Flotsam & Jetsam

Summer 2020 massachusettsmarineeducators.org Vol. 49, No. 1

OCEAN DISEASES A Danger to Humans?

MME Annual Conference and Meeting at WHOI CANCELLED

zoom

PANDEMIC

NATIONAL CONFERENCE ON SCIENCE EDUCATION 2020 BOSTON April 2–5 CANCELLED

MME Annual Meeting VIRTUAL

MME Fall Conference VIRTUAL

ISSN 1948-1004

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If you have difficulty accessing this journal, contact the editor at dimmick@esteacher.org . The next issue of *F&J* will be posted on the website on Sept. 8.

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2020 MME Calendar

Check website and F&J for details.

SEPTEMBER 9
MME Board Meeting

NOVEMBER 4
MME Board Meeting

Please check the MME website for details as we get closer to these dates.

All MME Members are invited to Board Meetings. If they are virtual meetings, please check with an MME officer for details.

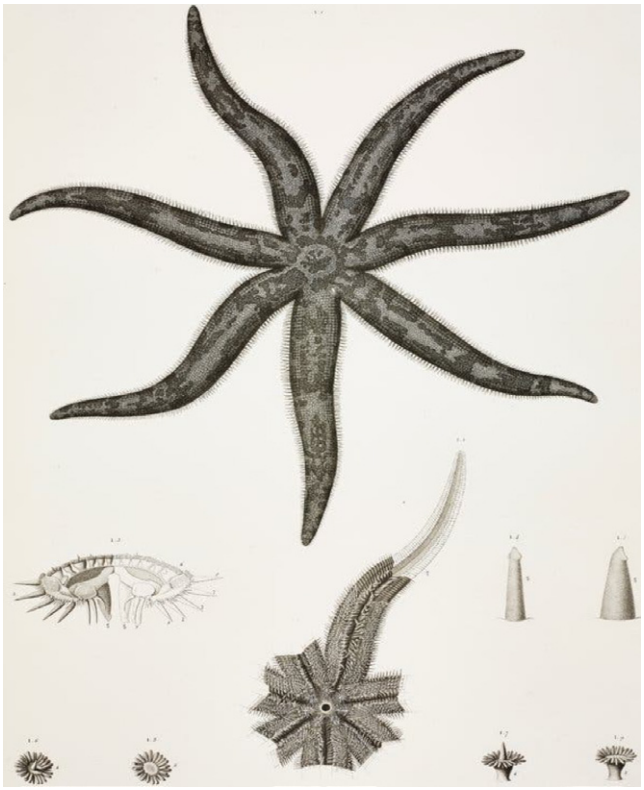
How Starfish, Snails and Salmon Fight Pandemics

They are resilient and immunologically cunning in ways we're continuing to discover.

Dr. Drew Harvell, Cornell University

FRIDAY HARBOR, Wash. — Six years ago, I began investigating starfish dying by the millions off the West Coast of the United States from a mysterious wasting disease. The deaths continue; more than 20 species of starfish have been hit. These predators are important to the health of kelp forests, and their demise has thinned or destroyed these places and their bountiful biodiversity. A virus is believed to be the cause.

Before that, I saw corals on reefs of the Yucatán, Australia and Palau dissolve from the spread of infectious bacterial diseases. Right now, Caribbean corals are under siege from what scientists think is a deadly, highly contagious microbial pathogen.



A 19th-century French engraving of starfish in Egypt. Credit: Engraving by Boquet Jeune after a drawing by Savigny, via Getty Images

As a marine biologist who studies disease outbreaks in the ocean, I am no stranger to pandemics. I have seen the devastation pathogens cause — and how it is amplified as the oceans warm. But I have also seen the remarkable adaptations that creatures like starfish, corals and abalones develop against these threats and the defenses they deploy. Like humans, they are resilient and immunologically cunning in ways we're continuing to discover.

Now the world is seeing the deadly path cut by a terrestrial pandemic, spread by a new coronavirus that has killed tens of thousands of people worldwide as it continues its sweep. If anything good is to emerge from this, it will be in the quest to better understanding pathogens and their hosts, to find nature's best defenses and to apply these findings to engineer a safer world.

The sea is a good place to start.

Right now, we are investigating whether some natural ocean habitats have superpowers to fight disease. In the tropical waters of Indonesia, our team has measured a 50 percent reduction of pathogenic bacteria and coral diseases in meadows of sea grass. These pathogenic bacteria originated in human sewage and make both people and wildlife sick.

We are replicating this environment in the urban waters of the Puget Sound to discover what special powers sea grass meadows contain that reduce pathogens. Vigorous production of oxygen by these underwater plants is certainly one line of defense, but we are also investigating how the microbiomes of sea grasses can regulate health.

Imagine if one day we could extract a critical defense against pathogens hidden in these sea grass meadows to use in medicines or diets. The oceans have long been a source of new antimicrobial agents and anticancer drugs, like Trabectedin from Caribbean and Florida mangrove sea squirts for liposarcoma, and carrageenan from algae to disrupt herpes and influenza viruses. We might benefit right away if we discover that humans living near sea grass meadows are more protected from deadly bacterial pollutants common in human sewage, like Clostridium and Staphylococcus.

We also know that corals living in protected areas of oceans with better-functioning, more-intact food systems have lower rates of disease. By preserving the intricacies of these ecosystems, we may be able to stop pathogens in their tracks — a lesson that can be applied to ecosystems where humans roam.

Scientists continue to study the epidemic that has struck starfish in the Pacific and has pushed one species, the once common sunflower starfish, to endangerment. But another starfish, the intertidal ochre sea star, is holding its own. Researchers are

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President's Message

Greetings all,

The last time I sat down to write this letter, it was early February. Maybe we were just becoming aware of COVID 19 then, but it was not a daily topic of conversation and I think for most of us, it felt far away. By the time the Spring F&J was published, we were overwhelmed by it. My last day of school was March 13, the date is still written on the whiteboard in my empty classroom. Life has not been the same since. And by the time this letter reaches you, it may have changed altogether again. I try to be a hopeful person, and my hope is that having gone through all this pain, we emerge a better people.

Of course we were forced to move our annual meeting and conference to a virtual format. I love going to Woods Hole. I spent many teenage summers there and it definitely has a feel of home for me. But I was so impressed with the turnout for our virtual meeting – we had about 40 people in attendance. We were delighted to have Gay Sheffield of Alaska Sea Grant share her perspective of the changes being brought to the Arctic by climate change.

We also welcomed several new board members at the annual meeting who are featured in this edition of F&J. Many of you will be pleased to see that Pat Harcourt has returned to MME as President-Elect! Personally I am thrilled to have Pat on board. She has a gentle wisdom and deep knowledge of marine science education, and she is the perfect choice to lead the organization in the coming years.

Looking forward, we have begun planning the Boston Harbor Educator Conference for the fall. At this point we expect it to be a virtual meeting, but we hold out some hope for an in-person conference for the spring of 2021. We continue to look for opportunities to expand our member offerings. Look for announcements in our e-News, or on Facebook or Instagram. You can also learn more about upcoming events on our new website, www.massmarineeducators.org.

As always, if you have any questions, ideas, comments or concerns please feel free to contact me directly at dpinkerton@rpsk12.org, or call/text me at (781) 718-5770. I am on Instagram and Twitter @pinkerteach.

Best regards,

Don

Don Pinkerton, President

There's a Plague in Our Oceans. Can Ecosystem Services Help?

By Drew Harvell

Sick seafan showing active lesions. © Ernesto Weil

Our oceans and the life forms they support are under siege, threatened by a formidable collection of forces that cause both sudden mass mortalities and a slow degradation of biodiversity.

Big disease outbreaks are making our ocean biota sick, from corals with spots and halos to starfish melting away to salmon anemic with viruses.

Although top threats for our oceans are the warming and acidification that accompany climate change, there are other threats including over-fishing, pollution from land, and oil extraction. As a marine ecologist specializing in disease, I worry most about the threat posed by microbes, because in oceans beset by all these stresses, microscopic disease-causing organisms can gain the upper hand, cause death on a massive scale, and thereby bring about rapid, wide-scale ecological change.

The Danger of Microbes

Microbes are scary in part because they are changeable and not under our control. Pathogenic organisms in the microbe category—viruses, bacteria, fungi, protozoans, and other disease-causing agents that don't fit neatly into these groups—are constantly evolving, their genetic codes often changing rapidly and staying one step ahead of their hosts' defenses.

Think about one of the deadliest of human diseases, the Ebola virus, which causes fever, severe headache, vomiting, diarrhea, and hemorrhagic bleeding in its victims. Available evidence indicates that the virus has existed in bats in Africa for a long time, occasionally jumping to human beings but never breaking out beyond Africa.

Then in 2013 a horrific epidemic of Ebola virus started in Guinea, Liberia, and Sierra Leone, spreading faster and further in Africa than previous outbreaks. Declared a Health Emergency of Special Concern in August 2014, it ultimately killed over 11,000 people and reached Europe and North America.

Why was this outbreak so much bigger than earlier ones? Scientists aren't sure, but one hypothesis, backed up by intensive study of the changing viral genome during the epidemic done by a team led by Daniel Park of Harvard's Broad

A sick sunflower star (Pycnopodia helianthoides), showing deflated and torn away arms and lesions exposing the inner body cavity. Photo © Ed Gullekson

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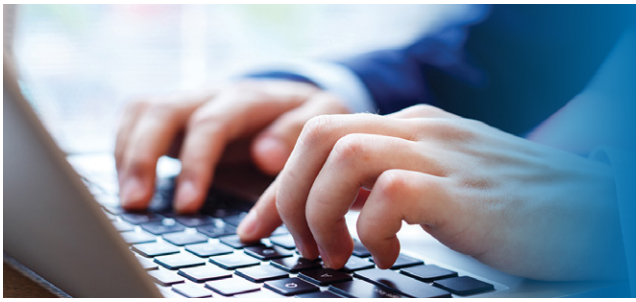
Related Articles

- New Science Shows Seagrass Meadows Suppress Pathogens By Cara Cannon Byington
- Time to Bust the Silos: Coral Reefs, Human Health + Sewage Pollution By Cara Cannon Byington
- Seven Wildlife Diseases You've Never Heard Of By Justine E. Hausheer



From the Editor's Desk

Many things have happened since I sat here preparing the spring issue of ***F&J***. The National Science Teaching Association Conference in Boston, our WHOI conference and annual meeting became casualties of the coronavirus, as have many other educational programs. NMEA postponed the summer conference in Hawaii until 2021. MME held a virtual annual meeting with about 40 members participating. Our school routines were disrupted and schools closed for the final 3 months of the year. We became very familiar with our own homes as a stay at home edict went into effect. Zoom, webinars and Google conferences suddenly became commonly heard terms. The fall schedule is still unclear.

Prior to this spring few persons had even heard the word pandemic, let alone know what it meant. Last September at an MME Board meeting when we were discussing theme topics for coming issues of ***F&J*** at our board meeting the topic of Oceans and Human Health evolved. As I have discussed with the board in the past, I will make contacts when they give me directions. I received several leads and an article from another source to start my search for materials.

I started [as I do for many themes] with NOAA websites. Then I checked with other sites to get pointed in the direction I needed to go. This gave me a few leads. I also took time to read over a document from one of our board members and this became a major help. Off to my Bing app to locate the author. That evening I sent an e-mail off to the author. The following morning, I had an answer from the author.

Dr. Drew Harvell, a Professor of Ecology and Evolutionary Biology at Cornell University, was the person I contacted. After we exchanged several e-mails, I had a clear idea of where I was going for the journal. We discussed through e-mail some ideas for the journal and this is the result. Two of her articles are found in the journal. She suggested the final chapter of her latest book ***Ocean Outbreak, Confronting the Rising Tide of Marine Diseases*** to be included. She contacted her publisher for authorization for our using this short chapter which I have used as an epilogue for the journal.

In our e-mails back and forth, Dr. Harvell suggested the following:

> "Since this is for educators, you could also announce that I am happy to do some discussions with classes that are reading the book (***Ocean Outbreak***). These have been really fun Zoom chats where students read this book and I come on for a discussion session. I am not charging a speaker's fee for this (yet), but can only do a couple per week, so first come, first served."

I have been reading the book and find it extremely informative, and if you are teaching a marine science class in the fall and are interested, contact me and I will give you information on contacting Dr. Harvell. A short review of the book is elsewhere in this journal. The book discusses the many diseases in ocean creatures, from starfish to corals, abalone, and salmon, diseases caused by various bacteria, germs and viruses in the seas. After reading the book I suddenly feel like there have been pandemics in the seas for quite a few years, and they are having a major effect on the life in the oceans, and perhaps even on us. Now with time available for reading this would be a good choice.

Howard

Howard Dimmick, Editor

Gone Home
Liz Duff

Remembering Liz Duff: Esteemed salt marsh educator and colleague

The marine education community suffered a great loss on May 15 when our colleague, Liz Duff, passed away. After growing up on the Essex marshes, it's no surprise that Liz went on to spend over twenty years working for Mass Audubon as the Salt Marsh Educator, also serving the Plum Island Long Term Ecological Research (LTER) project. In this role, she collaborated with dozens of Massachusetts schools to bring thousands of youth outdoors to conduct salt marsh science, with many of her students presenting original research at an annual coastal science conference that she convened with her LTER colleagues. She also regularly led educator workshops in the summer, and mentored many interns and volunteers. Liz was a regular presenter at MME's annual High School Marine Science Symposium, and received MME's highest honor, Marine Educator of the Year, in 2011. She was a consummate collaborator, being an active part of the Great Marsh Coalition, Great Marsh Partnership, Eight Towns & the Marsh Committee, the national LTER Education Program network, and many other professional groups. Liz's passion and work ethic epitomize what it is to be an environmental educator. She challenged her students and colleagues to depart their comfort zone in the pursuit of scientific discovery, science communication, and environmental citizenship. Please consider joining many of her fellow educators in pulling some pepperweed this month in her honor. And to Liz, may the golds and greens of the New England salt marsh be with you always.

Bill Andrake, Swampscott Middle School Teacher and former MME President, presenting the MME Educator of the Year award to Liz Duff at the 2011 MME Annual meeting at Woods Hole Oceanographic Institution.

How Starfish, Snails and Salmon Fight Pandemics

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trying to figure out whether it is developing resistance, and how.

And consider the abalone, a marine snail with blue blood that fights viruses. The protein that gives the blood its color can control cold sores and herpes through a newly discovered mechanism that blocks entry into cells by the herpes simplex virus.

We are now seeing a recently discovered coronavirus infecting salmon in the Salish Sea off southern British Columbia and northern Washington. It is in the same group of coronaviruses as the one that causes Covid-19 and those that cause MERS and SARS. It attacks the gills, so in this way is similar to the respiratory diseases caused by related mammalian coronaviruses. It has been named Pacific Salmon Nidovirus. More research into this pathogen's spread and the defenses mounted by its salmon hosts might offer us additional insights into how coronaviruses function and how we can curb their spread in nature — and in turn, reduce human infections.

These examples give me hope that we can find new ways to help protect us against the emergence of diseases. To do this, we need to figure out how pathogen-fighting processes work in nature.

We missed our chance to control the coronavirus pandemic at the beginning. The virus spectacularly evaded our best technology and, for now, has reduced the planet's most advanced species to fighting it by social distancing and hiding in our homes.

We will eventually prevail with testing and vaccines, but the current triumph of this virus is a searing message to our cavalier species. Going forward, let's focus on doing the basic science to understand what led to the emergence of this pathogen and use scientific understanding and technology to help protect us from these perils.

We need to pay more attention to the spread of infectious disease in wild animals and plants. Unlocking the secrets of those outbreaks on land — and in the sea — will help protect the planet's biodiversity and perhaps save us from another pandemic.

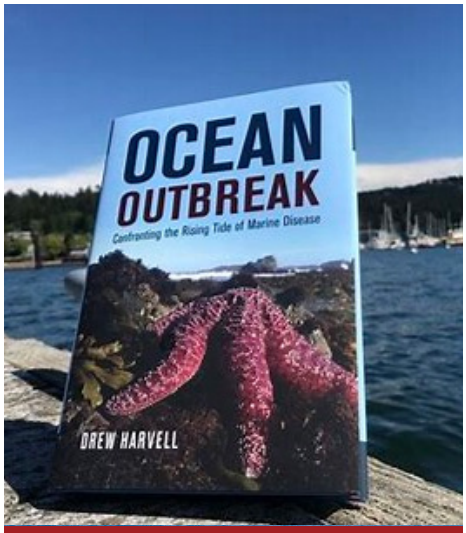
Marine Science in the News ***New York Times***

About the Author

Drew Harvell is Professor of Ecology and Evolutionary Biology at Cornell University and Curator of the Blaschka Marine Invertebrate Collection. Her research on the health and sustainability of marine ecosystems has taken her from the reefs of Mexico, Indonesia, and Hawaii to the cold waters of the Pacific Northwest and resulted in over 170 academic articles in journals such as *Science, Nature,* and *Science Advances*.

She is a Fellow of the Ecological Society of America and the Atkinson Center for a Sustainable Future and awarded the 2020 Cornell SUNY Chancellors Award for Excellence in Research, 2019 Seattle Aquarium Conservation Research Award, 2019 NW Yachting Magazine Outstanding Environmental Leadership Award, PROSE AWARD (*Ocean Outbreak*), National Outdoor Book Award (*A Sea of Glass*), Rachel Carson Environment Book Award, Honorable Mention (*A Sea of Glass*) and on the board of Friday Harbor Marine Labs. She is author of the newly released, award-winning book, *Ocean Outbreak*, which details increased infectious epidemics in the ocean and solutions that benefit people and biodiversity. Her current work focuses on health of marine ecosystems in the Pacific. This research has focused on the form, function, and evolution of defenses of marine invertebrates against their predators and competitors.

To see more about her books, see drewharvell.com or about the film integrating art and nature, visit the Fragile Legacy Blaschka Website at fragilelegacy.info.



Ocean Outbreak

Confronting the Rising Tide of Marine Disease

Ocean Outbreak is an engaging, eye-opening report on the diseases affecting the health of the ocean. The book follows Dr. Harvell and her colleagues as they investigate how four iconic marine animals — corals, abalone, starfish, and salmon — have been devastated by disease. Based on over twenty years of research, this firsthand account of the sometimes creeping, sometimes exploding impact of disease on our ocean's biodiversity ends with a hopeful message. Through policy changes and the implementation of innovative solutions from nature, we can reduce major outbreaks, save some ocean ecosystems, and protect our fragile environment.

The book is also available as an Audiobook or as a Kindle version.

Meet Your New Board Members

PAT HARCOURT

President Elect

Pat is an educator specializing in teacher professional development in marine science and climate change. Pat taught middle school science in Gloucester. She transitioned to Waquoit Bay National Estuariane Research Reserve where, for 12 years, she was involved in providing teacher professional development. In 2010 she became Program Manager at Center for Ocean Science Education Excellence (COSEE) West Los Angeles, CA where she worked with educators, scientists and informal educators for 4 years. She has moved back to her home in Falmouth. This is her second stint as President Elect for MME.

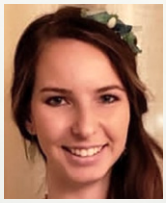
BOARD MEMBERS

Sarah Griscom

Sarah has a degree in Earth and Marine Science from the University of California at Santa Cruz and a PhD in Coastal Oceanography from Stony Brook University. She has worked as a research fellow at the Harvard School of Public Health and for the US Geological Survey. Currently she is Science Director of Pleasant Bay Community Boating Center.

Jocelyn Mitchell

In 2012 she accepted a position at the Ocean Explorium in New Bedford. She has collaborated with the national organization of educators working with the *Science on a Sphere (SOS)* project. She is Science Department Head at Our Sisters' School in New Bedford where she teaches grades 5-8 science.



Geneva Mommsen

Geneva is the Education and Volunteer Coordinator at the National Marine Life Center in Buzzards Bay. She has a degree in Zoology from Miami University and interned at the Cincinnati Zoo and Botanical Garden before coming east. Her passion for marine life is able to "swim freely" as she strives to understand the challenge of teaching about the entire ecosystem.

Nicolette Pocius

Nicolette is a teacher at the John D. O'Bryant High School in Boston where she teaches environmental science, AP Environmental Science and Biology. Nicolette studied Marine and Freshwater Biology at the University of New Hampshire. She has worked at the Seacoast Science Center and at nature centers in Pennsylvania and Colorado, aboard a Schooner in Connecticut, at the Franklin Park Zoo, and at an Aquarium in Australia. She currently is pursuing a second master's degree from Miami University through Project Dragonfly. She is passionate about marine science and providing equitable educational opportunities for all students.

Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

Over the past several weeks Woods Hole Oceanographic Institution has produced a series of Wednesday evening Webinars. Each featured prominent persons in Oceanographic studies including Dr. Sylvia Earle, Fabian Cousteau, Greg Skomal, and others including people working at WHOI. Each program was an hour long, with a short video and a question and answer period after the video. WHOI has posted them on their site along with many other videos for public viewing. They have also given MME permission to pass the information on to our members. The videos are ideal for classroom discussions.

A Window into the Twilight Zone

Exploring the least known habitat on Earth

Filmmaker Jennifer Berglund and researchers from the expedition will be answering all your questions during the premiere via **Youtube**

Exploring Inner and Outer Space

SPEAKERS: NASA Astronaut Sunita Williams, Captain, U.S. Navy, (Ret.) and Timothy Shank, Deep-Sea Scientist, WHOI

EMCEE: Barbara Moran, Senior Producing Editor, WBUR Radio Environmental Vertical

To view, **click here**

The Science of Shipwrecks

SPEAKERS: Ocean Explorer Robert Ballard and WHOI Biologist Kirstin Meyer-Kaiser

EMCEE: Barbara Moran, Senior Producing Editor, WBUR Radio Environmental Vertical

To view, **click here**

Corals in Crisis

How scientists are racing to stop a deadly disease

SPEAKERS: Marine biologist, ocean explorer, and conservationist **Sylvia Earle**, University of the Virgin Islands coral disease ecologist **Marilyn Brandt**, and WHOI marine microbial ecologist **Amy Apprill**.

View this video **here**

Sharks! New Insights into an Iconic Ocean Predator

SPEAKERS: Massachusetts Division of Marine Fisheries Shark Biologist Greg Skomal and WHOI Ocean Ecologist Simon Thorrold

EMCEE: Veronique LaCapra

To view, **click here**

Extreme Ocean Machines

Exploring impossible places

GUEST HOST: James Cameron, renowned ocean explorer and filmmaker

PANELISTS: Mark Dalio, Founder and Creative Director, OceanX; **Orla Doherty**, Producer of the BBC's *Blue Planet II*; **Andrew Bowen**, Principal Engineer and Director of the National Deep Sea Submergence Facility, WHOI; **Vincent Pieribone**, Vice Chairman of OceanX and Director of the John B. Pierce Laboratory, Yale University

Video is located **here**

The Future Ocean

What's in store for our ocean planet and our ocean science?

SPEAKERS: Fabien Cousteau, Aquanaut, Oceanographic Explorer, Environmental Advocate and Founder of the Fabien Cousteau Ocean Learning Center and **Mark Abbott**, WHOI President and Director

Video is located **here**

As we share in the horror and grief of the current events roiling our communities, WHOI is postponing the season finale of our Ocean Encounters series, "Oceans Beyond Earth." Although the ocean is, and will remain, the focus of our research, we feel that now is not the time for this event and will work to reschedule it at a more appropriate time and to organize it in a more diverse and inclusive manner that better reflects the diversity of our nation.

MME Awards

Recognizing Excellence in Marine Education in Massachusetts

MME MARINE EDUCATOR AWARD

Erik Hellmer

Erik teaches Marine Science, AP Environmental Science and Ecology at Lynn English High School. Erik is also co-advisor of the Science Club and advisor to the Photography and Environmental Clubs. This year, his co-worker Aemi has seen Erik promote marine science through his dynamic lessons and service projects. The Environmental Club has run campaigns on ending the use of plastics, specifically attempting to get our school to stop using plastic straws and extruded plastic utensils. Erik and his students advocate for the recycling of paper and all plastic bottles such that his class needed two curb-side recycle bins a week. Erik has taken his students to the Northeastern Marine Science Center in Nahant, to learn data collection techniques. Erik actively engages students with laboratories in class.

MME CERTIFICATE OF APPRECIATION

Patrick Flanagan

Patrick is the founder and director of Ocean Learning Lab and Immersive Experiences (OLLIE). With his 10 years of experience in scientific research and informal education, particularly in bringing science education to underserved communities, he is able to take that and create real-world, systems-based approaches to teaching. Patrick has also been an active member and friend to MME, most recently bringing his immersive experiences to our annual High School Marine Science Symposium, which was quickly a favorite for many.

MME AWARD OF DISTINCTION

Anne Smrcina

Anne has been a member of MME for over 20 years. She has spent her career educating children and adults about the Gulf of Maine ecosystems, and connecting and building the MME community. Most notably, Anne has been running the Marine Art Contest for the past 18 years. This contest provides youth, within Massachusetts and beyond, the opportunity to be inspired by the biodiversity found with Stellwagen Bank National Marine Sanctuary off the coast of Boston, Massachusetts. Anne has also held many chairs within the MME board, and is currently our past president.

Plague in the Ocean

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Institute, is that a key mutation allowed it to become more transmissible among humans. Because viruses have a very short life span and so many new virus particles are produced in the body of a single host, there is ample opportunity for such mutations to occur.

Microbes are dangerous too, because many can attack and infect more than one species or spontaneously develop that ability through a favorable genetic mutation. Pathogens that have a wide host range, called multi-host pathogens, tend to be deadly for at least some of the species they can infect. By deadly I mean they can kill every individual within a susceptible species, even driving them to extinction, while persisting in a more resistant host species.

Contagious individuals in a resistant species can keep exposing healthy individuals in a susceptible species until the susceptible species is wiped out. In these situations, we say that the pathogen has a reservoir in the resistant hosts—a nice comfortable hideout from which to spread. The starfish epidemic of 2013–14 was caused by a multi-host pathogen. It affected almost all the major species of the entire group we call starfish.

Those of us who study non-human diseases are worried that mass mortality caused by multi-host pathogens is becoming a common and recurrent event, threatening biodiversity in both terrestrial and marine environments. The frogs of the world's rainforests are a high-profile example.

A frog killed by the Batrachocytrium dendrobatidis, or amphibian chytrid fungus, in Panama. Photo © Brian Gratwicke / Wikimedia Commons

Drew Harvell photographs a tabulate coral with growth anomaly disease from Palmyra Atoll. @ Bette Willis, Crazy Corals.

Many rainforest frog species have been not just devastated but completely eradicated, at locations around the planet, by a skin-attacking fungus, *Batrachochytrium dendrobatidis,* called chytrid for short.

This lethal fungus grows in the skin of the frogs, spreading its killing tendrils and exploding cells from the point of entry throughout the frog's skin. It can kill some species within days and is wildly contagious.

In others, it lingers longer, so the infected frog continues to shed infectious spores from its skin into nearby streams. In 2015, using data from museum databases and field counts, John Alroy estimated the epidemic has caused the extinction of more than two hundred species of frogs.

The chytrid epidemic has happened so quickly and in such remote tropical locations that the exact number of extinctions is still unknown, but we do know that many species are forever gone from our planet.

Outbreak in the Caribbean

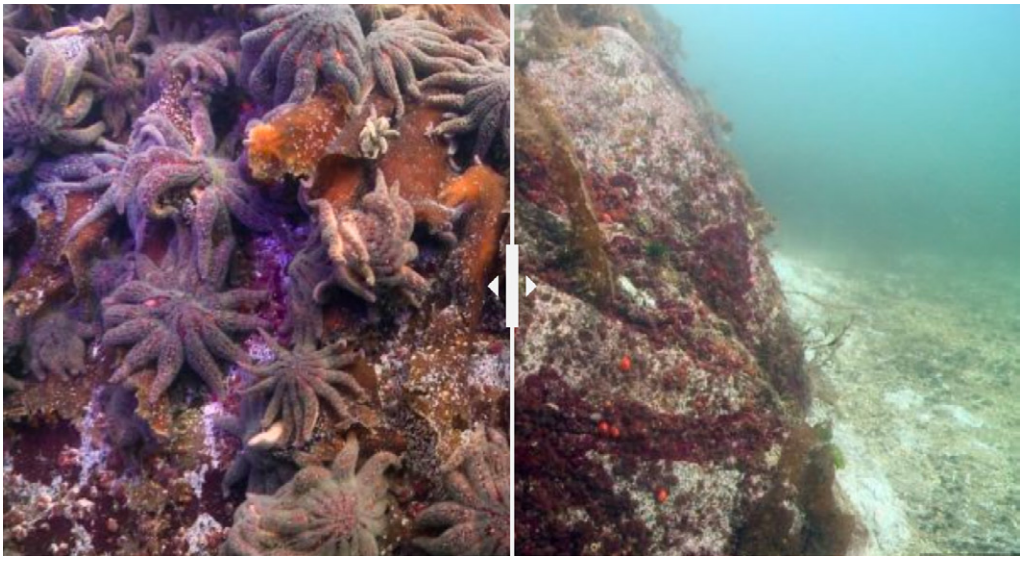
My career as a Disease Ecologist began in 1996, investigating a mass die-off of Caribbean sea fans on the tiny island of San Salvador, Bahamas. I first heard about these declines when one of my colleagues, Jim Porter, a professor at the University of Georgia, called me in Ithaca one day in 1994.

He'd heard at a meeting that sea fans were dying at many locations around the Caribbean. "If you need samples," he told me, "this is the time to get them; your populations are disappearing quickly."

In the following months, I communicated by phone and email with researchers who studied these animals and we all became unnerved by the growing reports of dying sea fans.

Given how widespread the die-off was throughout the Caribbean, I was worried about the impact it could have on sea fan populations. In the late 1990's we launched a study in the Caribbean to document the ecology of this underwater epidemic and monitor the defensive function of the coral's chemicals in nature.

I recount the story of this work in my new book, *Ocean Outbreak,* and how we eventually learned that the sea fans had super-powers to fight back.



Left: The sunflower stars on Croker Rock, British Columbia over a 3 week interval from October 9 to October 29 2013 at the beginning of the Sea Star Wasting Disease outbreak. Photo © Neil McDaniel. Right: This second photo shows mass mortality of almost every star on the rock and piles of white spicules from dead stars around the base. Photo © Neil McDaniel.

Although sea fans and all the group we call corals are some of the most ancient body plans on our planet, they possess sophisticated immune systems with potent weapons against infectious disease.

This outbreak is one of the few catalogued successes of a coral population to suffer huge mortality, but eventually develop resistance and survive a large epidemic. The work with Caribbean seafans next led us to study health of corals in the coastal waters of Indonesia, the heart of coral biodiversity.

In the fall of 2013, we were still in the middle of studying the health of corals in Indonesia when starfish in nearby British Columbia began dying catastrophically. The paired photos above shows how quickly a large population of the sunflower star died over 3 weeks in October 2013.

I tell the more complete story in my book, but this outbreak continues into 2019 and that sunflower star, the most susceptible to a multi-host pathogen in 2013, is now severely imperiled along much of its range from San Diego to Alaska in both near shore and off shore deep water.

Connecting Human Health and Wildlife Health

There are many other examples of infectious diseases causing massive underwater outbreaks from oysters and clams to abalone to herring and salmon.

Climate change is making it worse, since a warming ocean can both stress hosts and make pathogens grow faster and therefore become more damaging. Despite the increase from a warming ocean, we understand little about ways that infectious disease outbreaks begin and are transmitted in ocean waters.

There are more knowledge gaps than answers. With so much uncertainty about both the causative agents and how they transmit in our oceans, it is tough to manage underwater outbreaks.

But we can capitalize on the things we do know: that conditions that are bad for human health are also bad for wildlife health. I describe in my book how managing for both human health and health of the ocean biota can help. There are natural disease-fighting services in intact marine ecosystems that can reduce risk for both humans and wildlife like corals.

The links between coral health and human health became clear to us when our team ran a coral health workshop on an island in the Spermonde Archipelago in Sulawesi, Indonesia. As we were leaving the island, we were all simultaneously sickened with either amoebic dysentery or typhoid.

One of our scientists had to be evacuated because she had both infections and was dangerously ill. We vowed to return to see what was in the water.

Two years later, Joleah Lamb (then a TNC Nature Net Postdoctoral Fellow collaborating with me and now

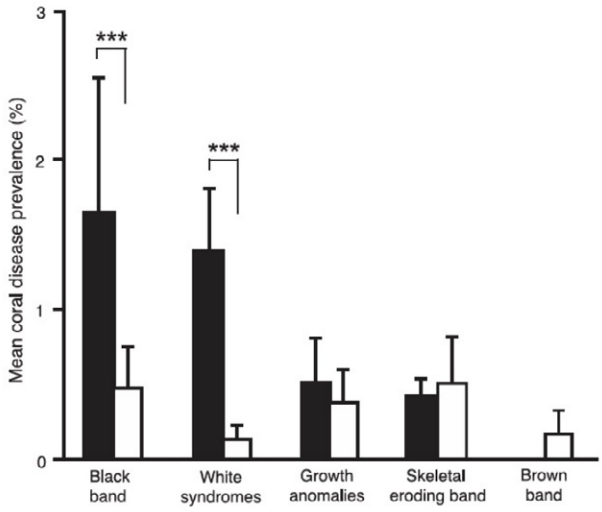
Healthy soft corals in the Maluku Islands, Triton Bay, West Papua, Indonesia. Photo © Jeff Yonover / TNC

Plague in the Ocean

continued from page 13

Assistant Professor, University of California Irvine), returned and took water samples and sequenced all the bacteria.

She found a long list of sewage-derived human pathogens in the water adjacent to four of these islands. But even more interesting, she found that human and wildlife pathogens were reduced by half in seagrass beds near the islands.

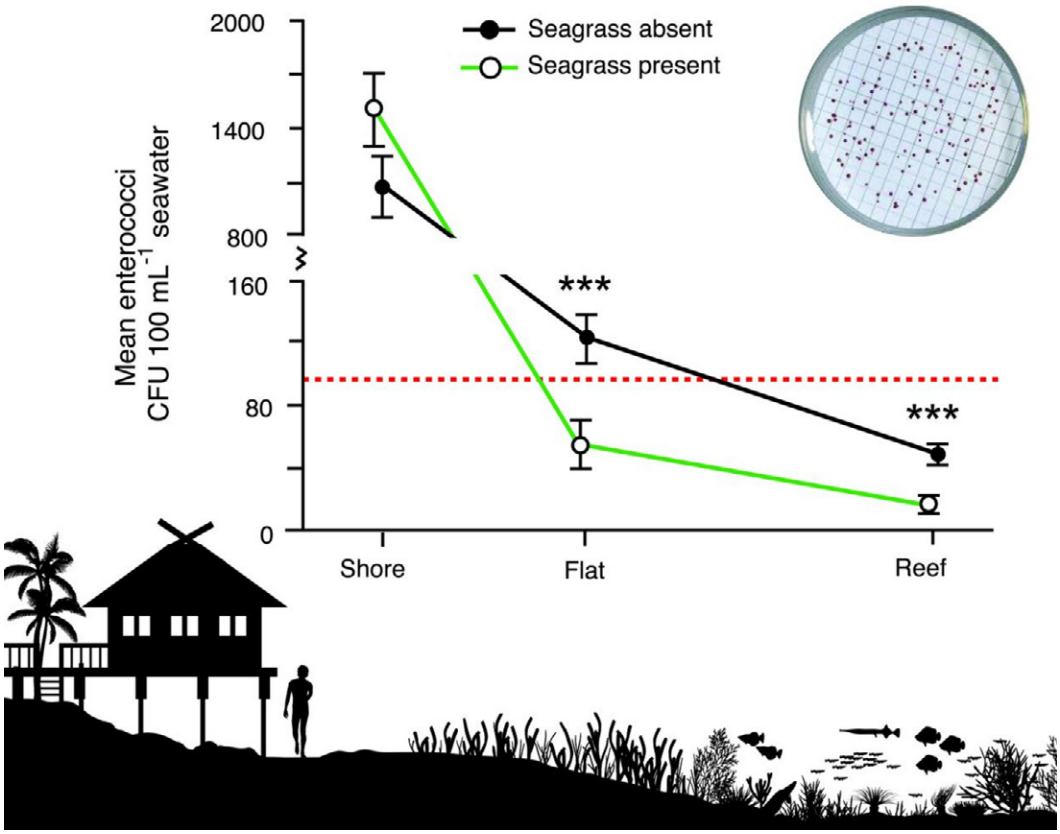


Joleah found that not only were pathogenic bacteria halved inside the seagrass beds, but coral health was improved. I show her graph from our paper below, documenting big reductions in the number of corals with disease inside seagrass meadows.

In those same seagrass beds, the levels of indicator bacteria are reduced by half when compared to adjacent non-seagrass sites near four separate islands. IN our paper, we also report the complete sequence data showing that many human and invertebrate disease bacteria are reduced in the seagrass beds

It is early days in this research program, but our goal is to look carefully at the ways that seagrass beds can reduce pathogenic bacteria. While we would never suggest that seagrass meadows be a replacement for state of the art septic systems, we do suggest that seagrass meadows (and other aquatic plants and intact ecosystems) are good backup hygiene for the ever-present spillover that does occur from many of our waste management systems on land.

Seagrass meadows may also have unrecognized ability to naturally reduce non-human pathogens of our ocean's biota. Nature's filtration and decontamination services can be particularly important for intermittent or unexpected introductions of new pathogens.



The observation that human and wildlife health are linked (as described in One Health) and can both be improved by better management of marine resources is a new approach that capitalizes on the value of natural filtration services of seagrass beds. This is only one of several new approaches to slowing a rising tide of new outbreaks I discuss in ***Ocean Outbreak****.*

This blog post was published in ***Cool Green Science****, The Nature Conservancy's conservation science blog April 24, 2019*

The Race for a Coronavirus Vaccine Runs on Horseshoe Crab Blood

Pharmaceutical companies use the creature's blue blood to test for contaminants

Horseshoe crabs are bled to harvest a key ingredient in tests used to ensure injected medicines such as vaccines are free of contaminants. This photo was taken in 2014 at the Charles River Laboratory in Charleston, South Carolina. by Timothy Fadek

ALEX FOX – SMITHSONIANMAG.COM

Humans owe a debt to the strange-looking, ancient horseshoe crab. Its blue blood is used in medicine to ensure that anything that gets injected or implanted into the human body is free of potentially life-threatening bacterial contamination. A special compound in the crab's blood quickly clots in the presence of endotoxins, microbial byproducts that can be harmful, supplying a perfect natural test for purity. In the race to find a COVID-19 vaccine, horseshoe crab blood is very important.

But an estimated 50,000 crabs die during the annual blood harvest, and these ancient arthropods are also being threatened by pollution, overfishing and habitat loss due to sea level rise, reported Sarah Zhang in the *Atlantic* in 2018. Moreover, humans aren't the only ones depending on the crabs (which are actually more closely related to spiders than true crabs). Migratory birds such as the threatened red knot are sustained by the blue-gray bunches of eggs the shelled creatures deposit by the thousands on beaches along the east coast of the United States.

For these reasons, animal rights groups, conservationists and a handful of companies have been pushing for the development and approval of synthetic alternatives to the milky-blue crab blood, reports James Gorman for the *New York Times*.

Now, an influential United States group has abandoned plans to list a synthetic alternative, called recombinant Factor C (rFC), alongside the tried and true blue fluid, reports John Miller for Reuters. The move by medical standards group U.S. Pharmacopeia (USP) would have given rFC equal standing with crab blood, which has long been the industry standard for testing, per Reuters.

The gist of the USP's rationale is that rFC requires more testing, and that the current crab-derived test has a 30-year track record of safe and effective use, reports the *Times*. Many expected the alternative test to be approved for widespread use as it was in Europe by the European Pharmacopeia, per the *Times*.

For drug makers in the U.S., using the synthetic alternative will require a kind of application designed to demonstrate that the non-standard test is up to snuff—a hurdle that makes companies less likely to abandon the animal-based test, reports Caroline Delbert for *Popular Mechanics.*

In 2018, the blood harvest drained a third of the vital fluids from nearly 500,000 crabs in the U.S., according to the Atlantic States Marine Fisheries Commission. After scores of steel needles suck their blood, each helmet-shaped crawler gets released back to where it was caught—but thousands of them die in the process. Exactly how many are lost is a matter of debate, but Miller, in another recent story for Reuters, reports that conservation groups estimate switching to rFC could save 100,000 crabs each year.

For their part, the companies that make Limulus amebocyte lysate (LAL), the component of crab blood isolated for use in drug purity testing, say the supply of horseshoe crabs is up to the task of approving the surge in vaccine testing amid the race for a cure to the novel coronavirus, reports the *Times*.

One company using rFC, which is created by inserting horseshoe crab genes into lab-grown microorganisms, is Eli Lilly, per the *Times*. Eli Lilly recently announced it had started testing a COVID-19 antibody in humans with nothing but rFC for purity testing, Jay Bolden, a biologist with the company, tells Reuters. Bolden tells the *Times* his company made the switch because of the synthetic product's consistent quality, its reduced costs, lack of reliance on an animal population as well as the company's desire to avoid harming animals where possible.

More than 40,000 samples tested by Eli Lilly using rFC suggested it was just as good as LAL, Bolden tells Reuters. "And that data is out there, and it's either not being looked at or it's being ignored… There's no reason the USP should be asking for more data."

'This is shocking.' An undersea plague is obliterating a key ocean species

An abundance of sunflower sea stars before the outbreak of "sea star wasting disease" off the coast of Canada. Neil McDoniel

ALEX FOX – An "underwater zombie apocalypse." That's how wildlife veterinarian Joe Gaydos of the University of California (UC), Davis, describes "sea star wasting disease," a blight that has decimated more than 20 species of sea stars from Mexico to Alaska since 2013. Now, a new study by Gaydos and colleagues has more bad news: The disease has hit the sunflower star (*Pycnopodia helianthoides*)—a key predator within kelp forests—hardest of all. This once-common species has vanished from the majority of its range, sending shock waves through the ecosystems it once called home. The team also found a worrying association between warmer ocean temperatures and the severity of the outbreak, suggesting climate change could exacerbate future marine epidemics.

"This is shocking," says marine ecologist Mark Carr of UC Santa Cruz, who was not involved in the study. "This is not just a population reduction, this is virtually the loss of a key species over thousands of miles. We've never seen anything like this before."

Sea star wasting disease progresses from "that looks weird," to "horror movie," over a few days. White lesions appear, then expand into fissures of melting tissue. Limbs fall off and crawl away. And finally, the sea star disintegrates into a pale mound of decaying flesh.

Scientists still haven't identified the pathogen responsible for the disease. Research suggests the culprit is a virus, but which one remains unknown. Similar die-offs have struck the West Coast in previous decades, but none has been so deadly over such a large area. Of the 20 species affected by the outbreak, lab tests showed the sunflower star to be among the most susceptible.

The meter-wide, 24-armed sunflower star stalks the kelp forest swallowing prey like kelp-munching sea urchins whole. As one of the top predators of invertebrates these supersize stars help maintain balance in the kelp forest ecosystem. Left unchecked, sea urchins can mow down kelp forests, leaving behind a denuded and depauperate undersea landscape. The sunflower star used to be a common sight underwater, but since its disappearance and the subsequent boom of urchins, northern California has lost more than 90% of its kelp forests, according to the California Department of Fish and Wildlife.

The loss of those kelp forests has left the other species that depend on them hungry, homeless, or dead. In December 2018, California moved to extend a ban on recreational fishing for red abalone (*Haliotis rufescens*) after surveys showed the mollusks, which feed on kelp, were starving to death in huge numbers. Impacts to fish species are more challenging to quantify, but Carr says kelp forests are of vital importance not just as food, but as habitat, especially for young fish hoping to evade predators.

To gauge the impact of sea star wasting disease on the sunflower star, Gaydos's colleague Drew Harvell, a Cornell University marine ecologist based in Friday Harbor, Washington, and other team members analyzed counts of the sunflower stars from nearly 11,000 shallow water scuba dives and close to 9000 bottom trawling surveys in deeper water. Hundreds of citizen scientists trained to identify and record the presence of the sunflower star conducted the shallow water surveys, and the National Oceanic and Atmospheric Administration (NOAA) conducted the bottom trawls, which consist of systematically dragging a net along the sea floor to sample marine biodiversity.

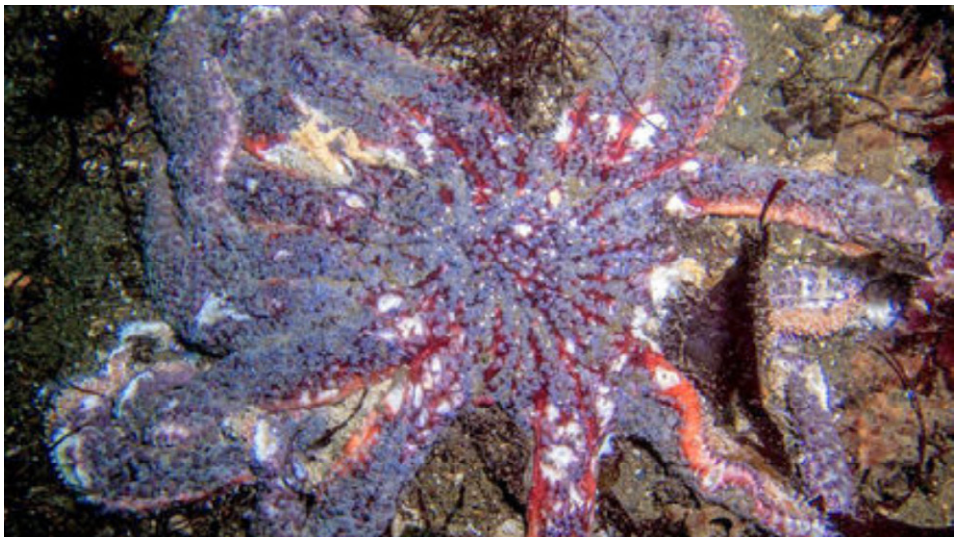
These data sets spanned nearly a decade prior to the collapse of sea stars and covered more than 3000 kilometers of coastline. Shallow and deep-water surveys showed stable populations followed by steep declines of the sunflower star ranging from a 60% population reduction up to 100% in some areas after the onset of the

wasting disease in 2013, the researchers report today in *Science Advances*.

"Many people expected the sunflower stars to be taking refuge in the deep water where we couldn't count them," says Steve Lonhart, a kelp forest ecologist with the NOAA based in Monterey, California, who was not involved in the study. "We hoped they were hiding down there—this research shows that hope was naïve."

The onset of sea star wasting disease also coincided with the warmest 3-year period on record for California's coastal waters—2014, 2015, and 2016—according to NOAA climate researcher Nate Mantua in Santa Cruz, who was not involved in the study. To see whether there was a connection between water temperature and the disease, the study authors compared sea surface temperatures from the times and locations of each survey with the decline in sunflower stars. Their analysis found that the times and locations of the biggest death tolls coincided with the presence of abnormally warm water.

Mantua is the co-author of a 2018 paper in the *Bulletin of the American Meteorological Society* showing that climate change played a large role in the warming of California's coastal waters from 2014 to 2016. Climate projections indicate those temperatures will become commonplace by the 2050s, he says.

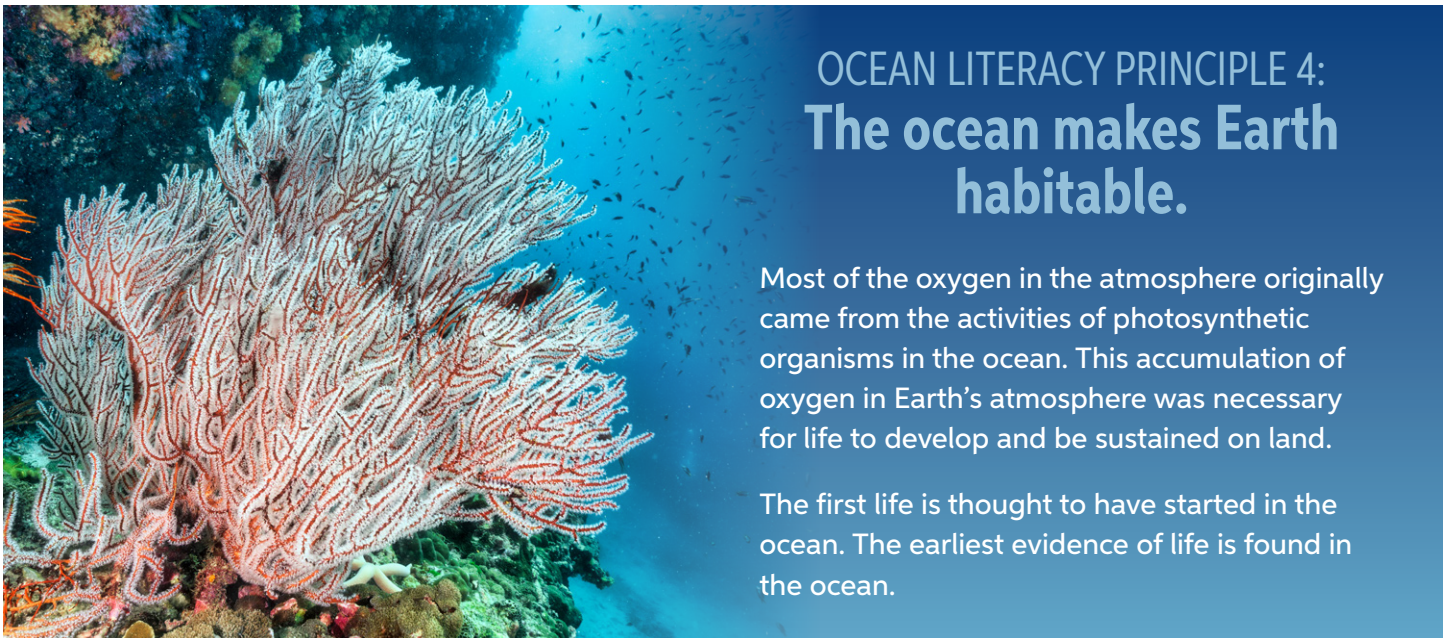


A dying sunflower star infected with "sea star wasting disease" in the Salish Sea off the coast of Washington state. Jenn Collins

"Many of these outbreaks are heat sensitive. In the lab, sea stars got sick sooner and died faster in warmer water," Harvell says. "A warming ocean could increase the impact of infectious diseases like this one."

The declining kelp forests of northern California are unlikely to recover unless sea urchins succumb to a pestilence of their own or their natural predators are restored. Harvell thinks the imperiled sunflower star should get strong consideration for being added to the U.S. Endangered Species List, and that a formal recovery plan may be necessary.

"I'm more worried now than I was before I read this paper," Lonhart says. "We could be watching the extinction of what was a common species just 5 years ago."



Afterword

The Next Big Outbreak

Infectious disease is nearly as old as life itself. Not long after multi-celled organisms evolved and proliferated in the oceans, some single-celled microbes took advantage of the bodies of these larger organisms as new homes for nourishment, growth, and reproduction. The arms race that ensued between pathogens and would-be hosts spurred the development of ever more elaborate immune systems among the multi-celled life forms and ever more powerful modes and tools of infection among the pathogens. In this age-old battle, victory has always been temporary; over the long term, the outcome has been the dynamic equilibrium of life on earth.

It may be, however, that human beings have inadvertently tipped the environmental scales in favor of the microbes. The outbreaks we've witnessed over the past few decades may only be the beginning of a period of microbial resurgence. Indeed, as my colleague Jeremy Jackson famously said, "We are on the slippery slope to slime." Destructive microbial activity is on the rise. But through scientific research, education, and policy change, we humans may be able to alter some of the forces that are giving microbes the upper hand.

I am looking out across our bay to the city of Victoria, Canada, and considering what might happen if we don't step up our game. What killing force could roll silently into our bay? There will certainly be more big outbreaks plaguing our oceans. Should we be watching for them, and where would we look? What will be the causative agents, and how destructive will they be?

The likeliest future outbreak is one that will strike a farmed species, such as shrimp, oysters, abalone, or salmon. Aquaculture farms can breed pathogens as well as seafood, since they typically contain animals in very high densities. Shrimp, oyster, abalone, and salmon farms are continually bombarded with small outbreaks that have the potential to spread. For example, the Taura virus that affects shrimp has been the world's largest marine pandemic for more than three decades and has fueled massive breeding programs aimed at developing resistant shrimp. There is also an outbreak of oyster herpes virus that threatens the health of oysters on the West Coast and worldwide. Deeper in the ocean, there are lurking salmon viruses that could rapidly cause a serious outbreak and devastate populations of the popular fish.

Although outbreaks of disease in farmed species are economically and socially expensive to manage, dangerous pathogens are also poised to threaten wildlife on a big scale. I worry, for example, about Morbillivirus attacking the endangered resident orca pod that swims just outside my bay. Morbillivirus, a close relative of canine distemper, has repeatedly caused killing outbreaks in seals and can be transmitted to orcas. In 2011, the US five-year status review of southern resident killer whales acknowledged that infectious diseases could impede recovery of this endangered species. Marine mammals, including orcas, are also susceptible to human viruses such as influenza and carry some of the antibiotic-resistant viruses that affect humans. Antibiotic susceptibility testing has revealed multiple antibiotic-resistant gram-positive and gram-negative bacteria in samples from the exhaled breath plumes of killer whales. These bacteria showed increased resistance to multiple antibiotics. Detection of multiple antibiotic-resistant bacteria in this natural setting has significant medical implications for humans who may recreate or work in the ocean, and for those who consume seafood.

While the health of orcas and humans is currently a priority in our waters, the outbreaks that worry me the most are those that suddenly attack foundational marine species and threaten to destabilize the natural ecosystems we rely on. The specter of how rapidly and unexpectedly the starfish outbreak spread still haunts me. One of the other doomsday-like scenarios I can imagine is an outbreak of some kind of pathogen with a very broad host range that affects all crustaceans, those hard-shelled invertebrates often with big claws and stalked eyes. A broad multi-host outbreak could take out all crabs, shrimp, and lobsters, and also the tiny crustaceans called copepods that make up much of the zooplankton. Don't let their size fool you: the copepods in zooplankton are an essential source of food for many types of whales and the entire food chain. They regulate the productivity of our oceans, and when their numbers dwindle, so do populations of the great plankton-feeding whales, like the right whales. An infectious disease of crustaceans with a broad host range would devastate ocean food webs as well as our own favored foods from the ocean.

Even worse than a multi-host pathogen affecting all crustaceans would be an infectious pandemic disease hitting organisms even lower on our marine food webs, like the one-celled plants called coccolithophores. In nutrient-poor waters of the open ocean, coccolithophores are an essential source of nutrition for small fish and all those diverse zooplankton. Coccolithophores are calcified and play an extremely important role in carbon and sulfur cycling in the oceans. Emiliania huxleyi is the most abundant coccolithophore globally, and we know quite a bit about its host-pathogen dynamics. Increases and decreases in its population are controlled by viruses. Coccolithophore susceptibility to the viruses is determined by the density of their calcified skeleton and the temperature of the water. So as temperatures warm and acidification continues to increase rapidly in our oceans, will this fundamental plant at the base of our great ocean food chains become more susceptible to its viruses? At this point in the story, we do not need a crystal ball to see the future. Warming the climate and polluting the sea will give new opportunities to underwater microorganisms, resulting in explosive new outbreaks of infectious disease. The bigger question is, how will we respond? We have transformative technology for disease diagnostics and surveillance on our side that could make a crucial difference if we put it to work. My hope is that we will be fast enough to develop innovative ways to control the eruptions of new outbreaks and save the ocean's biodiversity.

MME Anti-Racism Statement

We stand with our partner organizations in science education to put an end to racism and to support actions that will ensure equitable access to learning. We feel anger, shock and sorrow for the families of George Floyd, Breonna Taylor, Ahmaud Arbery and countless other Black people, indigenous people, and people of color who have been senselessly murdered, injured or harassed, often at the hands of law enforcement. This has gone on for far too long, and it is time for real change. Black lives matter.

MME, along with the National Marine Educators Association and all of its chapters, is committed to antiracist science education. We know that racism is ingrained in many of the policies and practices of our government, institutions, schools, and cultural organizations. We must do whatever we can to identify, confront, and change these policies and practices to just and equitable ones.

We ask that you, our members and friends, join us in pledging to:

- Identify racial prejudices within ourselves and our educational practices.
- Call out racism in our schools and learning environments.
- Create safe spaces for all students, especially Black students and students of color.
- Support one another in our quest for a more just and equitable world.
- Encourage and support minority students who are interested in careers in science
- Investigate ways to include indigenous scientific knowledge into our teaching practices

As scientists and educators, we know that strong biological systems depend on diversity. Evolution drives our world toward beautiful complexity. We will strive to recognize and enshrine this diversity as an essential element of the human condition, and critical to our survival.

In peace and friendship,

MME Executive Committee