient origin, perhaps even Precambrian. We further speculate that the origin of the effective internal re-use of CO_2 might simply be a fortuitous by-product of the evolution of internal air spaces that favored floating near the surface, maintaining macroalgae within the lit part of water columns, but in this case, also allowed repeated re-use of CO_2, which allowed the isotopic fractionation that betrayed that process. We conjecture that the same will be documented for the brown alga *Sargassum*, which also shows intermediate stable carbon signatures and features prominent air spaces within its fronds (figure below).

The case of the Yellow Sea is yet another example of two common major features. First, a demonstration of the powerful and increasing influence that humans exert on most of the natural world, particularly in coastal zones where terrestrial and marine ecosystems are contiguous and are strongly coupled by water transport, and which unfortunately, happen to coincide with the most intense human footprints. Second, this case study demonstrates once again that understanding applied problems often reveals important novel basic aspects about how the natural world is organized and evolved.



Values of stable nitrogen and stable carbon in Yellow Sea samples of the macroalgae *Ulva* and *Sargassum*, overlain over the ranges of isotopic nitrogen values, characteristic of wastewater and fertilizer sources from land; and isotopic carbon ranges for plants fixing carbon via C3 and C4 pathways

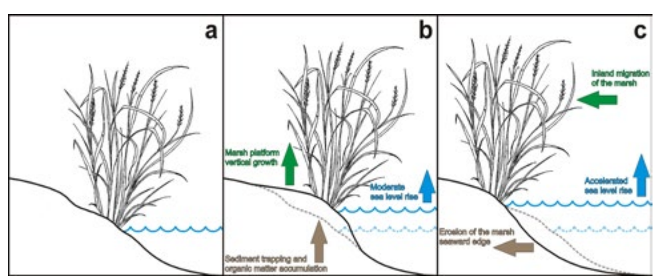
The uncertain future of salt marshes in an era of sea level rise

Aerial image of Great Sippewissett salt marsh, Cape Cod, MA. The image was made by digitally stitching a series of images from drone flights done in September 2015

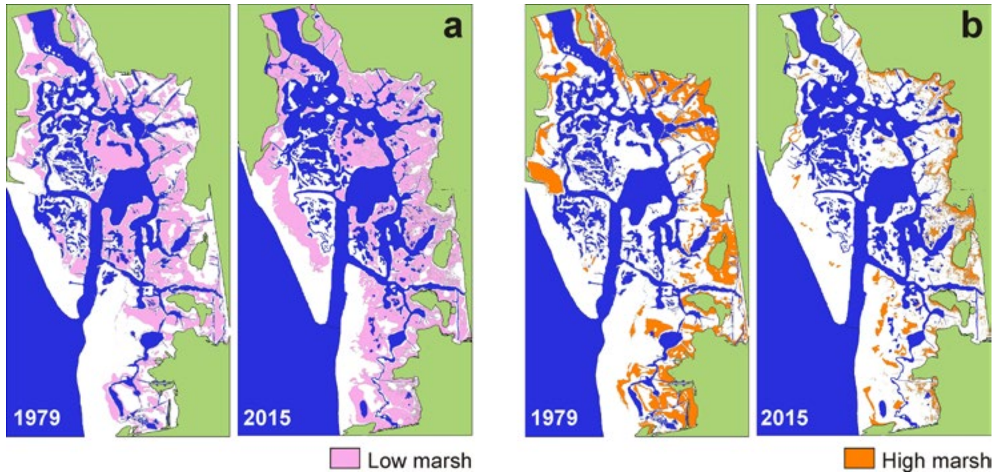
Salt marshes contribute to essential ecological functions and processes in temperate coastal landscapes. In doing so, marshes also provide valuable services that are of significant human benefit. A variety of human activities that take place in coastal regions result in increasing pressures to these valuable environments. For decades, observations of marsh loss around the world have accumulated. Best estimates are that 25% of salt marsh areas have been lost globally as a result of human disturbance. In addition, surging sea level rise adds new challenges to salt marsh survival.

Marshes occur at the interface between land and sea, and their survival depends on the ability of salt marsh platforms to accumulate sediment and rise vertically at rates greater than relative sea level rise, or else to migrate inland faster than erosion at their seaward boundary (schematic representation). Despite the ability of marshes to adapt to variable sea level rise rates in the past, a recent acceleration of sea level rise observed since the early 1990s, and the perspective of further accelerations as a consequence of climate change, have raised concerns about the future of salt marshes.

New England salt marshes are vulnerable to the consequences of sea level rise, for three reasons. First, the Atlantic North American east coast is a hotspot of accelerated sea level rise. Sea level rise in this region is accelerating at rates faster than the global average. For example, current rates of sea level rise in Cape Cod (almost 6 mm/yr), are five or six times faster than rates observed in previous decades, and more than double the regional long-term sea level rise rates since records are available. Second, the lack



A schematic representation of the response of salt marshes to sea level rise: a) In an initial state, marsh plants live at the interface between land and sea, and are inundated only for half of the day with the high tides. b) At moderate sea level rise rates, the accumulation of organic matter in the soils and the trapping of a fraction of the mineral sediments suspended in the water during each tide is sufficient to promote vertical growth of the marsh platform and keep pace with the rising seas. c) If sea level rise rates are too fast, vertical growth of the marsh platform is not sufficient and plants are forced to migrate inland to compensate the losses caused by the erosion of the seaward edge of the marsh of major rivers in the New England region limits the amount of mineral sediments in coastal waters. Sediment trapping by marsh plants is thus limited, and vertical accretion in New England marshes depends almost entirely on the accumulation of decaying plant matter in the soils. Third, the region is densely populated, and, in many instances, human structures will act as barriers and prevent inland migration of salt marsh vegetation.



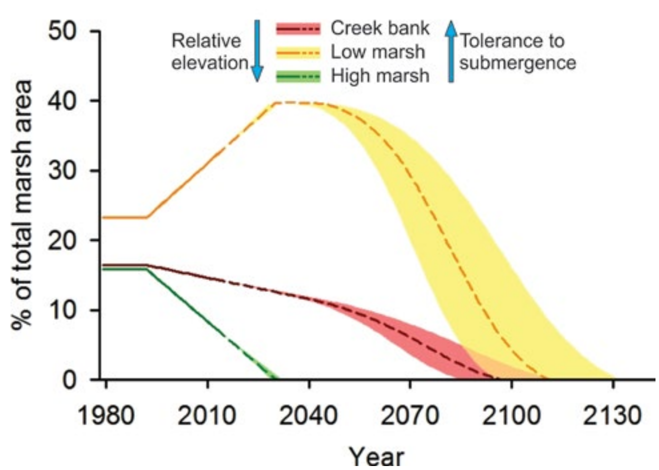
Spatial changes in some of the major vegetated habitats of the Great Sippewissett Marsh between 1979 and 2015, for a) low marsh, and b) high marsh

MBL researchers have been studying salt marshes since the 1970s. In 1979, before sea level rise rates showed signs of acceleration, Valiela and colleagues elaborated a detailed map of the different vegetated habitats in Great Sippewissett Marsh, a characteristic New England salt marsh. Four decades later, in 2015, Valiela and Lloret repeated the exercise, this time with the help of a drone. The analysis of these high spatial resolution datasets revealed impressive changes (images above). Sixty percent of the area occupied by high marsh vegetation, a group of plant species that prefer higher elevations and are less tolerant to submergence, has disappeared. The areas previously occupied by high marsh plants are now covered by *Spartina alterniflora*, a low marsh plant more tolerant to submergence, and that grows at lower elevations more frequently inundated by tides. These low marsh plants have also colonized other low-lying areas of sand and dunes as they became more frequently inundated. At the same time, there was a 15% decrease in the vegetation growing on creek banks. This was caused by the slumping of edges of the marsh, a symptom of increased erosion.

Other results derived from the analysis of these habitat maps are also consistent with sea level rise and increased submergence. The seaward margin of Great Sippewissett Marsh has receded around 22 m to the East. The area of open water within the marsh has also increased. Under natural conditions, as sea level rose, the bands of vegetation in wetlands such as Great Sippewissett would creep landward, overgrowing previously dry land. The Great Sippewissett maps showed no such progression upland, because an embankment, originally built to support a railroad trestle, and that now supports a bike path, prevented colonization of the landward border by marsh plants.

Our results show that the future of Great Sippewissett Marsh and other similar New England salt marshes is fraught with uncertainty. J. Lloret compiled observed changes in areas occupied by the different habitats and modeled their likely future trajectories, under the assumption that sea levels will continue to rise at current rates, and that the limitation to upland migration of the marsh—which has been called the "coastal squeeze"— will still exist in the future (figure below). Modeled trajectories predict the loss of high marsh vegetation in less than 20 years. All vegetated marsh habitats are predicted to disappear by the first third of the next century. If these conservative predictions prove true, what we see as a characteristic New England salt marsh today will become a shallow open water bay within only a hundred years.

The consequences of sea level rise acceleration for the future of other salt marshes around the world may vary greatly, as the relative magnitude of sea level rise rates and accretion differ among wetlands. It seems evident, however, that the future of wetlands such as salt marshes and mangroves is dire. In the New England region many salt marshes will experience profound habitat changes, or may be even completely submerged by the rising seas, causing severe consequences for the ecosystem and other wetland dependent biota, and losses of the valuable services these habitats provide.



Modeled trajectories of Great Sippewissett Marsh vegetated habitats. Values are expressed as percentages of total area of the marsh in 1979. Solid lines represent the observed changes in areas between 1979 and 2015. Dashed lines represent modeled trajectories into the future. Shaded areas represent the propagated uncertainty associated with the estimated areas of each habitat

Ecosystem responses to climate change and disturbance:
the co-dependence between vegetation and soil

Gus Shaver selecting and processing specimen in the Arctic tundra and in the lab at Toolik Field Station. Photos by Journalist and Emmy Award winner, Michael Werner

Ecosystems Center scientists Ed Rastetter and Gus Shaver are developing new perspectives on the responses of terrestrial ecosystems to elevated carbon dioxide and climate warming and on the recovery of terrestrial ecosystems from disturbances like wild fire in Alaskan tundra, logging of New England forests, and the clearing of Amazonian rain forests. These responses to global change and disturbance can take several decades and are constrained by the interactions among ecosystem carbon, nitrogen, phosphorus, and water cycles.

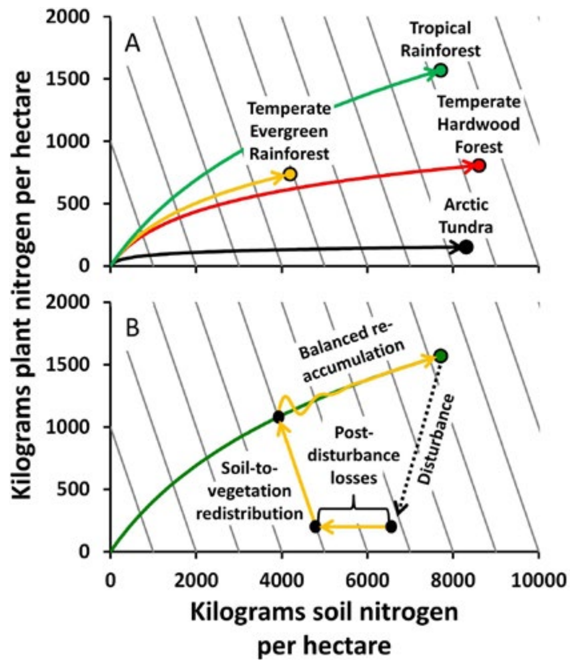
Forests, grasslands, tundra, and other terrestrial ecosystems recycle nutrients like nitrogen and phosphorus very tightly. The supply of these nutrients from sources outside the ecosystem such as nitrogen in rainfall and phosphorus from weathering of bedrock is very small, typically supplying less than 5% of the amount needed to support plant growth each year. Even nitrogen fixation, which can be a major source of nitrogen in young forests, contributes little to mature ecosystems. Thus the vegetation in these ecosystems relies almost exclusively on nitrogen and phosphorus released from soil organic matter by the microbial community. In direct correspondence, the soil microbial community relies almost exclusively on nitrogen, phosphorus, and especially carbon supplied by the vegetation each year in the form of falling leaves, dead branches, and dying roots. This co-dependence between vegetation and soils enables the ecosystem to accumulate and cycle nutrients and thereby sustain productivity rates that are twenty to fifty times higher than would otherwise be possible.

Rastetter and Shaver hypothesize that each ecosystem has a "balanced-nutrient-accumulation" trajectory that depends on the bedrock, climate, topography, and biota (Panel A in figure), the same factors identified by soil scientist Hans Jenny in the early 1940s as controlling soil development. As an ecosystem develops on a bare surface following, for example, the retreat of a glacier, or on a fresh lava flow, or on the bare rock left after a landslide, the vegetation and soils have to develop together, each supplying the other with vital resources. During this development nutrients accumulate in both vegetation and soils in unique proportions determined by the local conditions (colored lines in Panel A). Rastetter and Shaver predict that cold-wet climates will slow microbial activity, thereby retaining nutrients in soils and making those nutrients less available to support plant growth; the distribution of nutrients will therefore be shifted toward the soil (arctic tundra in Panel A). Warm moist climates will stimulate microbial activity thereby cycling nutrients rapidly through soils and making them available to support high plant growth; the distribution of nutrients will therefore be shifted toward the vegetation (tropical rainforest in Panel A). High rainfall and steep topography results in soil erosion thereby limiting nutrient accumulation; the distribution of nutrients is again shifted toward the vegetation, but overall accumulation is low (Cascade Mountains temperate rainforest in Panel A).

This co-dependence of vegetation and soils constrains how ecosystems can respond to disturbance. Disturbance often results in a loss of vegetation and soils and the nutrients associated with them (moving down and to the left in Panel B). Following the disturbance, the residual soil continues to release nutrients, but with little vegetation around to take up those nutrients, they are simply washed away by the rain. These post-disturbance losses of nutrients can be larger than the losses in the disturbance itself. As the vegetation begins to recover, it accumulates some of the nutrients that continue to be released from the residual soil, but because there is so little vegetation, the supply of nutrients to the soil from plant litter is not enough to replenish soil losses. Thus the soil organic matter and associated nutrients continue to decline as the vegetation begins to recover, resulting in a net redistribution of nutrients from soil to vegetation with little change in the total amount of nutrient in the ecosystem (moving up and to the left along one of the gray lines in Panel B). This redistribution accounts for the relatively rapid recovery of vegetation following disturbance. Rastetter and Shaver hypothesize that the ecosystem will continue this soil-to-vegetation redistribution of nutrients until vegetation and soils come back into balance with one another (ecosystem reaches its 'balanced-accumulation" trajectory indicated by the green line in Panel B). Once this balance is achieved, the ecosystem as a whole will accumulate nutrients and recover fully.

Rastetter and Shaver are now using these concepts to understand the interactions among ecosystem carbon, nitrogen, phosphorus, and water cycles. They are using these ideas as the basis for a major synthesis of the development of various types of terrestrial ecosystems around the world, and the responses of these ecosystems to disturbance and changes in climate.

Ed Rastetter on a small hill in the the Arctic tundra overlooking Toolik Field Station (Credit: Kelsey Lindsey/Alaska Dispatch News)



Partitioning of nitrogen between vegetation and soils in four ecosystems.

Panel A) Terrestrial ecosystems cycle nitrogen very tightly between vegetation and soil organic matter, but the distribution of nitrogen between vegetation and soils depends on climate and topography. In cold wet soils, like those in this arctic tundra in Alaska, microbial activity is slow and nitrogen builds up in soil organic matter and is only released slowly to the plants. In warm moist soils, like those in this Amazonian tropical rainforest, microbial activity is fast, releasing nitrogen from soil organic matter, making it available to vegetation, and stimulating plant growth. In steep terrain where there is lots of rain, like in this temperate rain forest in Oregon, soil tends to get washed away, so it is difficult to accumulate large amounts of nitrogen in the ecosystem. In most terrestrial ecosystems, vegetation relies almost exclusively on the nitrogen released from soil organic matter by microbes and the soil microbes rely on the vegetation for both nitrogen and carbon in falling leaves, dead branches, and dying roots. Thus the vegetation and soil microbes are co-dependent and the accumulation of nitrogen in the ecosystem depends on the balanced interactions between the two. The colored lines depict these hypothesized "balanced-accumulation" pathways from bare rock to mature ecosystem. Total ecosystem nitrogen is constant along each of the diagonal gray lines; total ecosystem nitrogen is nearly equal for this tropical rainforest, temperate hardwood forest, and arctic tundra, but the differing climate changes its distribution between vegetation and soils.

Panel B) The co-dependence of vegetation and soils also constrains responses to disturbance. After the disturbance, nutrients continue to be lost from the ecosystem because the residual soils continue to release nutrients but there is little vegetation to take it up. Most of the nutrients supporting the initial vegetation recovery are supplied by a net transfer of nutrients from the residual soil to the vegetation. Once the vegetation has recovered enough that it is back in balance with the soil, nutrients can accumulate in the ecosystem as a whole following the green "balanced-accumulation" pathway.

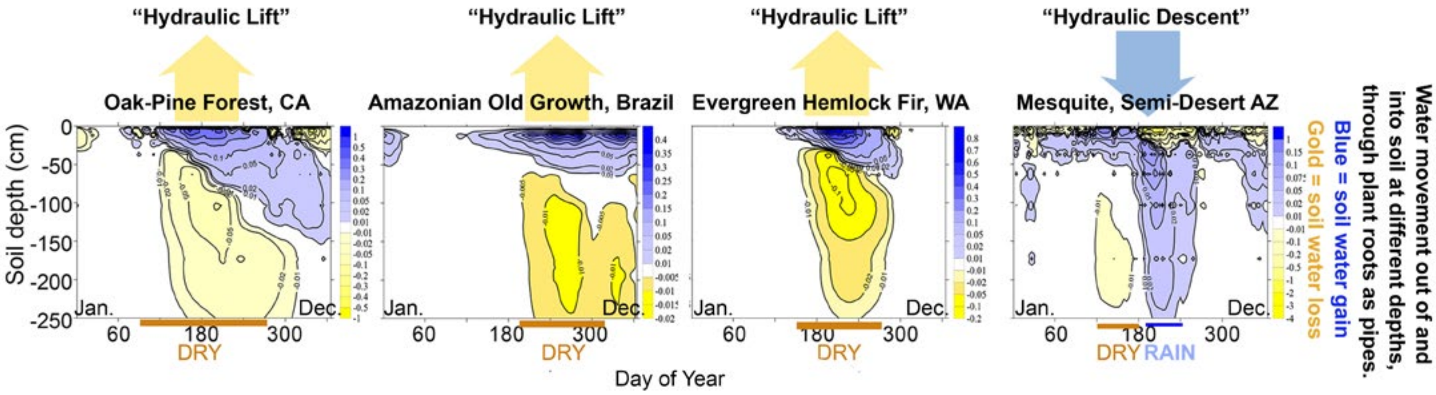
Plant plumbing serves up water in seasonally-dry ecosystems

Seasonally-dry ecosystems from the Pacific Northwest to California and from Arizona to the Amazon pose unique problems for plants. For one to six months each year, no rain falls and the surface layers of soil become extremely dry. Not only is there little water for roots to take up, but also the seasonal drought can slow or stop microbial activities in their tracks, inhibiting the microbe-controlled recycling of nutrients that is necessary for plant growth. But plants do not necessarily have to minimize their activities because of the surface soil drought. If there is water available down deep, and a few deep roots can reach it, that's when the process "hydraulic redistribution" (HR for short) can become very important. Plant root systems can serve as pipes for water flow upward, against gravity, from moist to dry soil. The flow through roots can also be downward once rains come, moving water to safe depth where it can be stored in soil and accessed during the next dry period.

The effects of HR on plant physiology and landscape hydrology are large, and they have been amply demonstrated in seasonally-dry ecosystems worldwide. During dry seasons, for example, 2-80% (multi-ecosystem average ~15%) of plant transpiration during daytime is supplied by upward HR the previous night. In other words, HR can support increased water loss from leaves during dry seasons. Though this may not seem to be in the plants' best interests, the water loss is a necessary consequence of keeping photosynthesis operating. Transpiration is water loss from leaves that occurs when stomatal valves in leaf surfaces are open; plants open the valves to allow carbon dioxide (CO_2) into the leaf for photosynthesis. HR allows those valves to open wider and/or longer, so plants can photosynthesize more.

Given that HR can keep plants more active long into seasonal drought, a number of modeling studies have now examined the impact of HR on water and energy budgets in seasonally-dry ecosystems. Cardon and colleagues Guiling Wang and Congsheng Fu at the University of Connecticut wondered how important HR might also be for the soil microbial communities in seasonally- dry ecosystems, particularly for their recycling of nitrogen through decomposition. In 2013, Cardon and other colleagues showed that HR can clearly make a difference for nutrient availability to individual sagebrush in northern Utah during seasonal drought, but how widespread is the phenomenon? Can HR be large enough to stimulate system-level nutrient cycling in ecosystems as diverse as Douglas Fir forest in Washington State, Mediterranean oak-pine forest in California, and tropical forest in the Amazon?

The answer appears to be yes. In recent research, Cardon, Fu and Wang used the Community Land Model CLM4.5 (a model that quantifies ecosystem processes, developed by the National



Modeled movement of soil water through plant root system "pipes" in seasonally-dry ecosystems from the old growth forests of the Amazon to the Pacific Northwest (Modelling by Fu, C., Wang, G. and Cardon, Z. , accepted, *Global Change Biology*.)

Center for Atmospheric Research in Colorado) to assess how strongly HR could affect soil nutrient cycling rates, plant uptake of nutrients, and exchange of CO_2 between ecosystems and the atmosphere.

They modeled four ecologically diverse, seasonally-dry temperate and tropical ecosystems arrayed from Washington State to the Amazon, with annual rainfall spanning ~400 to 2000 mm, soils ranging from clay to sandy loam and loamy sand, and diverse vegetation types.

Cardon, Fu, and Wang also collaborated with researchers who had deployed eddy flux towers examining whole ecosystem carbon, water, and energy fluxes at sites in each ecosystem, as part of the U.S. Department of Energy's Ameriflux network of research sites. Together, the modeling and the measurements indicated that across even such diverse types of seasonally-dry ecosystems, plant productivity and microbial nutrient cycling activities were stimulated by upward HR at the ecosystem scale, and that HR tended to increase annual ecosystem up-take of CO_2 from the atmosphere.

These enhanced capabilities during dry seasons are particularly intriguing in the face of global change. Intensification of soil drought and altered precipitation regimes are expected for seasonally-dry ecosystems in the future, and Cardon and colleague's work therefore suggests HR may play an increasingly important role maintaining ecosystem productivity during future drought.

A second surprising suggestion also emerged from the modeling. Higher plant hydration and moister upper soil layers maintained by HR during drought notably decreased the spread of fire modeled by CLM4.5 at both the Amazonian and California Mediterranean forested sites.

Field confirmation of this potential link between upward HR and reduced fire would be very important, because fire is known to be a major driver of the ecology of seasonally dry ecosystems, and any reduction of the spread of fire could translate into reduction of very large fire-induced CO_2 emissions to the atmosphere.

Spring lupine in bloom, in seasonally-dry landscape near Bear Lake, Utah (across left); seasonally-dry landscapes near Albuquerque, New Mexico (this page). Photo credits: Zoe Cardon

Semester in Environmental Science

Has the expansion of grey seal populations to Cape Cod beaches altered shoreline food webs?

What can adaptations of desert algae to tolerate extreme desiccation tell us about the evolution of land plants?

Do microplastics in the ocean adsorb and transport dissolved organic compounds?

How much nitrous oxide and methane, powerful greenhouse gases, is released during wastewater treatment at the local sewage processing plant?

How will the nutrient balance in a coastal pond change after the construction of a $40 million sewer system?

These are some of the questions that students in the Semester in Environmental Science (SES) addressed during their six week independent research projects in 2016.

Since 1997, 338 students from more than 65 colleges and universities around the nation have completed the SES program. Nearly three-quarters of these students went on to earn advanced degrees in fields related to ecosystems science, environmental engineering, policy, public health and environmental management.

During fall 2016, 20 students from 16 colleges and universities participated in the program including three students from Northwestern University and our first students from Trinity, Rhodes and Swarthmore Colleges. All completed ten-week long core courses in Ecosystems Analysis that emphasized issues related to global change, while collecting and analyzing data on coastal ponds, estuaries, marshes, forests and unique sandplain grassland ecosystems on Cape Cod. Through elective courses, students also deepened their understanding of either Mathematical Modeling of Ecological Systems or Microbial Methods in Ecology. About midway through the semester, students developed a research proposal, working with one of the dozen lead faculty members teaching the program. All formal coursework ended after ten weeks and students pursued their independent research full time during the last five weeks of the program, culminating in a public symposium (see: https://videocenter.mbl.edu/videos/channel/41/).

One of the unique and exceptional aspects of the SES program is the chance for alums to return to the MBL to work as research interns, teaching assistants or research assistants. About one-in-five SES alums pursue such opportunities in

Rachel Clifford (above) with a horse shoe crab specimen collected at Waquoit Bay National Estuarine Research and Reserve (Photo: Alison Maksym). SES students (below) recording water quality data during the aquatic week

Woods Hole after graduating college. Currently, eight SES alums hold positions varying from associate scientist at the Woods Hole Oceanographic Institution (WHOI), research assistant at MBL and WHOI, and aquaculture technician for the Town of Falmouth Department of Natural Resources. Below, we highlight stories of the three SES alums who have recently served as teaching assistants in the SES program. SES prepares students for careers in environmental science, engineering and management.

Alana Thurston, SES 2014: After graduating from Haverford College in 2016, Alana spent two summers as a research assistant in the Tang group, studying Arctic cotton grass at the Toolik Lake LTER site. Her SES independent research, focused on mycorrhizae in soils, prepared her well to work on the fungal/soil relationships in the tundra. In between summers at Toolik, she worked as a laboratory technician for the Philadelphia Academy of Natural Sciences, analyzing PCBs in fish collected from the Housatonic River System. The Housatonic River System is an EPA Superfund Site contaminated by the manufacture of electrical components in 1932-1977. Alana returned to SES during fall 2017 to serve as a dorm resident teaching assistant. She was hired shortly afterwards as a research assistant in the Conte Lab where she is analyzing samples from the Oceanic Flux Program time series of deep ocean particle flux in the Sargasso Sea.


Alana Thurston at Toolik Field Station, Alaska

Jordan Stark, SES 2013: Jordan returned to the MBL in the fall 2017 as the SES terrestrial teaching assistant. After graduating from Skidmore College in 2015 with a degree in Environmental Science, she worked at the Rocky Mountain Biological Laboratory measuring greenhouse gas fluxes. She then spent a year in Americorps working on prairie restoration in Washington State. In 2016, she conducted research on soil processes and carbon cycling at the University of California Berkeley in the lab of Whendee Silver. Jordan worked both in the lab and in the LTER field in Luquillo, Puerto Rico. Returning to SES, she was uniquely qualified to help train students in the fundamentals of soil biogeochemistry and plant ecology. After SES, Ecosystems Center scientist Zoe Cardon hired Jordan to work on soil microbial communities and processes.


Jordan Stark collects benthic sediment cores in Childs River for SES classes (Photo: Alison Maksym)

Emily Stone, SES 2015: Emily came to SES from Clark University where she completed both her Bachelors and Master's Degrees at Clark in the spring of 2017. For her graduate work, she studied the genome of microbial communities associated with the toxic diatom *Pseudonitzschia australis*, which is prevalent in algal blooms on the West coast. She completed an internship at the Luxembourg Institute of Science and Technology in applied microbiology, studying the pathogenic bacterium *Campylobacter jejun*i. While overseas, she wrote: "the information I learned from the core classes of SES is really helping! I understand how eutrophication has an impact on aquatic ecosystem and how it affects the outbreak of Campylobacters". Returning to SES in the fall of 2017, Emily was eminently qualified to work as the microbial course teaching assistant. After SES, Emily was hired as a researcher in the lab of Kristin Gribble, SES faculty member and assistant scientist at the MBL Bay Paul Center for Molecular Evolution.


Emily Stone, in Kristin Gribble's lab at the MBL Bay Paul Center (Photo: Ken Foreman)

SES 2016 cohort on Plum Island (Photo: Ken Foreman)

Education Highlights

Ruby An, SES Alumna 2015, working as an undergraduate research assistant in Toolik, Alaska

RESEARCH EXPERIENCE FOR UNDERGRADUATES (REU)

Student	Institution	Project	Mentors
Tynan Bowyer	University of Chicago, Jeff Metcalf Scholar	Decadal shifts in the vegetation structure Great Sippewissett Marsh in response to sea level rise	Ivan Valiela Javier Lloret
Christian Bruce	University of Richmond, Virginia	Can *in situ* aeration reduce eutrophication in coastal ecosystems?	Anne Giblin
Petra Byl	University of Chicago, Jeff Metcalf Scholar	Assessing microbial metabolic function and circadian rhythms over time and space in Siders Pond (Summers 2015 and 2016)	Joe Vallino Julie Huber (MBL Bay Paul Center)
Michael Callahan	Wentworth Institute of Technology, Boston	Carbonate in the sinking and suspended particles in the Sargasso Sea	JC Weber
Emily Defries	Purdue University	Understanding changes in estuarine food webs under the influence of increased nitrogen loads: an analysis of carbon and nitrogen isotopic signatures	Ivan Valiela Elizabeth Elmstrom Javier Lloret Linda Deegan
Erin Gleeson	Rhodes College, Tennessee	Applying the Multi Element Limitation model to four arctic ecosystem types	Ed Rastetter
States Labrum	Columbia State Community College	The effects of long term soil warming on soil respiration and carbon storage	Jerry Melillo
Lindsay Levine	Brown University	Atmospheric conditions driving Zostera marina: changes in climatic patterns, atmospheric nitrogen deposition and wastewater nitrogen loads	Ivan Valiela Javier Lloret Elizabeth Elmstrom
Clara Maynard	Brown University, Rhode Island	Spatial-temporal responses of estuarine Phytoplankton to Changes in Nitrogen Loads from Watersheds	Ivan Valiela Elizabeth Elmstrom Javier Lloret
Emily Manness	University of Tampa	Fatty acid and sterol composition of suspended particles in the Sargasso Sea	Maureen Conte JC Weber
Victoria Roberson	Auburn University, Alabama	Coastal carbon, a project for the Woods Hole Partnership Education Program (PEP)	Jim Tang
Toby SantaMaria	Kennyon College, Department of Biology Ohio	Long term responses to high N loading in West Falmouth Harbor: the elusive role of eelgrass meadows in determining water quality	Anne Giblin Melanie Hayn
Leonard Shaw	University of Chicago	Using lipid biomarkers to understand deep ocean organic particle flux	Maureen Conte JC Weber

THESIS ADVISING BY ECOSYSTEMS CENTER SCIENTISTS

Recent graduates (July 2016 – June 2017)

PhD Graduates	Mentors	Institution	Thesis	Current position
Maya Almaraz	Chris Neill, co-adviser	Brown University	Nitrogen availability and loss from unmanaged and managed ecosystems	NSF Postdoctoral Fellow at UC Davis
William Daniels	Anne Giblin, co-adviser	MBL-Brown University	Climate and ecological change in Arctic Alaska over the last 32,000 years inferred from lacustrine records and experiments	Postdoctoral Research Associate at UMass Ahmerst
William Longo	Anne Giblin, committee member	Brown University	Temperature and terrestrial carbon cycling in Northeastern Beringia since the last glacial maximum: insights from novel organic geochemical proxies	Postdoctoral Investigator at WHOI Marine Chemistry and Geochemistry
Marc Mayes	Chris Neill, co-adviser	MBL-Brown University	Forest nutrient cycling and remote sensing of land cover in Miombo Woodlands: insights for biogeochemistry and environmental monitoring of African dry forest landscapes	NatureNet Science Postdoctoral Fellow at The Nature Conservancy, UC Santa Barbara and Princeton University

CURRENT GRADUATE STUDENTS

Brooke Osborne, Brown University NSF IGERT "Reverse Ecology: Computational Integration of Genomes, Organisms and Environments" | **Zoe Cardon**

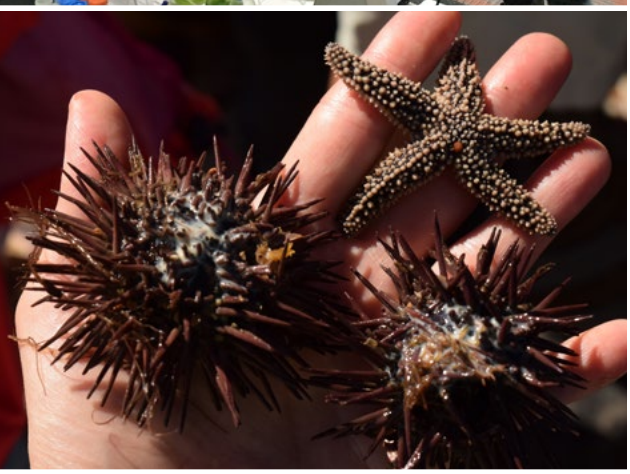
Victoria Gray, UMass Dartmouth SMAST
Nathalie Staiger, UMass Dartmouth SMAST
Yinsui Zheng, MBL-Brown University) | **Maureen Conte**

Lillia Aoko, University of Virginia
Sarah Foster, Brown University
Kiran Upreti, Louisiana State University
Kenneth Czapla, Virginia Institute of Marine Science
Ashley Bulesco-McKim, Northeastern University | **Anne Giblin**

Alex Huddle, Columbia University | **Chris Neill**

Michelle Wong, Cornell University | **Chris Neill**, **Robert Howarth**

Page across: Ruby An, SES 2015 amd University of Chicago student, building new reenhouses in Toolik, Alaska. This page, top: Ed Rastetter, Marshall More, Amy Marksteen, Will Longo, Anne Giblin and Will Daniels, also at Toolik Field Station. This page, bottom: Ph.D. student Michelle Wong at the National Center for Atmospheric Sciences boot camp (Credit: IGERT Cornell University)



WOODS HOLE PARTNERSHIP EDUCATION PROGRAM

The Woods Hole Partnership Education Program (PEP) was launched in 2009 by a consortium of institutions committed to increasing diversity in the Woods Hole science community. In the summer of 2016, **Jim Tang** mentored PEP student Kayla Williams. Kayla worked on quantifying biomass and carbon flux in freshwater and saltwater marshes on Cape Cod, taking measurements in freshwater at Herring River and at many saltwater sites, including at Waquoit Bay National Estuarine Research and Reserve in East Falmouth.

WOODS HOLE SCIENCE & TECHNOLOGY EDUCATION PARTNERSHIP

Ecosystems Center scientists continue to play an active role in the Woods Hole Science & Technology Education Partnership (WHSTEP) program, with **JC Weber** serving on the Executive Committee. In the picture across, **Suzanne Thomas** demonstrated ongoing projects to local residents during the WHSTEP Family Science Night organized at MBL. The event was titled "Thinking Big by Looking Small", depicting the science happening in Woods Hole from the microscopic to the molecular level and part of the Nikon Small World exhibit.

MBL LOGAN SCIENCE JOURNALISM PROGRAM

In 2016, the Logan Science Journalism Program at MBL entered its 31st year. The program allows established science and health journalists to "step into the shoes of the scientists they cover" through immersion in hands-on research, with **Anne Giblin** serving as the Environmental Course Director. On campus, the journalists attended a workshop on "Microbiome Deep Dive", organized by **Zoe Cardon** and Diana Kenney from the MBL Office of Communication. Zoe Cardon started with a presentation on "Understanding Microbiomes: From the deep ocean to the human body". It was followed by talks from **Elena Peredo**, **Joe Vallino**, **Anne Giblin** from Ecosystems Center; Mitch Sogin, Hilary Morrison, and Jessica Mark Welch from the Bay Paul Center; Hibbitt Fellow Kristen Hunter-Cevera and Loretta Roberson from the Marine Resources Center. Led by **Gus Shaver**, the Environmental Hands-On Fellows travelled to Toolik, for an immersion on Arctic Science

Top left, PEP Student Kayla Williams working with the Tang group in Cape Cod salt marshes (Photo: Jim Tang). Middle: Family Science Night at the MBL (Photo: Debbie Scanlon). Bottom left: sea urchins and sea stars collected during hands-on field trip on Vineyard's Sound (Photo: Ed Rastetter). Below: MBL Logan Journalists, 2016 cohort, listening to Gus Shaver in Toolik, Alaska. (Photo: Ed Rastetter)

COMMUNITY INVOLVEMENT

Ecosystems Center staff and scientists pursue their passion for science and for the environment outside the boundaries of the MBL and bring their expertise to the local communities and beyond.

- **Maureen Conte** is vice-president of the Sippewissett Association. The organization aims to preserve the natural attributes of the section of Falmouth located along the eastern shore of Buzzards Bay. Since 2000, the Association has been participating in the Baywatchers Water Quality Sampling organized by the Buzzards Bay Coalition. Maureen is a volunteer Baywatcher for three sites in the Sippewissett area.
- **Anne Giblin** is Chair of the Gulf of Maine Institute Board, a non-profit working with youth on environmental stewardship.
- **Mary Heskel** was selected as one of 20 fellows for the "Digging Deeper" project, a model for collaborative teacher-scientist professional development organized by the Botanical Society of America and the American Society of Plant Biologists.
- **Javier Lloret** participated in several meetings of the Technologies Review Committee of the Cape Cod Commission.
- **Chris Neill** is a board member of the Buzzards Bay Coalition and is Chair of its Science Advisory Committee. Chris is also a board member of the Falmouth Water Stewards, Biodiversity Works and the Coonamessett River Trust.
- **Rut Pedrosa-Pàmies** is a volunteer Baywatcher for the Buzzards Bay Coalition.
- **Ivan Valiela** is member of the EPA Southeastern New England Program Technologies Review Committee, a member of the Cape Cod Commission Research Advisory Committee and a member of the Research Advisory Committee at Waquoit Bay National Estuarine Research Reserve.
- **JC Weber** is a board member and outreach committee member of the Wareham Land Trust. JC is also a volunteer Baywatcher for the Buzzards Bay Coalition.

SCIENCE OUTREACH

In 2016, **Hap Garritt**, **Inke Forbich**, **Sam Kelsey**, **Bonnie Kwiatkwoski**, **Marshall Otter**, **Rut Pedrosa Pàmies**, **Suzanne Thomas and JC Weber** served as judges and/or mentors to students during the Falmouth High School Science and Engineering Fair, the Lawrence School Science Fair, the Falmouth Academy Science Fair and the Massachusetts State School Science and Engineering Fair.

Maureen Conte mentored Michael Callahan, a student from Bourne High School, to help in her lab.

Anne Giblin and **Zoe Cardon** were speakers at two of the Falmouth "Science Before Supper" series. Their respective presentations were on: "Rising seas and the fate of coastal salt marshes" and "Ebb and flow in soil down below: plant roots and the ecosystem commodities exchange"

Michael Callahan (top) demonstrates carbonate analysis to 6th grade students from the Morse Pond School visiting the Conte Lab (Photo: Rut Pedrosa-Pàmies); Michael Daugherty, working on organic pollutants in microplastics in the MBL Electron Microscopy facility with Louie Kerr (Photo: JC Weber); Marshall Otter judges a project by 8th grade student during the Falmouth Science Fair (Photo: Brenda Sharpe/The Falmouth Enterprise); Chris Neill and Linda Deegan install fish nets for River Herring sampling in the Coonamessett River, East Falmouth (Photo: The Coonamessett River Trust)

News 2016–2017

APPOINTMENTS TO OFFICES, BOARDS AND COMMITTEES

Zoe Cardon	Department of Energy Joint Genome Institute review panel, Small-scale Microbial/Metagenome Program; Department of Energy Environmental Molecular Sciences Laboratory review panel, Terrestrial & Subsurface Ecosystems program; Department of Energy workshop, Environmental Molecular Sciences Laboratory, "Breakthrough Science & Technologies"
Maureen Conte	US Regional Class Research Vessel construction, science oversight committee; American Geophysical Union member; American Society of Limnology and Oceanography, member; The Oceanography Society, member; NSF review panel
Jerry Mellilo	NAS Gulf Research Program Chair; NAS US Global Change Research Program, advisor; NAS US National Member Organization for International Institute for Applied Systems Analysis, committee member; NAS International Scientific Organizations, member of the board; U.S. Department of Energy Biological and Environmental Research, member of the board; Mistra Council for Evidence-Based Environmental Management Sweden, research advisory committee; Cary Institute of Ecosystem Studies, trustee and vice-chair
Elena Peredo	NSF Division of Molecular and Cellular Biosciences, Genetic Mechanisms, proposal reviewer
Gus Shaver	NSF-DEB Ecosystems Program, pre-proposal panel member
Jim Tang	NAS Developing a Research Agenda for Carbon Dioxide Removal and Reliable Sequestration Committee member; NSF's Research Coordination Networks program, Building a Collaborative Network for Coastal Wetland Carbon Cycle Synthesis, steering committee

SEMINARS, CONFERENCES, COURSES & WORKSHOPS

Scientist	Role	Conferences, courses & seminars
Zoe Cardon	Invited speaker	Hydrobiogeochemical interactions among plants, soil and microorganisms at molecular to single plant scales. Hydrology Section and Biogeosciences Section breakout sessions. American Geophysical Union, Fall Meeting. San Francisco, California
Mary Heskel	Invited participant	The Kok effect: beyond the artifact, emerging leaf mechanisms. 18th New Phytologist Workshop, University of Angers, France
	Ray Leuning Scholarship Recipient	Annual Course on measuring and modeling ecosystem fluxes. Mountain Research Station. Boulder, Colorado
Elena Peredo	Presenter	*De novo* transcriptome assembly and gene expression profiling of the desiccation-tolerant desert green alga Scenedesmus rotundus during desiccation and rehydration. Annual Botany Conference of the Botanical Society of America. Savannah, Georgia
Jim Tang	Invited seminar	Recent advances in carbon cycle research: abiotic and biotic controls. Department of Geological Sciences, The University of Texas at El Paso
	Invited seminar	Recent advances in carbon cycle research: phenology and coastal blue carbon. Odum School of Ecology, The University of Georgia
	Invited seminars	Dynamics, Controls, and Application of Ecosystem Carbon Cycling. 1) Center for Spatial Information Science and Systems, George Mason University. 2) Department of Earth and Planetary Sciences, Johns Hopkins University
	Breakout organizer	"Coastal blue carbon: an essential component of the global carbon cycle". Joint North American Carbon Program and AmeriFlux, Principal Investigators Meeting. North Bethesda, Maryland
	Convener	Coastal blue carbon: recent advances in measurement and modeling. American Geophysical Union, Fall Meeting. San Francisco, California Fall Meeting
	Symposium convener	Coastal blue carbon in a changing environment.10th International Congress of Ecology International Wetlands Conference. Changshu, China
	Symposium co-convener	Eco-evolutionary dynamics in anthropocene ecosystems. Annual Meeting of The Ecological Society of America. Fort Lauderdale, Florida
Joe Vallino	Investigator	Simons's Foundation Collaboration on Computational Biogeochemical Modeling of Marine Ecosystems

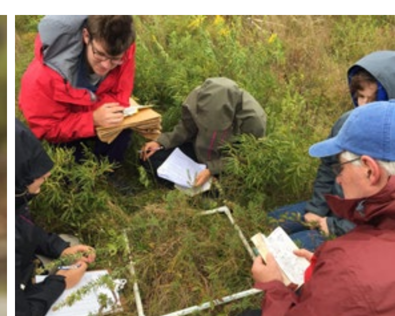
UNIVERSITY OF CHICAGO SEMINARS AND MEETINGS

Anne Giblin	Presentation to the University of Chicago Board in February of 2017.
Zoe Cardon	Lunchtime talks during University of Chicago President Robert Zimmer visit to the MBL in June 2017. Zoe's talk was titled "Partnerships at the Frontlines of Global Change." It focused on research, education and management associated with PIE LTER, and emphasized partnerships among organisms (plant root-microbe interactions in salt marsh sediment), partnerships across disciplines (ecosystems to plant to microbial ecology), and partnerships among institutions in the research and application of the research.
Chris Neill	Collaboration with Rao Kotamarthi and Beth Drewniak, both from Argonne National Laboratory on climate modeling and application of the Community Land Model to the Amazon frontier region.
Jim Tang	Invited speaker for a seminar on "Phenology and Solar Induced Fluorescence for Understanding Ecosystem Carbon Dynamics" at the Argonne National Laboratory (ANL) in July 2016.
Joe Vallino	Participant to in the Microbiome Center Collaboratorium that involved the MBL, the University of Chicago and ANL in the summer of 2016. The meeting led to collaboration between Joe and Dion Antonopoulos of ANL, culminating with a joint proposal submitted to NSF in November 2016.

ECOSYSTEMS CENTER STAFF AND SCIENTISTS IN THE NEWS & OTHER MEDIA PRODUCTION

Joanna Carey	A paper titled "Temperature response of soil respiration largely unaltered with experimental warming" co-authored by Joanna Carey, Jim Tang and several scientists gained national and international attention. The study was published in the Proceedings of the National Association of Sciences, which ranks the paper in the top 5% of research papers with the same age. In addition to being cited in over 30 scientific articles, the paper was also picked up by several news organizations, academic institutions and personal websites from the US and overseas. Other Ecosystems scientists who contributed to the study included Mary Heskel, Jerry Melillo, Ed Rastetter and Gus Shaver.
Anne Giblin	In a short video on "Understanding and protecting our marshes: the Importance of Long-Term Research", Anne talks about the benefits of long-term ecological research. Anne also gave an interview to WCAI, the local NPR station, on the same topic and how "Salt marshes keep us above water".
Linda Deegan up	A report on "Salt Marsh Loss in Westport River", published by the Coalition for Buzzards Bay, was picked by local news outlets. Several of them mentioned The Ecosystems Center; Linda Deegan and Chris Neill gave an interview to ecoRI News on the subject.
Elizabeth Elmstrom	The Falmouth Enterprise featured Elizabeth Elmstrom as one of several Falmouth residents and scientists who made the trip to Washington DC for the "March for Science" in April 2017.
Jerry Melillo	Jerry was honored with a Distinguished Alumnus Award by the Yale Forestry and Environmental Studies. In their news section, the Department described Jerry as a pioneering scientist who bridges research and policy to create a more sustainable future.
Chris Neill	In a column for The Falmouth Enterprise, Chris discussed how the town has benefited from the EPA and the Clean Air Act and acknowledged the bipartisan consensus to clean up air pollution passed by the U.S. Congress in 1970.
Jonathan Pekarek	UChicago student and SES participant, Jonathan Pekarek, was featured in The Falmouth Enterprise for his work on emerging denitrification technology, which he presented to members of the Falmouth Water Quality Management Committee. Jonathan was mentored by Ken Foreman.
Ed Rastetter Gus Shaver	In a short video titled "Lessons From the Arctic: Ecological Research with Lasting Value", Ed and Gus presented the long-term research and findings at Toolik Field Station, Alaska. The video was produced by Emmy Award winner journalist, Michael Werner.
Kristy Sullivan	SES student, Kristy Sullivan, was featured in The Falmouth Enterprise for her discovery of toxin-producing Microcystis and Aphanocapsa algae in Oyster Pond in fall 2016.

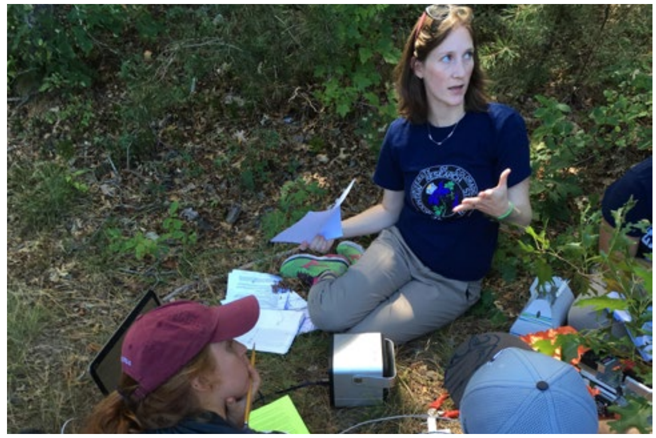
Joe Vallino at the 2016 SES final presentation (Photo: Olivia Bispott). Joanna Carey (Photo: joanacarey.com). Chris Neill with 2016 SES students during the terrestrial field day (Photo: Alison Maksym).



Postdoctoral Scientists

MARY HESKEL

Mary measures and models how leaves in forests exchange carbon dioxide under climate change. For the third year, she contributed to teaching SES students about canopy productivity in a Cape Cod forest system and mentored an undergraduate independent project that examined how trees allocate carbon at the end of the growing season. Mary will be starting a faculty position at Macalester College in Saint Paul, Minnesota, in the fall of 2018.



Mary Heskel teaching SES students during the Crane Wildlife Terrestrial field Day (Photo credit: Andie Nugent, SES 2016)

FAMING WANG

Faming's study is mainly focused on the carbon and nitrogen biogeochemistry in coastal wetlands, especially the CH_4 and CO_2 flux and their sources.

RUT PEDROSA-PÀMIES

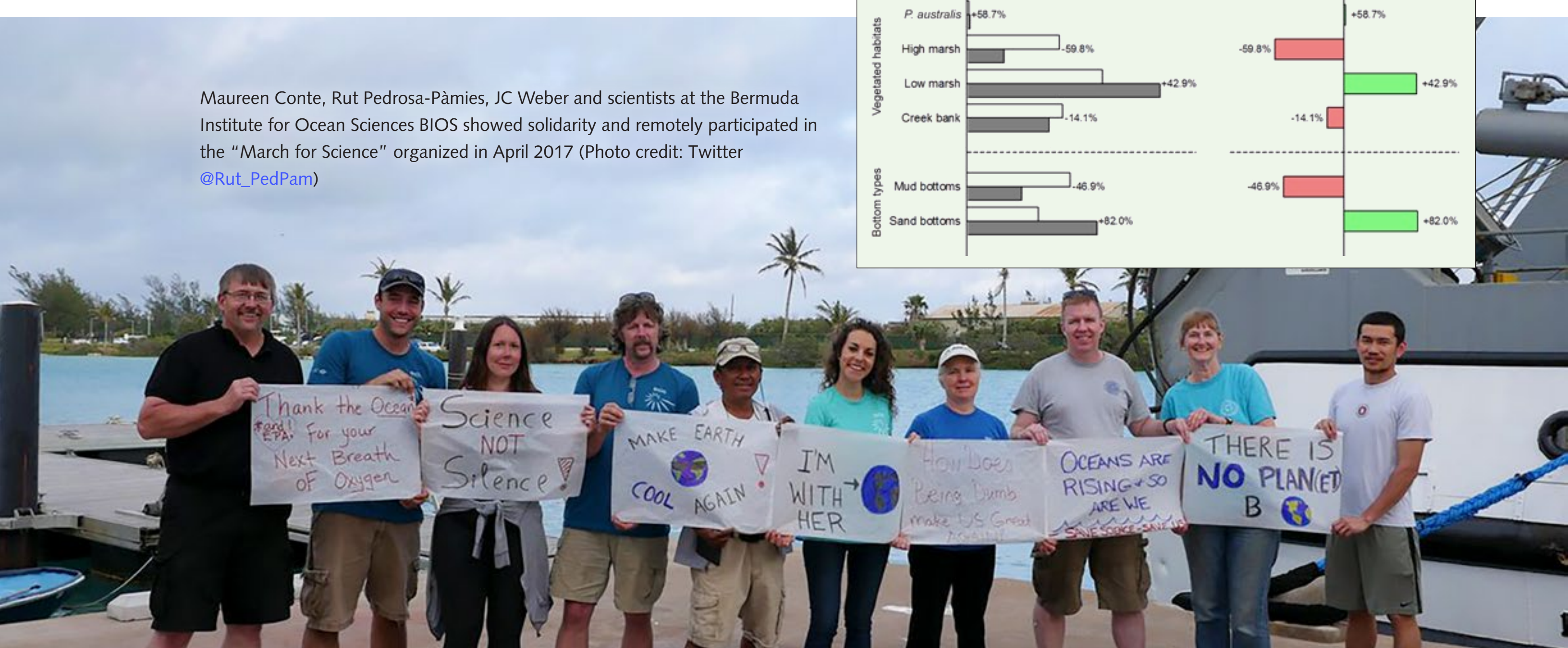
Rut is working with Maureen Conte to study the deep particle fluxes in the Sargasso Sea. She is currently focused on the impact of episodic extreme weather events, such as hurricanes, in the global carbon cycle and in the deep-sea ecosystems. To do this, she is examining the particulate organic matter from suspended and sinking particles at bulk and molecular level.

JAVIER LLORET

Javier's research interest is in fundamental issues as to potential couplings between processes taking place at different scales of ecological organization, and how multiple stressors at different scales determine the complex responses of coastal vegetated habitats to environmental changes. Figure: Spatial analysis of marsh vegetation by Javier Lloret

XIAOLIANG LU

Xiaoliang's research interest is in land surface processes modelling, biogeochemistry cycle, remote sensing and hydrology. Xiaoliang used the Terrestrial Ecosystem Model to analyze the impact of various environmental changes (climate, land cover and land use change, ozone, disturbance and nitrogen deposition) on the terrestrial ecosystems at different spatial scales. Presently, Xiaoling works on forest mortality at Oregon State University.



Maureen Conte, Rut Pedrosa-Pàmies, JC Weber and scientists at the Bermuda Institute for Ocean Sciences BIOS showed solidarity and remotely participated in the "March for Science" organized in April 2017 (Photo credit: Twitter @Rut_PedPam)

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Carey, J. C., Parker, T. C., Fetcher, N., & Tang, J. 2017. Biogenic silica accumulation varies across tussock tundra plant functional type. FUNCTIONAL ECOLOGY, 31(11), 2177-2187. doi: 10.1111/1365-2435.12912

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In Central America, where the forest meets the sea (Photo: Ivan Valiela)

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The Falmouth Department of Natural Resources helping Ecoystems Scientists install equipment at South Cape Beach (Photo: Jim Tang)

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Mangrove forests in Panama (Photo: Ivan Valiela)

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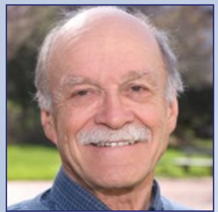

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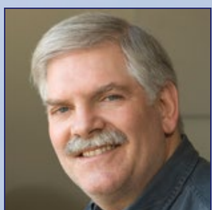

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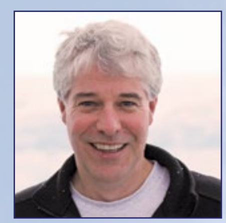

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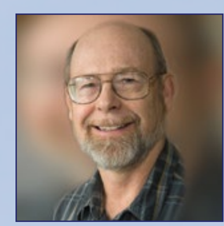

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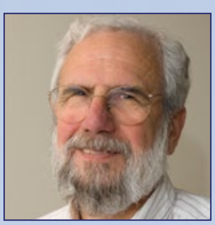

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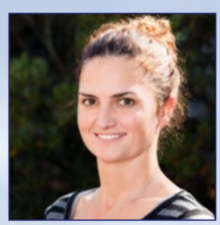

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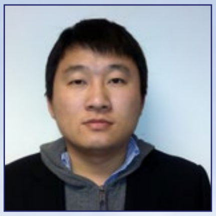
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Maureen Conte inspects an ADCP during the Oceanic Flux Program cruise (Photo: JC Weber)

Sources of Support for Research

The operating budget of The Ecosystems Center for the period of July 2016 – June 2017 was $6,519,946. Approximately 82% of the income of the center came from grants for basic research from government agencies, including the National Science Foundation, NASA, the Department of Energy and the Environmental Protection Agency. The other 18% comes from gifts and grants from private foundations, as well as from institutional support for administration and income from the Ecosystems Center's reserve and endowment funds. These non-governmental funds provide flexibility for the development of new research projects, public policy activities and educational programs.

The following donations were made to the Ecosystems Center and the SES Program between July 1, 2016 and June 30, 2017. More information can be found in the MBL Annual Report.

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The Foundation for Agricultural Integrity
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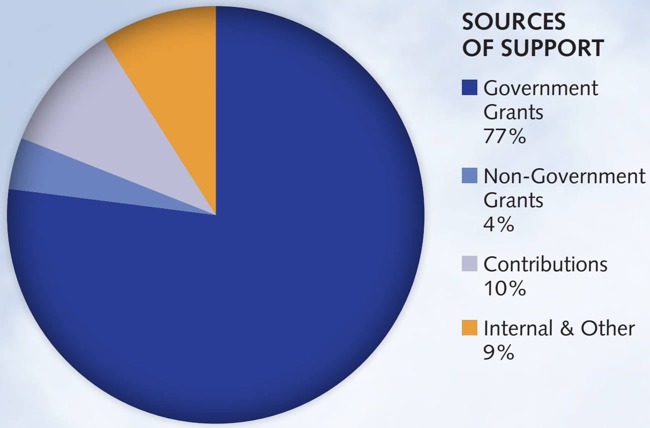
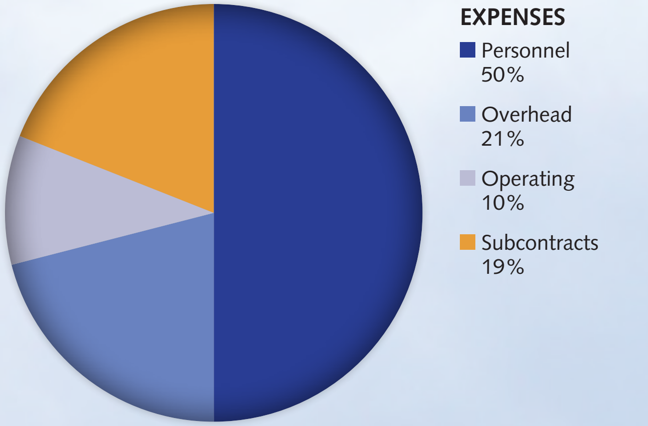
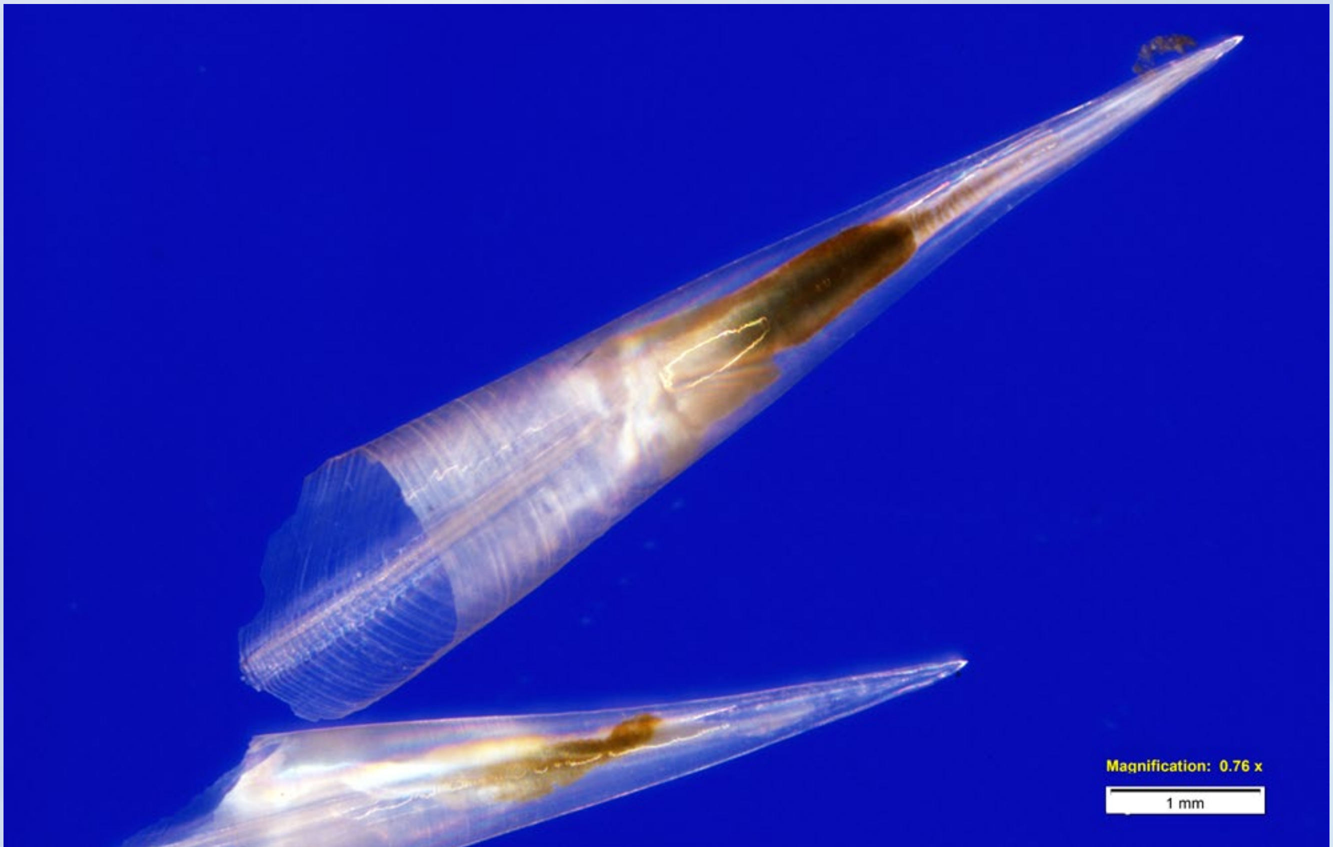




Shells of the pteropod *Styliola subula* collected at 500m depth by the Oceanicc Flux Program sediment trap (Photo: JC Weber)



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