Chesapeake Quarterly

MARYLAND SEA GRANT COLLEGE • VOLUME 17, NUMBER 1

Aquaculture Swims Ahead

contents

Volume 17, Number 1

CHESAPEAKE QUARTERLY *April 2018*

Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed. The magazine is produced and funded by the Maryland Sea Grant College. The college receives support from the National Oceanic and Atmospheric Administration and the state of Maryland.

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Cover photo: *Bronzini broodstock, also known as European sea bass* (Dicentrarchus labrax)*, swim in a tank at IMET's Baltimore lab.* PHOTOGRAPH, DAVID HARP

In the Chesapeake

Recently, I had the pleasure of listening to Dr. Yonathan Zohar, chair of the department of marine biotechnology at the University of Maryland, Baltimore County, discuss aquaculture. As usual, he had some interesting information to share, including a report in *The Economist* from 2016 that noted world aquaculture production exceeded that of beef. At the same time, however, data show that production in the United States is a fraction of the world total. Fisheries data clearly show many wild fish stocks are declining globally and will not keep up with the world's appetite for seafood. So how will the U.S. and the Chesapeake Bay region increase aquaculture production in a sustainable and economically viable way?

Growing seafood close to U.S. consumers makes ecological and economic sense, if we can do it without compromising the environment. Many researchers and entrepreneurs are thinking about how they can contribute to growing sustainable aquaculture in novel ways.

Having recently concluded two Maryland Sea Grant-sponsored aquaculture workshops, we are excited to bring this issue of *Chesapeake Quarterly* about "aquaculture beyond oysters" to our readers. Already oyster aquaculture thrives on both shores of the Chesapeake Bay, and Virginia's hard-clam industry leads in U.S. production of that species. In addition, though the numbers are small, wild populations of bay scallops occur in the coastal bays of Maryland and Virginia, and there is interest in building a bay scallop aquaculture industry.

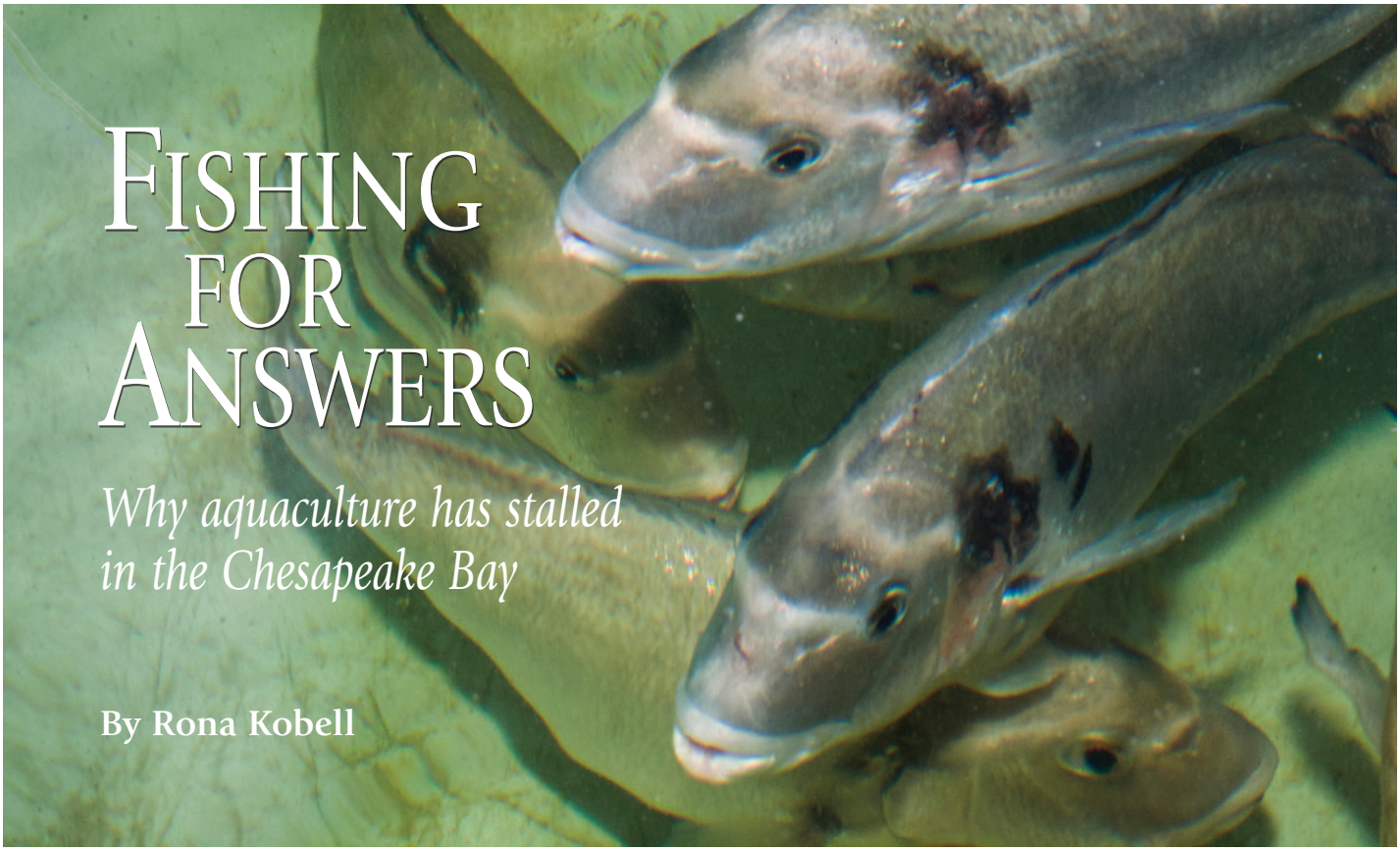
But what about developing other species, such as seaweed, bronzini, and sablefish? Or, developing technologies (e.g., closed system aquaculture, algal-based feeds and biosecure production) for sustainably raising fish and shellfish? Who are the leaders in the estuary's aquaculture efforts, and what new discoveries have they made to bring us to a sustainable future?

This issue of *Chesapeake Quarterly* examines those questions. It sums up our latest oyster aquaculture efforts, bringing together researchers and growers to plot a course for a robust future in which scientists help to solve in-the-water problems. And it discusses research efforts aimed at understanding and developing sustainable aquaculture.

In addition, we introduce you to our latest class of Maryland and the District of Columbia Knauss Marine Policy Fellows. These talented graduate students will spend a year working in U.S. executive and legislative branch offices exploring the interaction between science and policy. Finally, don't forget to visit our back page to meet our newest staff members here at Maryland Sea Grant.

We hope you enjoy this issue and, as always, we welcome your thoughts and feedback.

Fredrika Moser
Director, Maryland Sea Grant College



Fishing for Answers

Why aquaculture has stalled in the Chesapeake Bay

By Rona Kobell

More than a decade ago, Mark Luckenbach of the Virginia Institute of Marine Science said that aquaculture wasn't the future for fisheries worldwide — it was the present.

Since Luckenbach uttered those words in an interview with the *Baltimore Sun,* Virginia has become the U.S. East Coast's largest supplier of farm-raised oysters, producing a crop worth $18 million a year; its farm-raised clams are worth more than double that. In the decade since it legalized aquaculture statewide, Maryland's farmed oyster industry has topped $5 million. The farm-raised oyster harvest is expected to eclipse the wild fishery in Maryland in a few years. In Virginia it already has.

But for most other species in the Chesapeake Bay and coastal bays, the present for aquaculture has been a long time coming.

Other states, including Mississippi, Texas, Kentucky, Maine, North Carolina, Washington, California, and Florida, have robust industries for finfish, kelp, and shrimp. Not Maryland, though, where researchers were brought in three decades ago to build up those industries.

Why hasn't aquaculture taken off in Maryland? Why didn't the state capitalize on the striped bass research and technical expertise it developed in the 1980s during the moratorium on striped bass fishing? Why, when states from Alaska to Massachusetts are experimenting with scallops and seaweed aquaculture, is Maryland slow to follow in their footsteps?

Asked about the lack of aquaculture growth in Maryland, some researchers are at a loss to identify one culprit.

"I can't tell you why it happened, but it did happen," said Yonathan Zohar, who came to build a program 26 years ago, and is now the chair of the marine biotechnology department at the University of Maryland, Baltimore County at the Institute of Marine and Environmental Technology in Baltimore's Inner Harbor. "With fish, there is this idea that wild is better. Which is strange, because you don't hunt and gather for chickens, or bovines, so why should there be this idea that a wild fish is better?"

The seafood deficit

One thing is certain: Wild is not sustainable. Nearly 90 percent of the world's seafood stocks are overfished. Some, like bluefin tuna, are in such dire straits that they are considered endangered. Meanwhile, demand for fish has surged, and world agriculture now produces more fish than beef.

In the United States, demand outstrips the domestic supply, in large part because fish is considered part of a heart-healthy diet. The country's seafood trade deficit totaled more than $14 billion in 2016, the largest amount among agriculture products. (The National Oceanic and Atmospheric Administration [NOAA]

Broodstock *of Mediterranean seabream* (Sparus aurata)*, which is not native to the Chesapeake, could be an excellent aquaculture species. It's growing well at IMET.* PHOTOGRAPH, NICOLE LEHMING

IMET scientist John Stubblefield *checks on 1-year-old bronzini at the Aquaculture Research Center in Baltimore. IMET scientists were able to close the life cycle of this fish in captivity; spawning it, producing eggs and larvae, growing the fish to juveniles, to harvest, and then again to broodstock. In doing so, they have begun to solve a vexing problem of how to grow fish in captivity. It could have implications for the aquaculture industry.* PHOTOGRAPH, DAVID HARP

and the Food and Drug Administration largely regulate aquaculture, while the U.S. Department of Agriculture regulates meat and poultry products.)

The question of why Maryland hasn't done more to build an aquaculture industry is complicated, but several researchers and business professionals pointed to a few key reasons: A lack of investment by the federal government; sometimes opaque permitting requirements; expensive land prices; environmental considerations; and the challenge of taking technology developed in a laboratory and scaling it up for commercial use.

"People ask, 'Why aren't we doing more?' " said David O'Brien, deputy director of NOAA's aquaculture office. "And partly, it's because we have a very challenging permitting process. It's not for the faint of heart. It can take years, and even after several years, there's no guarantee the permit will be issued."

O'Brien said the Trump administration supports aquaculture and is "very much in a listening mode" as to how permitting processes can be made easier and NOAA requirements integrated with those of states and other federal agencies, such as the U.S. Army Corps of Engineers. Federal funding for pilot programs, including oysters, increased from $6.3 million in 2016 to $9.3 million in 2017.

It's a staggeringly small amount compared to other countries where stricter environmental guidelines have led to more investment and innovations in controlling the waste often associated with aquaculture. In the European Union alone, the Maritime and Fisheries Fund will invest 6.4 billion euros ($7.9 billion) in seafood marketing, data collection, and aquaculture over the next few years. The bulk of the investment — 4.3 billion euros ($5.3 billion) — will go to making aquaculture more sustainable and profitable.

In this country, a number of states, particularly in the South, have multi-million-dollar fish industries, and generally less stringent state environmental regulations. Maryland, in contrast, lost its last hybrid striped bass aquaculture operation a decade ago. (See "Striped Bass," page 11). A promising shrimp farm in Hurlock also closed, relocating to North Carolina.

Shrimp grows at Marvesta's new home *in North Carolina after the company left Maryland. The species,* Litopenaeus vannamei*, is commonly called both whiteleg shrimp and Pacific white shrimp. Though native to the Pacific Ocean, the shrimp in Maryland were raised in closed re-circulating systems on land, posing no risk of an introduction in Maryland waters. Raising Atlantic salmon in open Pacific waters, on the other hand, has been problematic.* PHOTOGRAPH COURTESY OF MARVESTA

Over the years, entrepreneurs have floated proposals to raise fish indoors in Baltimore warehouses, using technologies developed at the Aquaculture Research Center at the Columbus Center in the city's Inner Harbor. The aquaculture center is part of the Institute of Marine and Environmental Technology (IMET), a partnership including the University of Maryland, Baltimore County, the University of Maryland Center for Environmental Science, and the University of Maryland, Baltimore. At IMET, scientists work on techniques to sequence fish, crab, and oyster genes; synchronize the molting of crabs; sterilize fish for aquaculture growth; raise bluefin tuna juveniles; develop environmentally-responsible fish feeds; and reduce pollution from feed waste buildup in aquaculture tanks by converting it to biofuel.

Land for fish

Maryland and Virginia are tough states for fish aquaculture, said Reggie Harrell of the Northeast Regional Aquaculture Center at the University of Maryland. Land for creating farms that would house closed re-circulating systems is far pricier here than it is in, say, Kentucky or Tennessee.

Raising fish in net pens in the Chesapeake Bay is problematic, too, because watermen still ply those waters, and the pens also pose navigational hazards for ships passing up and down the Bay en route to ports around the world.

At NOAA's Chesapeake Bay office in Annapolis, oysters are still the main interest, and the type of aquaculture considered most viable, said Bruce Vogt, manager for ecosystem science and synthesis.

"Scale has something to do with it. You might need a lot of area to do a fish farm," said Vogt, who helped his parents set up their own commercial oyster farm in Virginia. "We run into a lot of user conflicts here as it is. Trying to get places where you are not in someone's way is difficult."

One way to overcome some problems related to fish farming is to raise species that don't compete with those that watermen are already catching. At the Columbus Center, Zohar and his colleagues are working on European sea bass (*Dicentrarchus labrax,* also known as bronzini) and the Mediterranean seabream *(Sparus aurata)* — neither of which occur in the Chesapeake Bay or Maryland's coastal waters. To protect the environment, Zohar said, such

non-native marine fish can only be cultured in fully contained, land-based, re-circulating aquaculture operations, which Zohar and his team have developed. He has, at times, sold the fish to high-end local restaurants, where the chefs have praised it. At a recent meal at McCormick and Schmick's in the Inner Harbor, Zohar was told by the chef how much customers loved the flaky white meat of his bronzini.

By working at the Aquaculture Research Center, Zohar has also circumvented a second problem: having to contend with neighbors who might not want a fish farm next door. That's an issue in Maryland, particularly when raising oysters. Several shoreline property owners have mounted legal challenges to oyster farming proposals, tying up lease agreements for years. Harrell said the same sorts of challenges could emerge if entrepreneurs applied for permits for finfish aquaculture operations.

For Marvesta, the shrimp farm that lasted about a decade in Hurlock on the Eastern Shore, the challenge was not the permitting process or town residents, who supported the endeavor. Nor was quality; the shrimp *(Penaeus vannamei)* were served in 20 restaurants, and chefs often noted that customers raved about the farm-raised sustainable shrimp. The company stopped growing its shrimp in Maryland because it couldn't produce enough to cover its costs, said Marvesta CEO Guy Furman. The overhead is the same for shrimp, whether raising 50,000 or 100,000 pounds, Furman said. And because of production issues, the company couldn't boost production to the levels it needed to sustain profits. In Maryland, it also had to rely on other companies' broodstocks because it didn't have a hatchery.

The farm has relocated to Charlotte, NC, which has cheaper land and labor costs. Furman is planning to scale it up again as a full hatchery instead of rearing the shrimp from the baby stage, as he did in Maryland, which will give him control over the whole production cycle and reduce costs. Furman has also turned his attention beyond shrimp. He now runs a Chicago business importing and selling mussels.

Patrick Kangas *of the University of Maryland, College Park, is interested in growing seaweed in the Chesapeake.*
PHOTOGRAPH, RONA KOBELL

"There's no margin for error in this [aquaculture] industry, unfortunately." said Furman. "It's just that tight."

As a businessperson, Furman said, he's not sure turning to the government for investment is the answer. But clearly, he said, it's difficult to succeed without investors who are willing to part with large sums of money.

"There's been a ton of aquaculture failures," he said. "Getting it from research into commercialization, that's the hard part, and there's just no money for that."

Money for scale

In 2000, then-Maryland U.S. Sen. Barbara Mikulski visited Zohar at the Aquaculture Research Center and asked him if he thought it would be possible to help the blue crab population. The wild crab fishery in the Chesapeake Bay fluctuates year to year, but at the turn of the last century, crabs were again in dire straits. Mikulski wondered if Zohar would be interested in starting a program to supplement the wild catch.

From 2002 until about 2008, Mikulski helped bring $15 million to the Blue Crab Advanced Research Consortium, which also included researchers at the Smithsonian Environmental Research Center, the Virginia Institute of Marine Science, North Carolina State University, and the University of Southern Mississippi. The state of Maryland and Maryland businessman Steve Phillips helped, too. Watermen in Maryland and Virginia helped with the field research.

The work taught scientists much about the blue crab's life cycle, how fast it grew, where it traveled, how it got there, and its mating habits. Zohar and his colleagues were the first to comprehensively understand the life cycle of the blue crabs in captivity and produce juveniles for both aquaculture and stock enhancement research. It also helped the IMET team investigate ways to synchronize the molting cycles of crabs, which would allow soft-shell crabs to be raised in aquaculture settings. Watermen raise soft crabs in "peeler pens," outdoor facilities, often under shade, where wild crabs shed their shells. Watermen constantly tend to the tanks to ensure they do not become hard again, and thus worthless. Zohar believes that, with the ability to hatchery-produce baby crabs and to eventually synchronize the molts, soft-shell crabs can become an aquaculture product, thus taking pressure off the wild fishery.

Seaweed is a new frontier as well, taking root in Maine and California. At the University of Maryland, College Park, environmental engineer Patrick Kangas is hoping to grow seaweed in the Chesapeake in tandem with oysters in cages and floats to see if the oysters stimulate plant growth. Earlier efforts, he said, were hampered by rains that changed salinities.

For shrimp, crabs, finfish, and now seaweed, the future has still not arrived in Maryland. But Zohar and Harrell, who came here to be part of an aquaculture revolution, hope the race is still on.

"The potential of what we can do is enormous," Zohar said. "Somehow, things need to change here."

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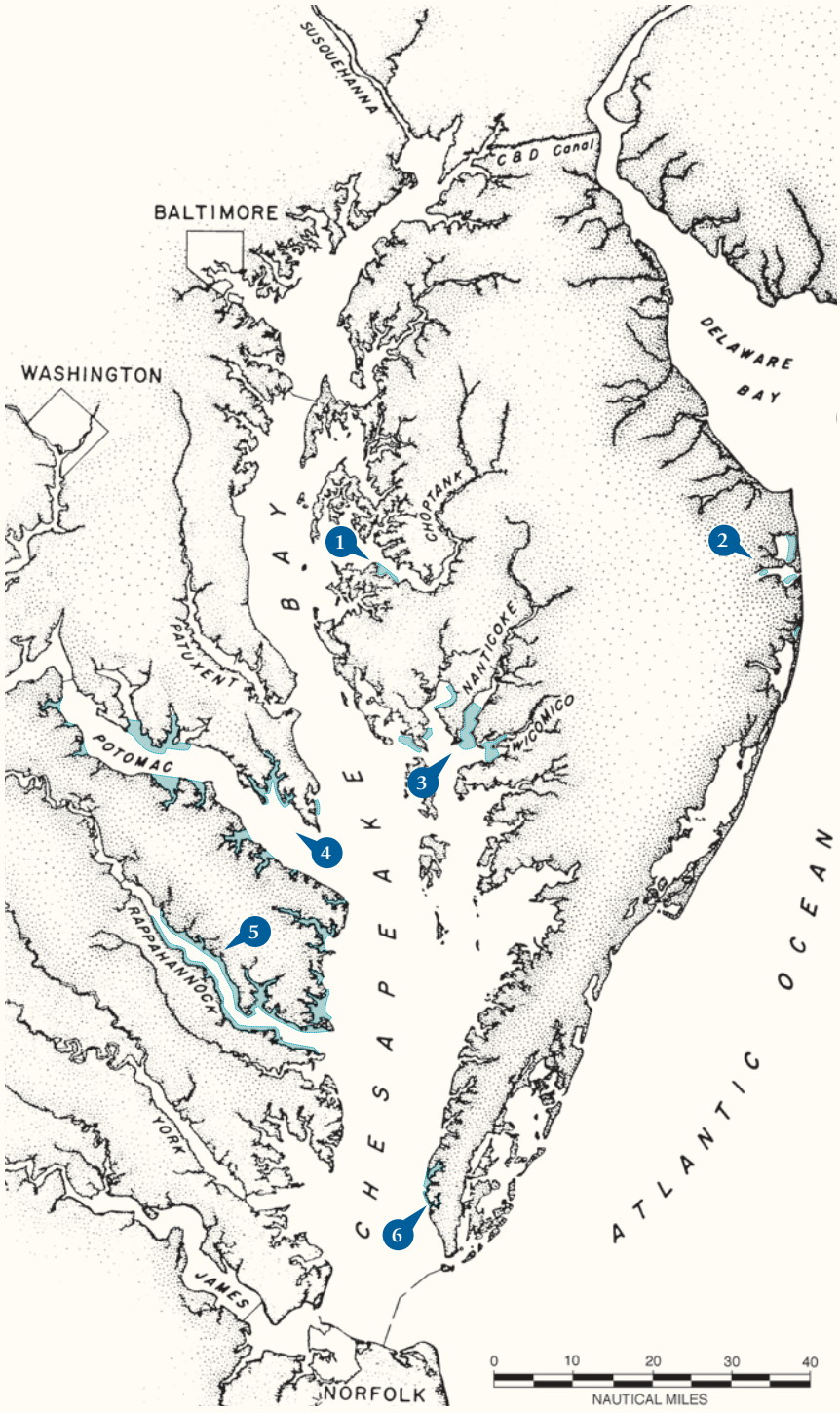
The Great Shellfish Bay

H.L. Mencken called the Chesapeake Bay the "great protein factory." And that it was, for close to two centuries, as watermen harvested oysters, clams, crabs, and striped bass from its wild waters. But in the past several decades, aquaculture for hard clams and oysters has taken off in both Maryland and Virginia. We look at some points of interest along the way.



Note: Locations on this map are approximate.

Sources: 1. University of Maryland Center for Environmental Science; **2.** Don Webster, Aquaculture Regional Specialist; **3.** *Washington Post;* **4.** *Chesapeake Bay Journal;* **5.** *Chesapeake Bay Journal;* **6.** *Baltimore Sun*

1 Choptank River

The University of Maryland Center for Environmental Science's Horn Point Hatchery is helping to restore oyster populations, both for ecological and economic reasons. It is near a commercial oyster farm, Marinetics, that uses floating cages to grow oysters.

2 Delaware Inland Bays

Maryland Extension specialist Don Webster is among those helping to start an oyster leasing program in these coastal bays — pushback from waterfront homeowners has been one of the biggest obstacles to a robust program.

3 Nanticoke, Maryland

While most of Maryland remained in the wild fishery and oyster leases were hard to obtain from the 1900s until 2010, especially on the Eastern Shore, the Nanticoke River had a leasing tradition — thanks in large part to the H.B. Kennerly Oyster Co., that was based there. Kennerly closed in 2005, but several oyster farmers have taken up residence in the river.

4 St. Mary's area, Maryland

(Hollywood, Ridge, Breton Bay)

A cluster of oyster farms have been set up in Southern Maryland, along the Potomac and St. Mary's rivers as well as the open Chesapeake.

5 Rappahannock, Virginia

A robust oyster aquaculture industry has set up shop in Virginia's Northern Neck. There are enough farms and restaurants here that the state set up an oyster trail for tasting.

6 Cheriton, Virginia

In the early 1980s, diseases had killed so many oysters that C. Chadwick Ballard decided to try something else: clams. He began planting beds on Cherrystone Creek, and the clams became famous all over the world. Other lease-holders followed, and Virginia's Eastern Shore became the capital of the state's hard clam industry, which is now the largest in the country. Some, like Ballard's company, have now returned to their roots, growing oysters again.

When a Dead End Becomes a Path Forward

How Baltimore scientists are re-routing reproduction to produce sterile fish

By Rona Kobell

Two environmental problems are eating away at aquaculture's promise around the world.

The first is genetic pollution. In the Pacific Northwest and elsewhere, aquaculturists have bred domesticated fish that have occasionally escaped from confinement. That could lead to farmed fish displacing wild stocks, or even to Atlantic salmon propagating in the Pacific, where it is non-native, all of which disrupt the ecosystem and food chain.

The second is that fish generate waste, which is often released into the coastal environment. There, it can have an adverse impact on the ecosystem.

At the University of Maryland's Institute of Marine and Environmental Technology (IMET), researchers are developing solutions to both of these problems. If scaled up, the researchers say, their innovations could change the way we grow fish, manage waste, and maintain wild stocks. Those fixes are already happening in countries like Norway, a world leader in aquaculture production, which have invested heavily not just in aquaculture but in the IMET scientists.

First, we look at the escape problem — a serious issue because a fish such as the domesticated Atlantic salmon *(Salmo salar)*, selectively bred to be different from wild stocks, can survive outside confinement and change the genetic composition in the environment. At IMET, scientists Ten-Tsao Wong and Yonathan Zohar have found a way to

Yonathan Zohar, *who focuses on marine and aquaculture biotechnology, feeds fish in IMET's aquaculture center. Chair of marine biotechnology for the University of Maryland, Baltimore County (UMBC), he spends time when he can with the fish.* PHOTOGRAPH, RONA KOBELL

produce reproductively sterile fish.

In their labs, they have developed a technology that can disrupt the early formation of cells that would otherwise develop into eggs and sperm in a fish. In doing so, they could produce sterile fish. Think of their solution this way: Stem cells on their way to where they will develop into sperm or eggs take a wrong turn and die. To make that happen, they have to silence a protein appropriately called dead end.

The team tested its concept on zebrafish *(Danio rerio)*, which share many genetic and physiological similarities with larger fish.

Zohar, chair of the Department of Marine Biotechnology at UMBC, located at IMET, believes it has "huge potential" for the industry. Wong and Zohar are now working to test the concept on several major aquaculture species, such as Atlantic salmon, rainbow trout, sablefish, and tilapia.

This innovation has major implications, financially and environmentally. Last year, more than 100,000 Atlantic salmon escaped into the Puget Sound. And though the company responsible, Cooke Aquaculture, said it doesn't expect any of the fish to survive and reproduce, an environmental group is suing the company in part over the risks due to genetic pollution of introducing a new species to the Pacific Ocean. If they were bred to be sterile, Zohar said, the risk of them possibly breeding in the Pacific would be far less — though he added that doesn't address the question of why we are raising Atlantic salmon in floating net pens in the Pacific, with the inherent risk of fish escaping.

Then, the waste: Building on the fully contained aquaculture operation in the basement of the Columbus Center — home to IMET — Zohar initiated a project where fellow IMET scientists Kevin Sowers and Keiko Saito are working on a technology, sponsored by a Norwegian company, to use microorganisms known as methanogens to break down fish waste. These tiny microbes flourish in conditions with little or no oxygen and produce methane gas as they digest the waste.

Yonathan Zohar, Keiko Saito, and Kevin Sowers *on a boat in Norway. They are en route to the salmon farms they are working with on technology to turn fish waste into energy.*
PHOTO COURTESY OF IMET

"We had never seen such a big operation incorporating this kind of technology. . . . It will accelerate the whole aquaculture industry."

Using these beneficial microbes as their workhorses, the team built a system to collect wastewater from fish tanks, concentrate the solid waste in an airtight container, and then let the microbes do the work of converting the waste to methane gas. The biogas produced, much like the natural gas used in homes for heating and electricity, can then either be used as an energy source for the facility where the fish are raised or be sold to an electric company.

In Norway, where aquaculture is an $8 billion industry second only to oil, private companies are turning to Zohar and other scientists for solutions. They cannot continue to discharge the salmon waste produced by land-based hatcheries and nurseries into the fjords, according to stricter government rules, and will eventually have to collect and treat the waste produced by floating net pens too.

The IMET team tinkered in labs overlooking Baltimore's Inner Harbor until they found the right microbial mix. "This is the test case," Sowers said of the methanogen conversion apparatus he and his colleagues keep in the basement of IMET. He and Saito just returned from Norway where they helped launch a waste-to-energy system, based on the IMET technology, at one of the country's largest land-based salmon aquaculture operations.

"We had never seen such a big operation incorporating this kind of technology," Saito said. "It will be a great demonstration project. It will accelerate the whole aquaculture industry."

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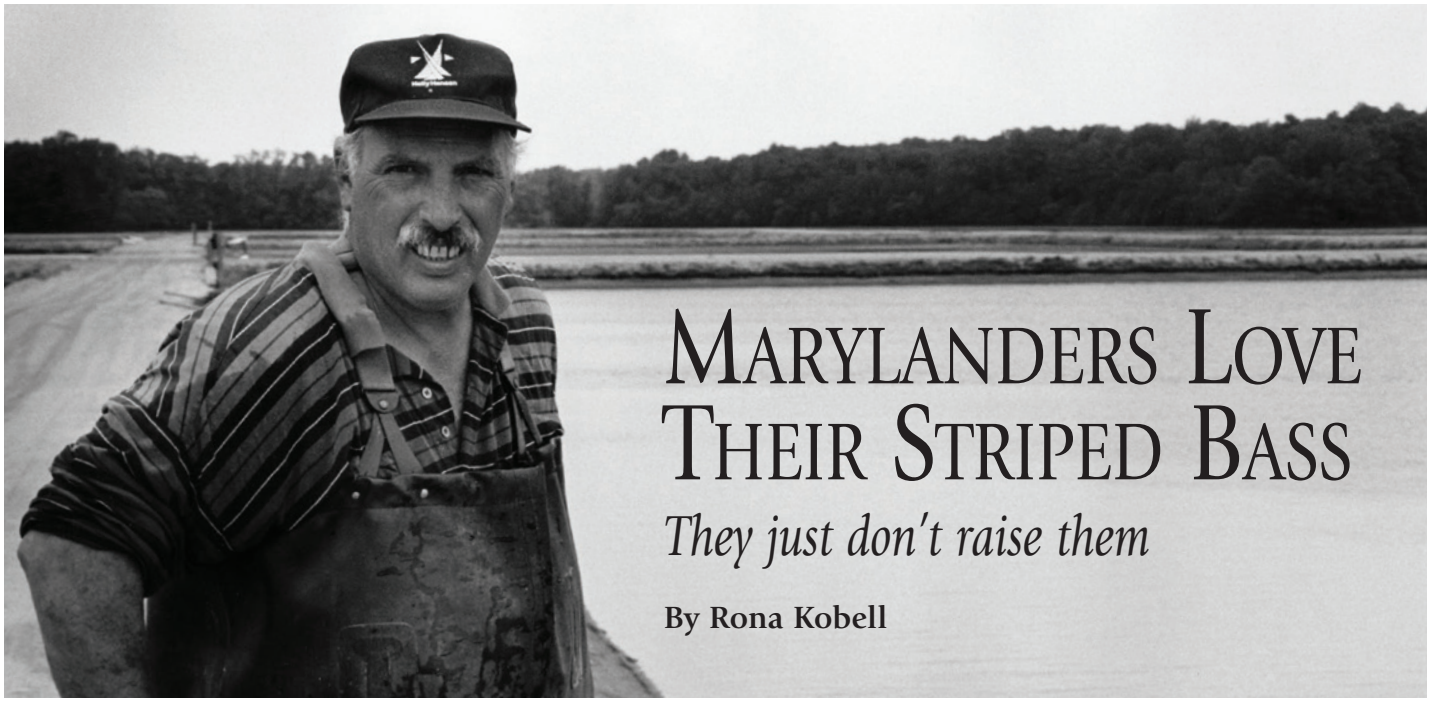
An Aquaculture PRIMER

How do you make a small fortune in aquaculture? Start with a large one. So goes an old joke. What makes a species ideal for one body of water can tank it in another. Growing an industry takes the right combination of temperature and salinity, in addition to an appetite for spending the research dollars to cultivate certain species. Here are some species already growing here, and a look at why others have struggled.

SPECIES	WHERE GROWN	STATE IN THE BAY
 **Hybrid striped bass** *Morone chrysops x Morone saxatilis*	The first hybrid striped bass was raised in the 1960s in South Carolina by crossing eggs from a female striped bass with sperm from a white bass. The fish have since become a big industry in the Carolinas as well as Kentucky and Indiana.	In the 1980s, striped bass were raised in Maryland, but by 2003, commercial production ended due to economic and other constraints. (see "Striped Bass," p. 11) Much of the broodstock and technology for growing hybrid striped bass was developed in Maryland and helped other states.
 **Oyster** *Crassostrea virginica*	Here, mostly south of Annapolis on both sides of the Chesapeake Bay to Norfolk and in the coastal bays. Nationwide, on the Gulf Coast, the Pacific Northwest, and New England waters.	Virginia had aquaculture for more than a century, while Maryland opened up all its waters to oyster aquaculture in 2009. Virginia now has the largest oyster aquaculture industry on the U.S. East Coast, with a value of $18.5 million in 2016; Maryland's was valued at $5 million that year. Virginia's farmed oysters long ago eclipsed their wild harvest; Maryland's farmed oyster harvest is on pace to do the same in the next few years.
 **Whiteleg shrimp** *Litopenaeus vannamei*	Largely in the southeastern U.S. and Texas.	Three Baltimore friends opened a shrimp business in landlocked Hurlock, on Maryland's Eastern Shore, in 2003. It moved to North Carolina (see "Fishing for Answers," page 3) in 2014. There are no other shrimp farms in Maryland; Blue Ridge Aquaculture, in Virginia, experimented with commercial shrimp production and found a lack of space limited its success.
 **Clam** *Mercenaria mercenaria*	High-salinity parts of the Chesapeake and coastal bays, largely in Virginia; some farms operate in the Maryland coastal bays near Ocean City.	Clam aquaculture took off in Virginia in the 1980s when diseases devastated oyster populations there and forced the wild fishing industry to seek alternatives. That proved highly successful. In 2016, the market value of Virginia's clams was $38.1 million.
 **Macroalgae** *Gracilaria* and *Agardhiella*	Kelp and related seaweed products are showing great promise as a commercial aquaculture product in Connecticut, Maine, and Alaska. Federal and state governments are supporting research and further development of seaweed as an aquaculture product.	Little is known about how seaweed grows in the Chesapeake Bay. Researchers at the University of Maryland, College Park experimented with growing native *Gracilaria,* and studied whether it might work in tandem with oyster farming. Similar work is underway in California.



Marylanders Love Their Striped Bass

They just don't raise them

By Rona Kobell

Maryland, one of the states most associated with the silvery, flaky striper *(Morone saxatilis)*, would seem to be the most logical place to grow them, given how many residents love to eat them. And the past couple of decades would have seemed an opportune time: Nationwide, the striped bass aquaculture industry is the fourth largest for finfish — behind catfish (primarily channel catfish, *Ictalurus punctatus*), salmon (both Atlantic, *Salmo salar,* and Pacific, *Oncorhynchus spp.*) and trout (primarily rainbow trout, *Oncorhynchus mykiss*). By 2012, the market for farm-raised striped bass was worth $30 million, according to the U.S. Department of Agriculture.

But you won't find many of those fish in ponds or pens in the Old Line State. And you won't find striped bass — not the *Morone saxatilis* that swims wild in the Chesapeake, or the hybrid striped bass — scientific name *Morone chrysops x Morone saxatilis* — so named because it is a striped bass crossed with a white bass and that is the dominant species in aquaculture.

Economics, politics, and timing inhibited the effort just as research in Maryland was underway to both domesticate the striped bass broodstock and improve the grow-out technology for the hybrid fish. In other words, the hope was to restock wild populations of *Morone saxatilis* and develop a thriving industry of pond-raised hybrids. But instead of using that technology to build an industry here, Maryland scientists shared their knowledge and helped states far from the Chesapeake Bay become the major producers of hybrid striped bass.

North Carolina, South Carolina, Arkansas, Kentucky, Indiana, California, and Tennessee are all major hybrid striped bass producers. North Carolina favors ponds; other states use closed re-circulating systems. Extension specialists and scientists from Maryland Sea Grant and Cooperative Extension offices have helped build up an industry that has created hundreds of jobs and generated new research about how best to grow these fish. The aquaculture industry is mostly hybrids. The first hybrid striped bass was grown in South Carolina, and industry has continued to thrive in ponds in the southern states because of high demand for the fish and strict fishing limits on the wild population for commercial anglers.

Maryland, in contrast, had loads of fish when it lifted its striped bass moratorium in 1990, say the watermen who fished for stripers then. It also had a drop in effort, as many of the watermen found other ways to make a living when they couldn't fish. Fewer anglers and more fish led to much less of a need to supplement the fishery with aquaculture. And watermen at the time did not want the hybrid striped bass raised in ponds to compete with their wild catch.

Maryland legislators from coastal communities, who had been successful in fighting oyster aquaculture for decades, were not interested in easing regulations for a finfish species to compete with striped bass. Regulations in Maryland are stringent, as well, with local counties and towns having a lot of control over whether pond aquaculture comes within their borders. And the constituents and their elected representatives were not necessarily eager to welcome enterprises that would compete with wild harvests.

But more than politics, regulations, and timing, the lack of striped bass aquaculture in Maryland was an issue of cost. So said Reggie Harrell, a fisheries biologist and Extension specialist who came to Maryland in 1984 to help the

Tony Mazzaccaro *stands by the Manokin River, where he ran Maryland's last striped bass fish farm.* PHOTOGRAPH, LISA HELFERT

state cultivate striped bass, both for possible stock enhancement in the Bay and for aquaculture out of it. Land and water use is expensive, and the fish could not sell for a high enough price to make up the difference.

"Once the economics are there, then you fight the political and the regulatory battles," said Harrell, who directs the Northeast Regional Aquaculture Center at the University of Maryland, College Park. "But there's no need to fight them if you're not going to make any money at it."

Harrell arrived as the wild striped bass fishing industry in the Chesapeake Bay was collapsing, or at least in dire straits. In 1985, populations of stripers had dipped so low that the state instituted a five-year moratorium on fishing. Harrell, who had come to Maryland from South Carolina to raise striped bass larvae and fingerlings, was focused on enhancing the Chesapeake's wild stocks. At the University of Maryland Center for Environmental Science's Horn Point Hatchery, in Cambridge, he worked with state and federal colleagues to put millions of hatchery-raised striped bass fingerlings into the estuary in hopes of boosting the dwindling populations.

The moratorium devastated fishermen like Billy Rice of Southern Maryland. "I lost about 45 percent of my income in one fell swoop," he said. To make ends meet, he trapped muskrat, used haul seines for white perch, potted for eels, and worked on his father's grain farm. Working for someone else was out of the question. So was getting into striped bass aquaculture.

Many watermen actively opposed any kind of striped bass aquaculture during the moratorium days, and let their representatives know it. Rice didn't object; he just didn't think pure stripers were amenable to being raised in ponds. Tasting one at an aquaculture expo on the Shore confirmed his suspicions. He said it was "like tasting mud."

Not so for the hybrids. Farmers are able to raise an attractive, tasty hybrid striped bass today in part because of

"Those fish owned me. I did not know what a weekend was."

the work of scientists like Reggie Harrell and Curry Woods in Maryland; reproductive endocrinologists Craig Sullivan at North Carolina State University, and Yonathan Zohar, then at the Maryland Center of Marine Biotechnology; and nutritionist Delbert Gatlin of Texas A&M University in College Station. Most of the fish raised now in ponds across the country go to New York's Fulton Fish Market, which sends it to Manhattan restaurants and sometimes far beyond.

Harrell had faith in the hybrids even then, and was hedging the state's bets on a wild striped bass comeback in the late 1980s and early 1990s. He was also raising the hybrid, a white bass crossed with a striped bass. They reached two pounds in 18 to 30 months, much faster than wild fish. Regulators would not allow hybrids to be sold commercially during the moratorium, a condition Harrell understood. But if the wild fishery did not bounce back post-moratorium, Harrell was readying an alternative.

And he wasn't alone. Farther north, in eastern Baltimore County, another southerner was helping Baltimore Gas and Electric grow hybrid striped bass *(Morone chrysops x Morone saxatilis)* at the Crane Aquaculture Facility, named for the Charles P. Crane Generating Station along Seneca Creek. Curry Woods was the Kentucky scientist who was in charge of raising the fish in the 1980s and 1990s. At the time, the breeding program for hybrids was the only such work in the world, according to Jim Carlberg, president of Kent Sea Farms in San Diego and one of the nation's largest striped bass producers.

Harrell worked with University of Maryland Extension agents Don Webster and Don Meritt on a hybrid striped bass farm operation at Walnut Point, near Chestertown in Kent County. He continued to work on breeding and reproduction techniques throughout the moratorium years, when none of the fish could go to market. Even transferring them across state lines proved tricky, and involved some tangling with regulators. The site eventually closed. Harrell had hoped that both a wild fishery and hybrid aquaculture could thrive in Maryland. But at the time, it was not to be.

Tony Mazzaccaro had the state's last hybrid striped bass farm. The Hyrock Farm in Princess Anne finally shuttered its doors in 2003. Toxic algae blooms of the dinoflagellate *Karlodinium veneficum* killed many of his fish. The water for the fish farm came from the Manokin River. Desperate to eradicate the dinoflagellate, he sprayed a copper sulfate pesticide that, when added to the water, killed the dinoflagellate *and* his fish. That led researchers to wonder if a high copper content was to blame for deaths in the ponds. But by then, Mazzaccaro was done. And the former University of Maryland Extension agent, who now teaches at the University of Maryland, Eastern Shore, said he does not miss it.

"Those fish owned me," he said. "I didn't know what a weekend was."

Harrell believes that farm-raised striped bass might have suffered from a wrong-fish, wrong-time problem. A high-dollar industry that didn't compete with anything wild caught could benefit from the husbandry techniques developed for stripers, and open new markets. Some possibilities include closed indoor systems that could grow other high-value fish, such as, barramundi, sea bream, or bronzini.

Rice, former chair of the state's Tidal Fisheries Advisory Commission, thinks watermen would welcome that.

"If it was something that we don't produce anyway, I wouldn't see a big pushback," he said. "It could even be a way for us to expand our own markets."

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HOMEGROWN

Two forums explore the future of Maryland aquaculture

By Rona Kobell

In 2014, half of the seafood consumed in the world came from aquaculture. Very little of that was produced in the United States, and hardly any of it came from Maryland. Why? What are the barriers to producing more seafood in a state with thousands of miles of shoreline and a bay once known as "the great protein factory?" How can Maryland entrepreneurs, researchers, and consumers capitalize on a greater interest in producing domestic seafood, and a government that is increasing funding for such endeavors?

To find out, Maryland Sea Grant convened an Aquaculture Researcher Roundtable on Jan. 10 in College Park. The meeting complemented a gathering last November in Annapolis that focused on the Maryland aquaculture industry's needs, particularly oyster farmers, the largest aquaculture industry in the state.

The idea of the January meeting was to ask questions about expanding aquaculture, including and beyond oysters *(Crassostrea virginica)*. Once the concerns were clear, it would be possible to match researchers interested in projects with those in the aquaculture industry willing to work on them. The meeting began with an overview given by Yonathan Zohar, chair of the Department of Marine Biotechnology at the University of Maryland, Baltimore County, on the status and challenges of the aquaculture industry globally and nationally. This was followed by presentations on the current situation in Maryland — from finfish to oysters to razor clams — and the challenges and opportunities in growing sustainable aquaculture here. Following the talks by researchers and short perspectives from those in the industry, the room broke up into discussion tables. Topics ranged from genetic bottlenecks and species survival rates to legal and marketing concerns.

Sea Grant provided a briefing book that included descriptions of federal funding opportunities, so participants understood the range of aquaculture research the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the Atlantic States Marine Fisheries Commission, among others, might be interested in funding.

"We're trying to build innovative, cross-disciplinary teams, and see if there is funding to match the needs," said Fredrika Moser, Maryland Sea Grant Director. "We're trying to ask, 'How would you go about solving some of the problems confronting growing sustainable aquaculture in Maryland?'" Among the issues addressed:

Breeding and genetics: Triploid oysters are bred to be sterile and resistant to the two diseases that have devastated wild Chesapeake Bay populations. There is generally high mortality in small oysters in hatchery settings. But neither scientists nor farmers know why older oysters sometimes have inexplicably high mortality rates. Is it related to water quality in a certain tributary?

Oyster farmers and researchers *share a laugh at the Aquaculture Researcher Roundtable in College Park, hosted by Maryland Sea Grant.* PHOTOGRAPH, NICOLE LEHMING

Salinity? Temperature? Would a certain hybrid oyster do better in a low-salinity or high-salinity location? Could a seed catalog, as garden stores have for plants, help indicate which varieties of oysters would grow best in which places? Further, could innovative technologies used to develop sterile fish be used to create sterile oysters with lower mortality rates? Scientists at the Institute of Marine and Environmental Technology (IMET) are working on such new approaches for sterility in oysters.

Business optimization: Maryland Sea Grant Extension business specialist Matt Parker helps prospective oyster farmers obtain loans through state programs and develop business plans and farm-level economic information regarding the use of water-column cage or on-bottom aquaculture methods. But participants also identified a need to create more shucking houses to accept product and send the shells back to oyster farmers. In much of the Chesapeake Bay, shucking houses have dwindled. Yang Tao, an engineer at the University of Maryland, College Park, who has already developed an apple sorter and packer, noted his current research to develop a robotic oyster shucker that would cut down on labor costs. Oyster farmer Jon Farrington, also an engineer by training, said the state needs to investigate ways to return shucking capacity to Maryland and to efficiently recycle shells.

Theft prevention and enforcement: Currently, Maryland has 408 active leases covering 6,000 acres in the Chesapeake Bay and its tributaries. The value of those oyster aquaculture businesses, according to the Maryland Department of Natural Resources (DNR), is $5 million, and expected to continue to grow rapidly. Karl Roscher, who spoke at the meeting and manages the aquaculture program at the Maryland DNR, said 125 more applicants are currently waiting for leases of varying sizes to be approved. The increase in oyster aquaculture has opened the door for an increase in theft on leased areas.

Scott Budden, *who owns Orchard Point Oysters in Kent County, weighs in at Maryland Sea Grant's aquaculture meeting. Before the meeting with researchers, Sea Grant held a meeting with oyster farmers to determine what research might fill the gaps in their knowledge and help them become more successful.*
PHOTOGRAPH, RONA KOBELL

One solution discussed at the meeting was a technical innovation that could alert leaseholders and police that a boat has entered a lease area. Several oyster farmers expressed their interest in this and other novel ideas to explore how technology could reduce theft.

Diversification: Marylanders don't generally eat razor clams *(Tagelus plebeius)*. Instead, they are used as bait, even though they cost $6 a pound. Same with eels. Tuck Hines of the Smithsonian Environmental Research Center urged researchers and entrepreneurs to think about eels, razor clams, and aquatic plants as high-value products Marylanders can raise that may not become food staples or products for us, but would be popular in other regions.

Finfish in closed aquaculture systems: IMET has been raising striped bass, bronzini, cobia, bluefin tuna, and blue crab in closed re-circulating systems. But it only operates at approximately 50 percent of its capacity. Other countries do much more because their governments invest millions in scaling up these systems. Participants discussed how re-circulating aquaculture production may portend a future where these bio-secure, disease-free systems could grow fish far from the sea at low environmental risk.

Legal issues: Oyster farmers have long complained about a protest system that can tie up their leases for months. Were finfish aquaculture to expand in Maryland, similar protests and lease use restrictions could occur. Property owners often fear cages, floats, and tanks next to their homes will obstruct views. Interestingly, when property owners complain about agriculture practices near their homes, they don't go to the courts, but to a state mediation board. Conference attendees wondered if an aquaculture mediation board could be developed.

Continued dialogue and tangible proposals: Everyone who completed a post-meeting survey wanted the roundtables to become an annual or semi-annual event. Maryland Sea Grant hopes sustainable aquaculture in Maryland continues to develop with input from industry, regulators, and scientists all across Maryland — from oceanographers at the U.S. Naval Academy to engineers at the University of Maryland, College Park, and pathogen experts from the University of Maryland, Eastern Shore. Many attendees found potential collaborators who they wouldn't have met if not for this event.

The College Park meeting was the first in many years to bring together researchers and the industry, and certainly the first to broaden the topic beyond oysters. Many oyster farmers, including J.D. Blackwell, Scott Budden, and Jon Farrington, have already worked with researchers on their farms. After the meeting, Farrington, an aerospace engineer by training, said he hoped many more would.

"This," he said, "is pretty much the best thing ever. Getting growers and researchers into a room together. What could be better?"

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Maryland's 2018 Knauss Fellows

The Knauss Fellowship, established in 1979, provides an educational experience to students interested in ocean, coastal, and Great Lakes resources and in the national policy decisions affecting those resources. The program matches highly qualified graduate students with "hosts" in Congress or the executive branch of government in the Washington, D.C. area for a one-year paid fellowship. Meet our fellows!

Aixa Alemán-Díaz has joined the NOAA Office of Oceanic & Atmospheric Research (OAR), National Sea Grant Office as the coastal ecosystems and resilience specialist. She obtained her Ph.D. in sociocultural anthropology at American University in Washington, D.C. Her research compares the way in which the social background — place of residency, employment, education, and age — of residents, technical experts, and short-term visitors influences their social relationships with Puerto Rico's beaches and coastal bioluminescence. Like land, the coasts face pressures due to the multiple uses, or on-site activities, such as recreation, biodiversity conservation, scientific research, and public uses. Born and raised in Puerto Rico, Aixa earned an M.A. in anthropology at Rutgers University and bachelor's as a double major in psychology and anthropology at the University of Michigan.

Noelle Olsen is serving as the bycatch, release mortality, and observer program specialist in the NOAA National Marine Fisheries Service's Office of Science and Technology. She is a master's student in the Marine Estuarine Environmental Science program at the University of Maryland, Eastern Shore. Noelle studied the reproductive biology and sexual maturity of Jonah crabs *(Cancer borealis)* in the Mid-Atlantic Bight with Bradley Stevens. After discovering a love for lobsters, she began looking at the prevalence of epizootic shell disease in lobsters while working aboard commercial fishing boats. Noelle received her B.A. in biology with a specialization in ecology and conservation biology and a minor in marine science from Boston University in 2013. After graduating, she was a marine mammal research intern with Whale and Dolphin Conservation, collecting data and educating passengers on whale-watching boats. She enjoys traveling, cooking, and concerts. She is proud to be a part of the LGBTQ community.

Lauren Tavar is serving as a legislative fellow for U.S. Sen. Cory Booker. She will be working on environmental and agricultural issues. Lauren earned her bachelor's degree in political science from the University of Miami. She then went on to study environmental law at American University's Washington College of Law and has since become a member of the D.C. bar. Throughout law school, Lauren worked with environmental nonprofit organizations including the Center for Biological Diversity, Endangered Species Coalition, Environmental Integrity Project, and Natural Resources Defense Council. Upon graduating, she completed a legal fellowship at Public Employees for Environmental Responsibility, working on environmental whistle-blowing cases.

Ammar Hanif joined NOAA's National Centers for Coastal Ocean Science, Monitoring and Assessment Branch as a senior scientist studying the presence and environmental impacts of microplastics in the Great Lakes using bioindicators in mussels. He focuses on using molecular techniques and bioinformatics as tools to study the marine environment and answer ecological questions to better manage marine resources. His Ph.D. work, at the University of Maryland Center for Environmental Science, focused on the diet and microbiome of menhaden using DNA barcoding and bioinformatics. His master's work involved developing a molecular tool to study the ecology of a parasitic dinoflagellate that infects blue crabs. His expertise includes extracting DNA from difficult samples, marine and estuarine ecology, handling large datasets, bioinformatics, and analyzing high-throughput sequencing results of microbial communities using statistical methods. He enjoys fishing, running, cycling, boxing, and Brazilian Jiu-Jitsu.

The Knauss Marine Policy Fellowships run from Feb. 1 to Jan. 31 and pay a stipend plus allowances for health insurance, moving, and travel. Students can apply through the Sea Grant program in their state. For more information, please visit:

Maryland Sea Grant Program
mdsg.umd.edu/education/knauss

National Sea Grant Program
seagrant.noaa.gov/Knauss

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University System of Maryland
College Park, Maryland 20740

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Meet Maryland Sea Grant's New Team Members

This issue, we say goodbye to Jeffrey Brainard, who led our communications team for six years and wrote frequently for this magazine. Jeff accepted an editorial position at *Science* magazine. We thank him for his many contributions, which included working with colleagues here and at the *Chesapeake Bay Journal* to create a multimedia package on coastal flooding and sea level rise in the Chesapeake Bay.

Maryland Sea Grant is excited to welcome two new staff members:

Rona Kobell joins Maryland Sea Grant as a writer and editor. She will write and edit for *Chesapeake Quarterly,* and contribute broadly to our communication team's other outreach efforts. She is a former reporter for the *Bay Journal,* where she also produced a long-running radio show on Maryland's main NPR station, and for *The Baltimore Sun,* where she was the first official Chesapeake Bay reporter. She is a graduate of the University of Michigan. She lives in Towson with her husband and two children. She enjoys long, slow runs, and meandering paddles whenever possible. Reach her at kobell@mdsg.umd.edu.

Taryn Sudol is the new Chesapeake Bay Sentinel Site Cooperative coordinator with Maryland Sea Grant. Previously, she was an Extension agent with the University of Florida. She received her M.S. in conservation biology and sustainable development from the University of Maryland, College Park. She will continue our work to improve the integration of research and outreach across federal coastal reserves in the Chesapeake and coastal bays. She will be based in College Park but will travel to Annapolis and to various sites often. She enjoys birding, rock-climbing, and paddling. She lives in Washington, DC. Reach her at sudol@mdsg.umd.edu.

Rona Kobell, left, and Taryn Sudol.

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