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35th Anniversary Issue

Tracking the Blue Crab Comeback

contents

Volume 11, Number 2

3 The Blue Crab Conundrum
What brought blue crabs back?

8 The Offshore Odyssey of Blue Crab Science
A new theory about blue crabs launches a long search for answers.

15 The Value of Crabbing
Do watermen want to sell back their rights to go crabbing?

18 Crab Processors Get High Tech
Flash freezing helps an old Maryland industry compete in a new global marketplace.

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Cover photo: *Blue crabs big enough for the "basket trade." These crabs can be sold for steaming and eating at summertime crab feasts. You can tell these are female crabs: they "paint their nails red."* ***Page 2:*** *A blue crab being measured during the winter dredge survey.* ***Page 3:*** *Driving his boat out of Chesapeake Beach, Bobby Abner looks ahead for the next crab pot. Donny Eastridge gets ready to toss out a crab pot baited with razor clams. Over a long day of crabbing, they will empty and rebait over 500 pots.* PHOTOGRAPH ON COVER AND P. 3 BY MICHAEL W. FINCHAM; PHOTOGRAPH ON P. 2 BY SKIP BROWN.

35 Years of Blue Crab Research

Forty years ago this summer, Hurricane Agnes arrived over the Chesapeake Bay watershed in late June and began altering the ecology of the estuary. Coming ashore as a tropical storm dense with moisture, Agnes immediately began unleashing heavy rains and historic floods in the Bay's great rivers. Riding those floods came huge brown loads of sediment that surged down into the mainstem of the Bay and began burying oyster bars and underwater grass beds, two biological communities that were essential to the health of the ecosystem.

The floods of Agnes, however, had little or no effect on another popular Bay species: blue crabs. (Their harvest actually increased over the next two years.) That puzzled two young scientists — one working in Maryland, one in Delaware — who were already rethinking the current theory about where blue crabs spend their early lives. The result would be a new theory that helped solve a long-standing enigma: why do blue crab populations go through so many sudden booms and slumps?

One birthplace of this new paradigm was probably a restaurant in Seaford, Delaware, a midpoint meeting place where once a month scientists Steve Sulkin and Chuck Epifanio could rendezvous and spend a long lunch talking blue crabs. (See "The Odyssey of Blue Crab Science," p. 8.) Other birthplaces were the new Sea Grant programs recently established in Delaware, Maryland, and Virginia that soon provided support.

In 1977, Maryland Sea Grant began its work with joint funding from the National Oceanic and Atmospheric Administration and the state of Maryland. Its goals included research, education, and extension focused on developing and communicating science-based approaches to restoring and managing key resources of Maryland's Chesapeake Bay and Atlantic coast.

Once Sulkin and Epifanio were ready to test their new thinking about blue crabs with laboratory experiments and ocean-going research cruises, they were able to turn to Maryland Sea Grant for long-term funding support. One of the new program's first commitments was funding innovative research on blue crabs, work that would later bring together biologists and oceanographers in cross-disciplinary work. Sea Grant Extension agents soon began providing technical advice to watermen and seafood processors on sustainable fishing, aquaculture, and seafood safety and packaging. (See "Crab Processors Get High Tech," p. 18.)

The Chesapeake has suffered other serious onslaughts besides Agnes, onslaughts like overharvesting of finfish and shellfish, invasive oyster-killing parasites, dead zones of low oxygen every summer, and nutrient overenrichment from the runoff of farms, sewage plants, cities, and suburbs. Managing the ecology of a system under such stress calls for a deep understanding of underlying ecosystem processes, and Sea Grant now has a long history of supporting basic research that investigates problems like nutrient enrichment and explores the resilience potential of the ecosystem.

Funding investments in this kind of research have come from Sea Grant and, of course, from larger institutions like the Environmental Protection Agency and the National Science Foundation — and they have begun to pay dividends. Over the last two decades, research findings have led to new approaches for replanting seagrass beds, rebuilding oyster reefs, and developing a profitable oyster farming industry.

And science-based management has helped reverse declines in traditional fisheries for striped bass and, most recently, for blue crabs, a favorite recreational target for Maryland residents and now the most profitable commercial fishery in the state.

— *Michael W. Fincham*

The Blue Crab Conundrum

Michael W. Fincham

What's behind this year's boom in Chesapeake Bay blue crabs? Good management? Good weather? Or good luck?

The question sounds simple, but the answer may not be. Not if you look for an answer among the various scientists who study blue crabs for a living. Some of them, the crab biologists, focus on the in-Bay travels and travails of this colorful, two-clawed crustacean. Others, the oceanographers, track the offshore exodus of blue crab larvae — the tiny offspring who will grow into the next generation of Bay crabs — but only if they work their way off the ocean and back into the estuary.

So what's behind the comeback? Martin O'Malley's answer: good management. He's not a biologist — he's the current governor of Maryland — but he has a lot of biologists backing his answer. This April, Governor O'Malley stood on the back deck of a local crab house on the Severn River and announced that there were 764 million crabs in the Chesapeake Bay this year, a huge increase from five years earlier.

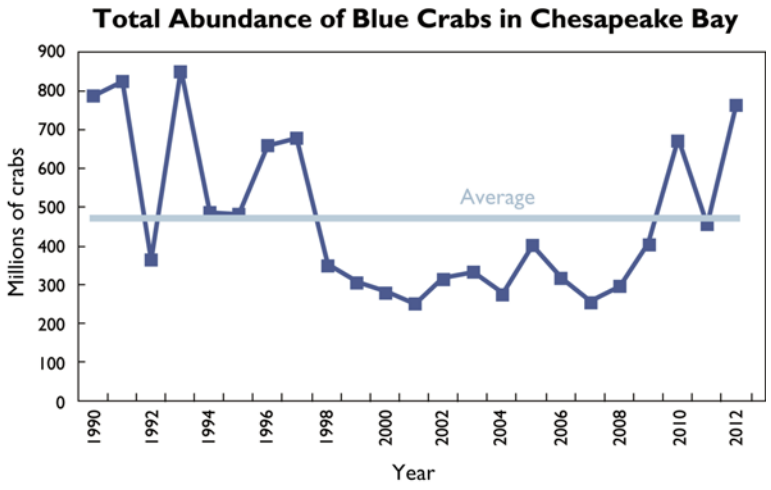
Posing behind him was an array of officials, most of them men, most of them dressed in shirts and ties, all there to represent state agencies, environmental organizations, and the Maryland Watermen's Association. Standing in front of the governor was an array of reporters, some of them in jeans, none in ties or jackets. As he delivered a short, triumphal speech, the newspaper people scribbled in notebooks, the television people worked their big cameras.

Crab numbers matter in Maryland. Several thousand watermen catch them for profit, working from their traditional deadrise workboats, and many other natives catch them for fun, leaning off local docks with dip nets or wading out into creeks and rivers. "The crab represents for many people some of the best moments they share with family," said O'Malley from the deck at Mike's Crab House. "You pull one of these beautiful creatures up out of the dark waters, and they are shining there in all their color — the red and the blue and the greenish hues. It's a moment every child remembers, and it's a moment that every parent remembers."

By the next day, most people in the state who read a paper, watch television news, or listen to the radio knew about this year's blue crab number, and they knew it was a good number. How good a number? There are more crabs out there now than any year since 1993, said the

governor. After a long losing streak, the Bay looked like a big winner in a blue crab lottery that seems to spit out up years and down years in a random sequence.

The governor's good-news number came from the annual winter dredge survey that biologists from Maryland and Virginia have been running since 1990. Working with watermen, scientists spend weeks motoring around the Bay to 1,500 randomly selected spots where they dig crabs out of the mud, count them, measure them, weigh them, record their sex, and estimate their ages. They work from November through early March. It's the best time to count crabs because they all stay in place, buried in the mud, waiting for warmer water. After crunching the numbers, the biologists come up with an annual crab estimate, a kind of Baywide census of blue crabs. It's a number that goes up and down.



The annual winter dredge survey *has been estimating blue crab populations since 1990. This year's survey counted 764 million crabs, the highest number on record since 1993 when the survey estimate reached 852 million. The graph shows clear evidence that populations can rise and fall dramatically from year to year. It also highlights the 10-year slump (1998-2007) that led scientists and managers to argue that current fishing levels were unsustainable. New restrictions on the harvesting of female crabs were enforced in 2009, and crab populations began to recover.* GRAPH SOURCE: MARYLAND DEPARTMENT OF NATURAL RESOURCES.

In 2007, when the crab number sank to the lowest point of a low decade, the survey results drove home a gospel that scientists and managers had been preaching for years. "Our female crabs were being overfished," O'Malley told the press, echoing the consensus of many crab biologists, "and our fishery was at risk of complete collapse."

The answer to the crisis was a new management policy, a cutback on the harvest of female crabs. In 2008, Maryland, Virginia, and the Potomac River Fisheries Commission agreed to reduce the harvest of female crabs by 34 percent. Their options included limiting the number of fishermen, the number of pots and traps, the number of hours in a fishing day, and/or the number of months in a fishing season. In Maryland, the major change was shortening the fall crabbing season. And in Virginia, the big change was outlawing the winter crab dredge season.

It was a policy change based on the hard-won findings of crab biologists who've documented the life cycle of the species in impressive detail. In the fall, female crabs start south after mating, headed for their spawning grounds in the high salinity waters near the mouth of the Bay. During this mass migration down-Bay, females have to run a gauntlet of crab pots, trotlines, bank traps, channel pounds, and grass scrapes, especially in Maryland where watermen are hoping to catch females before they reach Virginia waters. During past winters, Virginia watermen were allowed to dredge the bottom of the Bay and dig up many of the hibernating females that made it out of Maryland. The net result of this fall and winter crabbing: many female crabs never got a chance to spawn.

The management solution — a cutback on catching females — sounds like simple biology, one scientist called it "the kindergarten solution." But it's a solution that took some courage and some complicated politics. The two states that share the Chesapeake also share a long history of disagreeing with each other about how to manage the blue crabs that travel back and forth across that invisible, watery state boundary that bisects the Bay. And the sharpest disagreements center on the harvest of female crabs.

As early as 1917, for example, Maryland banned the harvesting of sponge crabs, females carrying packets of fertilized eggs, but Virginia refused to go along with the idea. It took a series of poor harvests and a rising sense of crisis before Virginia finally banned sponge crab fishing in 1926. When harvests rose soon after, especially in Maryland waters, Virginia backtracked, re-opening its sponge crab season in 1932. Crab harvests were soon cut in half in Maryland, and that state responded by extending its fall crabbing season through November. That allowed Maryland watermen to catch more south-moving females before they could reach Virginia waters.

This bi-state game of regulatory volley and response would be played and replayed numerous times over the decades. The two states eventually negotiated a 1935 deal with Virginia promising to reduce its harvest of sponge crabs and Maryland, in a quid pro quo, agreeing to once again shorten its fall crabbing season. The deal sounded a lot like the 2008 bi-state agreement, but it would not last. In later years Virginia would expand its harvest of sponge crabs, and in a tit-for-tat, Maryland would lengthen its fall fishing season. Both states on occasion would try their own conservation efforts. Virginia established a crab sanctuary near the mouth of the Bay, and Maryland several times shortened its fall fishing season.

If it lasts, the bi-state deal of 2008, with its cutback on the fishing of females, could be a final reversal of that

history of interstate wrangling. If so, it's a hard-won reversal engineered in part by the Bi-State Blue Crab Advisory Committee (BBCAC), a multi-year effort to get groups from both states to talk with each other about crab science and management. Organized and managed by the Chesapeake Bay Commission, BBCAC set up workshops and conferences that brought together legislators, scientists, watermen, seafood processors, and resource managers to review crab science, debate the management options, and struggle towards consensus. BBCAC ceased operations in 2003 after it was defunded by the Virginia legislature, but its technical workgroup kept going.

Despite its demise, BBCAC left an important science legacy. The committee kept crab biologists working together long enough to hammer out an action plan that set threshold and target levels that resource managers could use in maintaining a sustainable fishery. A threshold spells out the reality that crab populations can crash if they are fished below a certain minimum level. And a target establishes a population level that managers should aim for to keep populations in safe territory.

With the 2008 cutback on harvesting females, both states finally seem to be moving towards bi-state management based on ecology more than economics. "Both states took a lot of economic losses for doing that," says Tom Miller, director of the Chesapeake Biological Laboratory at the University of Maryland Center for Environmental Science (UMCES). "I think Maryland and Virginia," he says, "have a lot to be proud of in the way they've approached their crab fishery."

Sounds like good management is the best answer then, the true cause behind the current blue crab recovery. Following the 2008 cutback, female crab numbers went up at the end of the first year, while male numbers did not. Good evidence says Miller "that the conservation effort on females actually increased female abundance." In the second year after the cutback, the number of new, young crabs went up. More good evidence, according to Miller, that crab populations were responding to the new policy.

"Maryland and Virginia have a lot to be proud of in the way they've approached their blue crab fishery."
— Tom Miller

Unless those populations were responding to something else, a suggestion that comes from Tuck Hines, a blue crab biologist with the Smithsonian Environmental Research Center. According to his analysis, the count of adult crabs actually dropped in 2011, the third year after the cutback on female harvests, and then dropped again in 2012 to the lowest-ever count of females on record. Watermen, he says, may still be finding ways to get around the new regulation and keep fishing out a lot of females.

And some force besides females may be pumping up the high crab number that Governor O'Malley announced back in April. Swelling the 2012 crab census was the highest number of juvenile crabs ever recorded in the annual survey. Why were juveniles increasing while spawning females were decreasing? "Perhaps offshore storms brought more (crab) larvae into the Bay," wrote Hines in a recent blog. Good weather, rather than good management, may be behind the blue crab recovery.

Good and bad weather conditions can play a big role in causing all those ups and downs of blue crab abundance. When female crabs spawn near the mouth of the Bay, each female releases millions of tiny, barely visible larvae, up to eight million larvae according to some estimates. These first-stage larvae, looking like extraterrestrial fleas rather than tiny crabs, tend to rise up into the Bay's seaward-flowing surface waters and ride the flow right out of the estuary into offshore coastal waters. Whether these fleas ever get back into the Bay to become crabs depends in large part on weather-driven forces like winds and currents. If a good number return, the Bay's blue crab population will jump two years later. If hardly any return, it will plummet.

With all the right weather and wind and current forces kicking in, only a small percentage of larvae make it back into the estuary during a high-return year. According to one model, that influx can drop by 90 percent during a low-return year.

Here's the attraction of weather-based scenarios: they help explain why crab populations have jumped and plummeted numerous times in the past.

And here's the problem with weather-based scenarios: they are not much help in predicting how many crabs are coming next year or the year after — at least not yet. Winds and currents are complicated topics, a domain ruled not by biologists who describe the life cycles of crabs but by oceanographers who describe the physics of offshore air and water masses that push blue crab larvae around.

What are the big forces that drive the winds and currents that, in turn, can bring the blue crabs into Chesapeake Bay? In recent years, oceanographers have looked at river flows and freshwater plumes and phases of the moon, and now they are moving farther afield trying to examine larger-scale climate forces. Forces like the Bermuda-Azores High, for example, can create winds that drive larvae toward or away from the Chesapeake. The North Atlantic Oscillation (NAO) can, in turn, create favorable or unfavorable Bermuda-Azores Highs. And the Atlantic Multi-decadal Oscillation (AMO) creates a warming or cooling of ocean waters that lasts for decades. It can also play a role in creating all those pressure systems and wind events and current patterns that eventually push tiny, flea-like crab larvae towards the Chesapeake Bay in large numbers — or scatter them far out on the waters of the continental shelf.

The good-weather scenario is becoming the big-weather scenario. "We are just kind of opening our eyes to large-scale weather patterns and what that means for coastal circulation on weekly to monthly scales," says Elizabeth North, a fisheries oceanographer with the UMCES Horn Point Laboratory, who has led ocean-going cruises designed to track blue crab larvae. "It is exciting to think that what's going on over Iceland has anything to do with blue crabs here on our tables," she says.

So back to the big question: what's behind this year's great blue crab number? Good management or good weather? A cutback on the harvest of female crabs? Or some big-weather patterns that blew a lot of crab larvae back home?

Probably both, says Tom Miller. "We could have had females go up, and if the oceanic conditions hadn't been right, we may not have seen the recruits go up," he says. "An increase in females is important, but it is not guaranteeing you great recruitment."

The right weather conditions, on the other hand, almost guarantee great recruitment. In past decades, after all, those weather forces have lined up to churn out great, unexpected blue crab abundances — often during eras of heavy fall fishing in Maryland and annual winter dredging in Virginia.

You see the dilemma faced by fisheries managers and scientists: they can make the smart move, say increasing the number of females, and still get no results. Or they can do nothing and perhaps get great results.

It's a sobering thought. "We can manage for female abundance," says Miller. "But we can't manage for oceanographic conditions."

And where does good luck come in? This time the Chesapeake Bay blue crab lottery seems to have spit out a big crab number, 764 million crabs for 2012, just when good management and good weather were both in play.

— fincham@mdsg.umd.edu

Maryland-Style

When Marylanders go crabbing for fun or a family feast, most of them use some chicken necks on a line to bait the crabs and a dip net to catch them. The more ambitious, however, can try some of the tools the pros use. Those who go crabbing for profit are called watermen, and they chase hard crabs with crab pots in the Bay's mainstem and with trotlines and net rings in the tributaries. When they're hunting peeler crabs, crabs that are getting ready to molt, watermen use peeler pots, bank traps, or crab scrapes.

Hard shells make up most of the commercial harvest by far, with crab potters catching twice as many as trotliners. Most large crabs go to the "basket trade" and are sold live by the dozen or by the bushel for steaming and eating. Smaller crabs and most females go to seafood processing houses to be cooked and picked, their meat sold in cans and cartons.

Peeler crabs will molt and become soft-shells. A small percentage of the total commercial harvest, soft-shells can sell for 10 times the price of hard crabs. Buyers include local restaurants and large seafood processors who freeze them for shipping around the country and the world.

Crab Potting: Outguessing a Quick-Moving Quarry

Michael W. Fincham

Wherever blue crabs go, *Bobby Abner is sure to follow. When they head for the deep, he moves his pots. When they bury themselves in the Chesapeake mud come winter, he heads to Florida for warm-weather crabbing.*

Bobby Abner has a good idea where he's going to find crabs today. He's been crabbing since he was 11 with time off for college and a government job he quit pretty quickly. It's been mostly crabbing ever since with its daily guessing game about where the crabs are moving now.

He's heading out of Chesapeake Beach on *The Brittany Mae*, a classic deadrise workboat with a short front cabin and a long, covered cockpit that will offer shade on this bright, windless day.

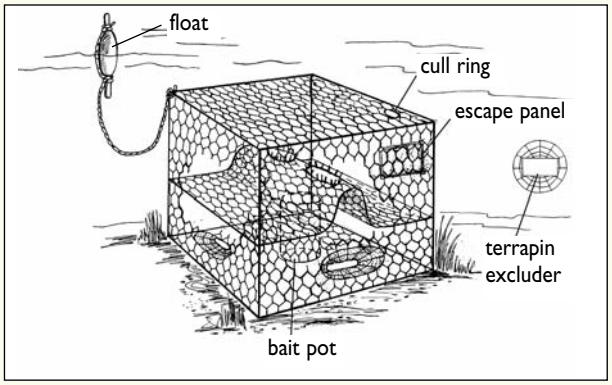
A nor'easter blew through several days ago, and he figures the crabs in shallow water took a pounding. A number of his pots are in the shallows just off all those new townhouses lining Chesapeake Beach and North Beach. Those pots don't hold many crabs.

Crab potting with Abner is a three-man job. He drives the boat along a long line of floats, timing the speed for a smooth workflow. Leaning over, he hooks the line under the float and passes it to Donnie Eastridge, a lean and weathered man who's worked with Abner for 40 years. Eastridge whips the line into a winder, steps on the pedal, hauls the pot out of the water, dumps out the old bait, shakes out the crabs, sticks in the new bait, shuts everything up, and heaves the pot and float back in the water. All before the boat hits the next float.

Tommy Dorsey starts grading the crabs into three baskets: number ones, number twos, females. He's the rookie on the crew. He's only worked three years with Abner.

The work has rhythm, and they'll keep it going for 500 pots. And Abner's guess was right: the best hauls are out in the deeper waters. That's where the crabs went, and when he finishes crabbing that's where he moves his shallow-water pots.

— M.W.F.



Crab potting. *The float leads a crab boat to the line, the line leads down to the pot, and the bait leads crabs into the pot. There's also a small cull ring that leads small crabs back out into the Bay. In a hard shell pot, the bait can be razor clams or menhaden. In a peeler pot, it is often a declawed male to lure females ready to molt and mate.*

Crabbing

Trotlining: One Man and His Catch

Bobby Whaples loads about a dozen bushel baskets, recently emptied of jimmies and sooks, onto his boat, now sitting idle along a wharf in Madison, Maryland. At 54, this ex-Marine is one in a long line of crabbers. Whaples's grandfather and father both worked the water, and his own son had his first skiff when he was nine years old. But despite nearly 30 years spent hunting for blue crabs, Whaples says the animals are still a mystery to him: "Right when you think you have them figured out, you don't," he says.

And predicting where crabs are going to go and how they'll behave lies at the heart of his harvests. Whaples fishes with trotlines, essentially long fishing lines about 2,400 to 3,000 feet in length, with bait attached every few feet. Whaples runs three of these lines at a time, sinking them down into the water where the crabs scuttle. Then he makes his rounds, slowly pulling sections of those lines up to the surface to net the crabs still clinging to their meals of bull lips or chicken necks.

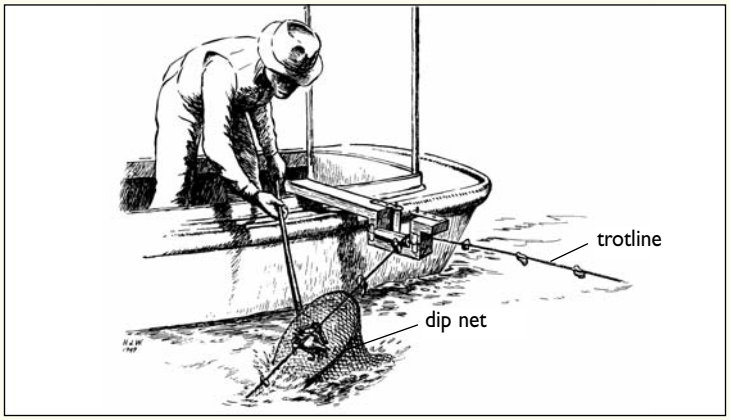
On a good day, he says he can bring in 16 to 18 bushels of crabs from this river, the Little Choptank. But, he adds, "Some of the best of them you can't catch if you try."

Trotliners, who represent just over a third of all the crabbers in Maryland, follow a more solitary existence than crab potters. But Whaples, who's tried out both techniques, says he likes this life better. As a trotliner, he doesn't have to head out with a crew, a necessity for crab potting. If things go wrong, "you only have one person to blame," he says. "That's you."

— D.S.

Daniel Strain

After a long day *spent crabbing, Bobby Whaples stows the last of his bushel baskets onto his boat, the* Courtney Drew *— named after his daughter and first grandson.*



Trotlining. *To run a trotline, a waterman shuttles his boat slowly down the length of his line, pulling his bait up and over a "prop stick" — typically, a wooden board with a metal roller. As the bait rises into sight, he has to be quick, skimming his dip net into the water before the crab falls off and out of sight.*

Bank Trapping: In Pursuit of Peelers

John Barnette skims his 17-foot skiff along the green marshes that border the south side of the Wicomico River, then throttles down into neutral, and glides up against a tall, cage-like structure that sits just out from the shore, its top jutting above the water line. Five feet tall and four feet square, the cage looks like the world's largest crab pot, but Barnette calls this contrivance a bank trap.

Michael W. Fincham

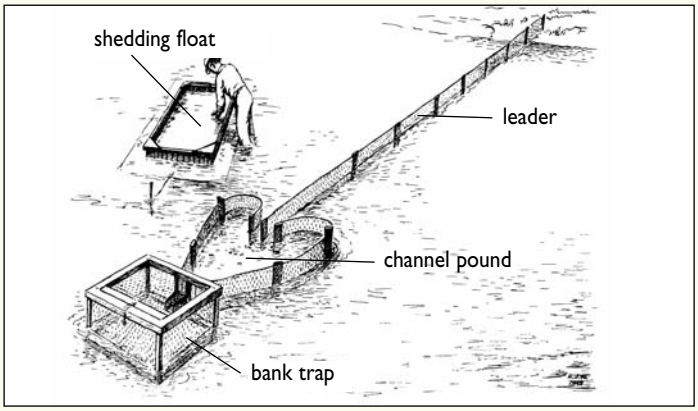
When he empties *his big, boxy bank trap, John Barnette no longer finds turtles in among the fish and crabs. Bank traps are built tall to give breathing room at the top for turtles. Now he keeps them out with a TED (turtle exclusion device). It's not just for conservation: "Turtles eat crabs."*

Cutting his motor, he lashes his skiff to a wooden pole, then swings a small boom out over the top of the cage. He hooks the top of the trap and then, pulling hard, he heaves the whole contraption up out of the water and bangs it onto the washboard of his boat. In the bottom of the trap is a bonanza of Bay life: flopping fish and scuttling crabs. Most of the crabs are peelers, crabs that moved close to shore looking for a safe place to molt — only to end up in a cage.

Bank trapping is a little-known, cleverly designed crabbing technique that targets peeler crabs for the higher-paying soft-shell market. Bank traps for crabs look a lot like pound nets for fish. Wire netting is strung along a row of wooden poles stretching straight out from the river bank. A shore-crawling crab hits the net, then follows the "leader" right into a heart-shaped pound. To get out of the "heart," the crab heads through a small funnel and ends up in the trap.

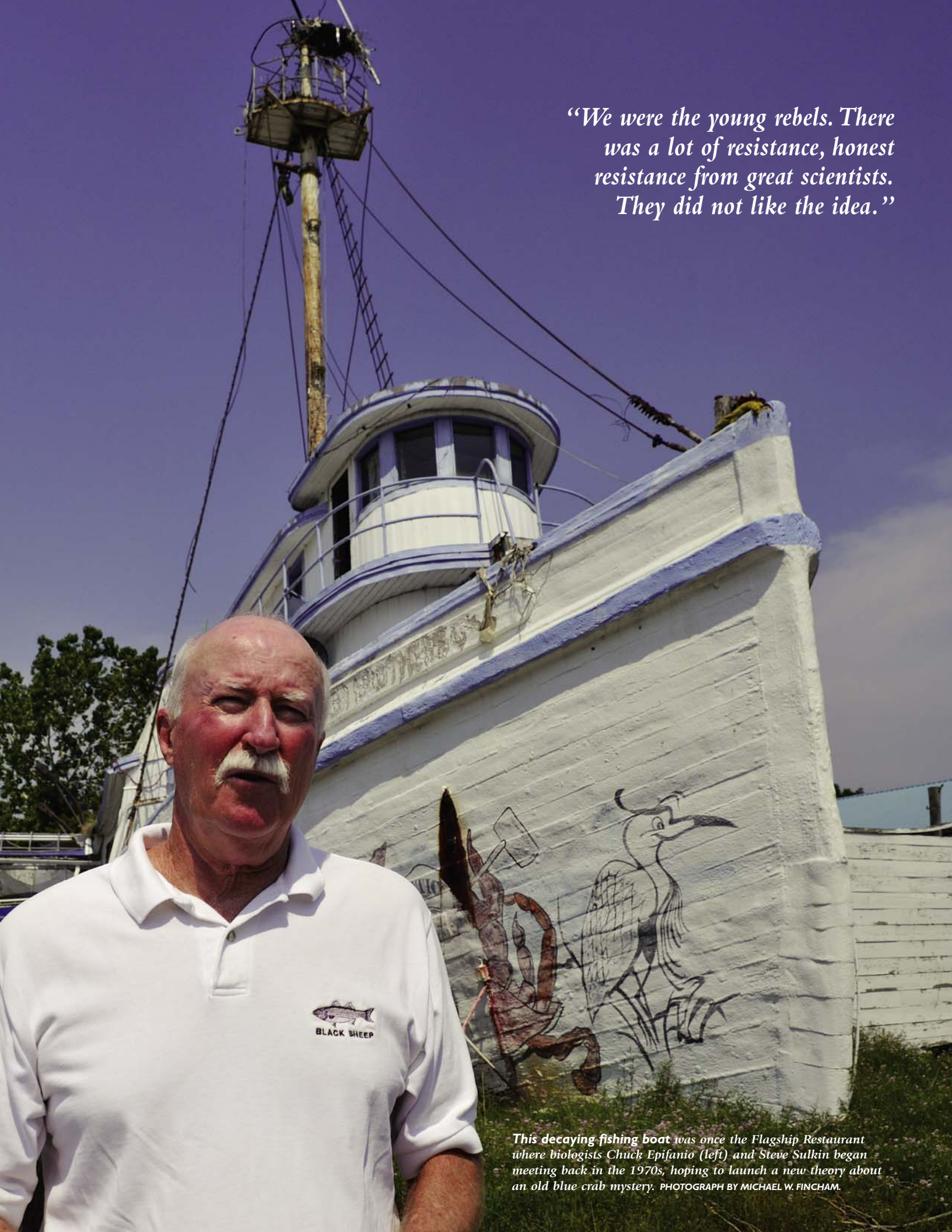
Somerset County, a hub of soft-crabbing activity located down at the southern end of Maryland's Eastern Shore, is the only county that still allows bank traps. That's why Barnette only works the south side of the Wicomico. The north side is part of Dorchester County. You could say the river divides Somerset from the rest of the world.

— *M.W.F.*



Bank trapping. *Here's what a peeler crab looking for shelter can run into: a leader, a heart, a trap. It may then spend the rest of its days in a shedding float, waiting to molt into a soft crab. Watermen can "read" the back fin of a peeler crab looking for "sign." White sign: a week or two from molt. Pink sign: less than a week. Red: two or three days. A "rank" crab is hours away.*

DRAWINGS FROM THE VIRGINIA INSTITUTE OF MARINE SCIENCE



"We were the young rebels. There was a lot of resistance, honest resistance from great scientists. They did not like the idea."

This decaying fishing boat *was once the Flagship Restaurant where biologists Chuck Epifanio (left) and Steve Sulkin began meeting back in the 1970s, hoping to launch a new theory about an old blue crab mystery.* PHOTOGRAPH BY MICHAEL W. FINCHAM.

The Offshore Odyssey of Blue Crab Science

Michael W. Fincham

When the talk around the Chesapeake turns to blue crabs — and the talk turns that way every spring — there are two questions that matter most: When will blue crabs start moving up the Bay? And how many will be coming?

John Barnette was talking about blue crabs this spring, saying he can predict when the crabs are coming each year. He's a waterman who goes crabbing on the Wicomico River with bank traps, a little-known technique found only on a few Eastern Shore rivers. Getting ready for crabs, he spent his work days wading out in the river, planting poles, stringing wire netting, and setting up tall cages designed to trap peeler crabs, blue crabs that are scuttling along the shore looking for a safe place to molt. As he worked, Barnette kept his weather eye on one species of local vegetation.

"We go by certain plants, when they bloom," says Barnette, a lean and thoughtful man who's a sharp observer of life along his river. His preferred crab predictor is the snowball bush. "When the snowball bush blooms," says Barnette, "you got soft crabs."

When Willard Van Engle would talk about blue crabs, he would say he could predict two years ahead of time when a big year for blue crabs was coming. This was shortly after the end of World War II, and Van Engle was a well-known crab biologist with the Virginia Institute of Marine Science who claimed he had discovered the perfect predictor. Water flow down the James River, he said, told you how many blue crabs would be coming up the Chesapeake.

The ups and downs of blue crab harvests may be tied to the ins and outs of blue crab larvae.

River flow was his snowball bush. High river flow in the James, he said, would lead to a low blue crab harvest two years later. And vice versa: low river flow would bring a high harvest total. This was an inverse correlation, and it seemed to make sense: blue crabs spawned down near the mouth of the Chesapeake, and a rainy, wet year could wash crab larvae right out of the Bay into the ocean where they would be lost to the system. A dry year would do the opposite: it would keep crab larvae near home and turn the lower Bay into a big nursery for new crabs.

A reliable forecast for blue crab harvests has long been a holy grail for scientists in the Chesapeake, where crab harvests have a history of bouncing up and down, seemingly at random, sometimes doubling the previous harvest, sometimes halving it. So crab biologists spent a lot of time talking about Van Engle's prediction — until it fell apart.

"Van Engle kept track of that relationship every year, and every year that he added data, it got weaker and weaker," said Gene Cronin, a noted biologist who was talking blue crabs at a symposium some 40 years later. "It was a false correlation, a coincidence. You have to watch out for those things."

When Chuck Epifanio and Steve Sulkin would talk about blue crabs, and they spent years talking about them, they decided Van Engle's blue crab predictions might be right sometimes — but usually for the wrong reasons. This was the early 1970s when they were young biologists, new Ph.D. graduates up from Duke University now working at marine labs in Delaware and Maryland. They wanted to bring some fresh thinking to the old mysteries about the up-and-down harvests of blue crabs.

The best predictor, they said, wasn't the river flow coming down the James River. According to the new guys, the real predictor was probably the currents and wind fields at work out on the ocean. But it would take a while for the old guys to believe them.

For their blue crab talks, Epifanio and Sulkin would meet at a restaurant that was once a menhaden fishing boat. Epifanio was a new hire at the Lewes lab run by the University of Delaware, and Sulkin a new hire at the Horn Point Laboratory down near Cambridge, Maryland, some 60 miles away. Once a month Epifanio would leave his office and start driving south. Sulkin would start driving north.

Mid point was Seaford, Delaware, a small town with only two good places to eat, and one of them was the Flagship Restaurant, an eatery operating out of a large wooden boat. Built for menhaden fishing, it once spent time patrolling for German subs but now sat beached along the banks of the Nanticoke River. According to one of the locals, the

Flagship was where you went for birthdays and anniversaries. That's where Epifanio and Sulkin went to talk science, lab politics, and Duke basketball. The new faculty members called their monthly meetings "mini-sabbaticals."

Over beers and crab cakes, meeting once a month, year after year, Epifanio and Sulkin used these mini-sabbaticals to begin pulling apart the classical theory about the blue crab life cycle. The heart of the older theory was what Sulkin called "the in-Bay hypothesis." Blue crab larvae were hatched in the summer waters of the southern Bay, all the way down near the entrance capes, and most of them stayed in the area except when heavy river flow washed some of them out of the estuary. "The in-Bay hypothesis," Sulkin said at the time, "is the intuitive, reasonable, and widely accepted hypothesis."

Shortly after Epifanio and Sulkin began meeting, Hurricane Agnes arrived over the Chesapeake watershed and helped jump start their rethinking of the old paradigm. Curving inland from the Atlantic, Agnes came ashore as a tropical storm and immediately began unleashing heavy rains that sent historic floods surging down all the Bay's great rivers. It was late June 1972 and female crabs were smack in the middle of their spawning season, releasing eggs and larvae into the waters of the southern Bay.

Those huge floods of river water would surely wash most of those crab eggs and larvae, billions and billions of them, out into the coastal ocean, and all those new, wannabe crabs would be lost to the Chesapeake forever. Two years later, blue crab harvests would probably slump.

That was the expectation for scientists working within the old paradigm. And they were half right: most of those newly hatched crab larvae were indeed swept out to sea by the flood waters of Agnes. But they were also half wrong: two years later, blue crab harvests went up slightly. How did those crab larvae get back into the Bay?

Other leaks in the theory came from other scientists. An oceanographer at the Lewes lab came to Epifanio with some tiny, strange-looking species that were turning up in his nets. Epifanio grew out the samples in culture, and when he did he discovered they were blue crab larvae well into their second life stage. What were these larvae doing so far out on the ocean? Epifanio started driving south. Here was food to chew over at a lot of lunch-time mini-sabbaticals. "I went to Steve," says Epifanio, "and said, well what do you think is going on?"

The young biologists began building an alternate paradigm, an "offshore hypothesis" that made some startling claims. Perhaps a lot of blue crab larvae were swept out to sea every year — not just during an Agnes year or a big river flow year. Good evidence came both from lab studies and from early research cruises that went looking for larvae. In lab studies, first-stage larvae seemed programmed to move upwards; in field studies most of them were netted in seaward-flowing surface waters, especially at night. Epifanio and Sulkin came to think that nearly all blue crab larvae leave the Bay every year. The big nursery for feeding new blue crabs into the Chesapeake would not be found in the southern Bay but in waters off the coast, waters that also held crab larvae from Delaware Bay and North Carolina estuaries.

The upstarts from Duke felt some strong pushback. "To the established Chesapeake Bay blue crab aristocracy," says Epifanio, "it was anathema to think there might be larvae from a dirty place like Delaware Bay contaminating the Chesapeake stock."

Epifanio can now look back on those years with some detachment. The biologist eventually published over 120 articles, many of them on the mysteries of blue crab population shifts, and he now holds an endowed chair at the University of Delaware. Sulkin soon became a lab director, first at the Horn Point Laboratory, and later at the Shannon Point Marine Center in Washington State. "When Steve and I started this, we were the young rebels," says Epifanio. "There was a lot of resistance to the idea. It was honest resistance from great scientists, guys like Van Engle and Gene Cronin," he says. "But they did not like the idea."

Elizabeth North did like the idea behind the offshore hypothesis, but she knew it left some big questions unanswered. The biggest goes like this: how do all those blue crab larvae floating out there in coastal waters ever find their way back into Delaware and Chesapeake Bays? How does their offshore odyssey end?

North was a young fisheries oceanographer who was getting her first chance to serve as chief scientist leading a large-scale research cruise. This was September 2005, and the boat was the120-foot *RV Cape Henlopen*, scheduled for a night departure out of Lewes, Delaware, Epifanio's home base. When he dropped by the dock to say bon voyage, North had a request. "I asked Epi to bless the boat," she said, joking with her crew as they unpacked sampling gear. "He said, 'I bless the boat.'"

And well he should. Nearly 30 years after his mini-sabbaticals in the Flagship

Atlantic blue crab
Callinectes sapidus

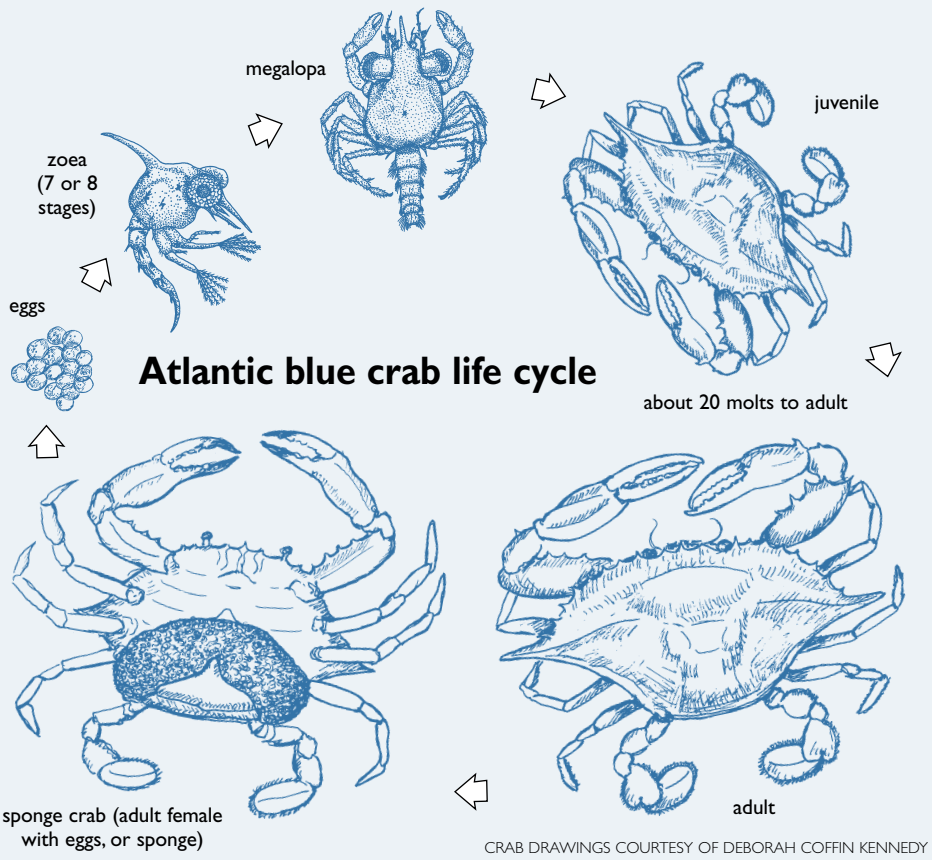
Iain McGaw and Carl Reiber

Distribution: Atlantic Ocean and Gulf of Mexico, from Nova Scotia to northern Argentina; it is most abundant from Texas to Massachusetts. Half of the U.S. harvest comes from the Chesapeake Bay.

Key distinguishing markings: Brilliant blue color on their front claws (tips are red on females) with an olive or bluish-green carapace. They have a pair of paddle-shaped legs that are excellent for swimming.

Size: Adults can grow up to 9 inches, or 23 centimeters (carapace width).

SOURCE: MARYLAND DEPARTMENT OF NATURAL RESOURCES.



CRAB DRAWINGS COURTESY OF DEBORAH COFFIN KENNEDY

When female blue crabs release their eggs, they hatch into zoeae. These strange-looking beings (gnatlike? shrimplike?) can float and swim, mainly to move up and down in the water column. They need high salinity water to grow and molt.

After molting up to eight times, zoeae go through metamorphosis to emerge as megalopae. Now they look more like wannabe lobsters than soon-to-be crabs. They can crawl as well as swim. And they have claws.

Not many megalopae make it to the next stages, but a few become tiny blue crabs, called the instar stage, and then juveniles. Clearly recognizable as small crabs, juveniles will molt up to 20 more times in their journeys up the Chesapeake and into adulthood.

Just after her final molt, a mature female will have her first and last chance to mate. Once she mates, she will then hang onto the sperm while she migrates south to higher salinity waters near the mouth of the Bay. A female can produce several broods of eggs which she'll carry on her belly as a dense orange mass. When it was legal to catch and sell them, crabbers called these pregnant females "sponge crabs."

When they're ready, females can produce millions of eggs (from 8 to 14 million). Only two have to reach adulthood to give the Bay a steady-state population.

— *M.W.F.*

Restaurant, Epifanio has seen his thinking become the flagship paradigm setting the research agenda for a new generation of scientists, many of whom are oceanographers rather than biologists. In fleshing out his offshore hypothesis in the 1980s, Epifanio teamed up with the late Richard Garvine, one of the rare oceanographers willing to work with biologists. "Physical people basically didn't like to talk to biologists," says Epifanio. Working with Garvine changed everything, says Epifanio. "We became much more sophisticated in our understanding of coastal circulation."

To get her cruise started that night, North and her crew were working under lights on the back deck, setting up nets and electronics and communications. With her hair tied back in a bun, she hustled between the work deck an the stern and the ship's lab. In a sweatshirt and loose pants, she could pass for one of her graduate students.

The cruise plan called for 10 days of data gathering. Five days and five nights around the mouth of Delaware Bay. Then five more days and nights down at the mouth of Chesapeake Bay. The sampling would start that night if they could get the gear ready in time.

Before casting off, Captain Bill Byam called the science group together for his speech: small craft warnings, winds from the northeast, a four-to-seven-foot swell, Dramamine available in the galley, breakfast at 5:30 a.m. No mention of a hurricane called Ophelia already meandering off the coast of Florida.

This North-led cruise was the latest in a series of cruises launched over several decades to test various theories, hunches, and guesses about the wanderings of blue crab larvae in coastal waters. Epifanio's offshore scenario has, in effect, sent blue crab scientists off to sea on their own three-decade odyssey, a search that's still trying to explain to everyone's satisfaction how blue crab larvae come home.

If you want to solve the puzzle of blue crab migrations, sometimes it helps to think like a crab (or like you think a crab thinks). "If I were in charge of crab larvae," says Bill Boicourt, "I would ask myself how would I maximize my chances of getting back into the estuary?" Like North and Roman, Boicourt works at the Horn Point Laboratory of the University of Maryland Center for Environmental Science (UMCES). One of the lead scientists for the *Henlopen* cruise, he's one of those physical oceanographers who's willing to talk with a biologist or think like a blue crab.

Smart crabs seem to understand the basic physics of how water masses behave in an estuary, something smart oceanographers figured out only 60 years ago. The Chesapeake Bay, it turns out, is driven by a two-layer flow in which two streams of water are moving in opposite directions. Along the surface flows a stream of freshwater that drains out of all the rivers in the watershed. Along the bottom runs a second stream of denser, saltier water that surges in from the ocean. The river water slides south toward Norfolk, headed out

to the ocean. The bottom-water inflow surges north toward Baltimore, headed up the estuary. Twice a day their progress is interrupted by two flood tides and two ebb tides.

Blue crabs apparently figured out all that physics eons ago, or evolution figured it out for them, and they learned how to go with whatever flow is likely to help them. Most crab larvae, for example, take the opportunity to ride the surface waters out to sea. Why head for the ocean? Because there aren't as many predators out there. And because larvae need saltier water to help them make it through their early molt stages, especially the big switch from the zoeae stage to the megalopae stage. That's the creature that will try to get back into the estuary.

If you're a crab megalopa trying to come home from offshore, you face some trickier choices. If you swim down, maybe you ride back into the estuary with the bottom-water inflow; if you swim up, maybe you ride in with a big wind event like a nor'easter, or maybe with a flood tide, or maybe a nighttime flood tide, or a full-moon flood tide, or a quarter-moon flood tide.

That's a lot of maybes for smart crabs to try. And so far smart scientists have found evidence that supports each idea — and other evidence that undercuts it. The physics of offshore waters, it turns out, is more complicated than estuarine circulation, also more variable and less understood, despite the best efforts of oceanographers like Boicourt who spent years mapping the circulation of mid-Atlantic coastal waters.

All that offshore science helps him think like an offshore crab larvae. "I would say, 'Let's play the market and hedge our bets,' " says Boicourt, in his crab mode. " 'Let's try a number of different mechanisms.' " Flood tides, spring tides, hurricanes, nor'easters, bottom-water inflow. Whatever works.

That, of course, leaves a lot of options for scientists to test and debate.

The net rose out of the night sea, looking like a black, snakelike monster and trailing four long scraggly tails. It's called the MOCNESS (multiple opening and closing net, with an environmental sensing system), meaning it can open and close its nets at multiple depths. Its tails are actually plankton nets, and the whole contraption does resemble its namesake, the Loch Ness Monster. Elizabeth North and Dave Kimmel, a plankton ecologist at Horn Point Laboratory, wrestled the contraption onto the deck of the *Cape Henlopen* and started unhooking the PVC canisters from the end of each net.

Michael W. Fincham

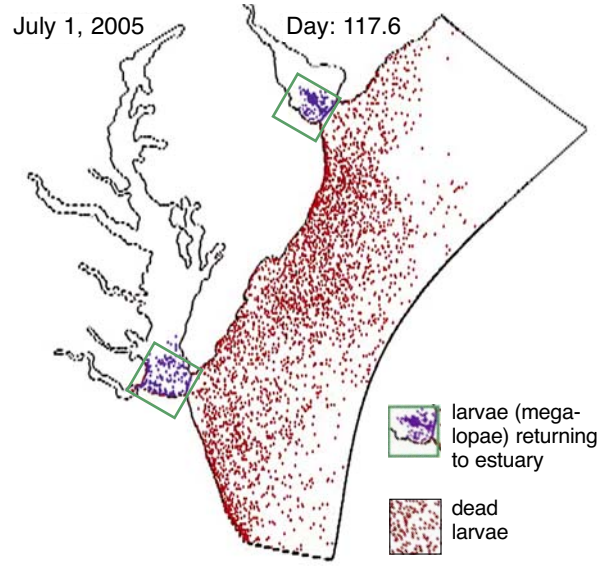
The canisters were designed to catch crab larvae, but they were crammed with jellyfish. North and Kimmel started pouring the gloppy contents into a bucket. They rinsed out the canister and poured the bucket through a screen and into small glass fruit jars. The payoff should be samples holding crab larvae from four different levels of the water column.

To track blue crab larvae, scientists first try cutting the offshore world into little data pieces: the number of larvae at each depth, temperature, salinity, oxygen, data on flood tides and ebb tides, winds, and currents. Then over months and years they try putting the world together again back in the lab and on their computers. Graduate students will find and count any larvae lodged in the gummy mess. North and her collaborators will correlate those larvae numbers with all those other numbers. The result, everyone hopes, may help answer some questions: Where were the crab larvae? Were they moving up or down? Were they moving towards the estuary? Or away from it?

Crab larvae, oceanographers once predicted, would usually be moving away from an estuary, a prediction that would blow a big hole in Epifanio's offshore scenario. When larvae leave Chesapeake or Delaware Bay, they are riding seaward-flowing water, and that water generally takes a right turn as it exits each estuary and flows south. It joins an expansive, south-flowing current that can be 60 miles wide. If nothing alters this broad flow, the oceanographers warned, then most Chesapeake larvae should end up in North Carolina.

One of the breakthroughs that would keep the new blue crab theory afloat began with data from a single instrument, a meter tracking current flow.

When Bill Boicourt first started talking about the current meter at mooring 408A, some scientists dismissed his data as a curiosity. The meter at mooring 408A bobbed in the waves some 17 miles offshore, just south of the mouth of the Chesapeake Bay. During certain months of the year, it recorded consistent evidence of a current moving north.



Researcher Elizabeth North *(opposite page) grew up in Annapolis catching crabs along the Severn River. As a fisheries oceanographer she catches blue crab larvae in the coastal waters between Delaware Bay and Chesapeake Bay. For part of her research, North created a modeling project that used particles to estimate where larvae end up after they're spawned at the mouth of the two bays. Her model cranked in all the known data from 2005 and 2006 that could affect larval movements: freshwater flow, sea temperatures, humidity, wind fields, tidal current velocities. Her key findings: only a small percentage of megalopae make it back to their home estuaries (green boxes); in good years, weather patterns could bring in 10 times more larvae than in other years; crabs from Delaware Bay may, indeed, make it into Chesapeake Bay but not vice versa.* MAP COURTESY OF ELIZABETH NORTH.

It was a single data point, but its implications were huge, at least for blue crab theory. The north-moving current that Boicourt discovered was a band of water that cut right through that broad swath of south-moving water. It was a discovery based on data from that one mooring and on mathematical equations showing how wind from the southwest could start a narrow current of water moving north. That current could keep crab larvae hanging around their home estuaries.

The clinching evidence for Boicourt's discovery, however, came from the logs of old lightships that were once anchored all along the Atlantic coast. Vessels like the *Chesapeake Lightship* or the *Diamond Shoals Lightship* marked entrances to rivers and estuaries or warned of dangers like reefs and shoals. On these ships that were going nowhere, crewmen would try to estimate the speed and direction of currents that seemed to be going somewhere. They would toss out drift poles, each with one end weighted, and then take bearings as the poles drifted with the current.

Instead of one current meter, Boicourt now had 40 years of drift logs dating from 1930 back into the 19th century. In the logs: clear evidence that a current reversal would often rise in July and August and flow north from Cape Hatteras toward the Chesapeake. "It was," he says, "the most exciting data I had ever seen on this issue."

Blue crab larvae, in theory at least, now had a way to stay near home, and blue crab scientists had another good reason to hang onto the offshore hypothesis.

Currents play a big role in keeping crab megalopae near their estuary of origin, but the larvae themselves may also play a big role in their own homecoming. Another breakthrough came when biologist Richard Forward discovered that offshore larvae seem to smell the water from their home estuary. And when they do, they take action.

Working at the Duke University Marine Lab, Forward originally set out to study mud crabs only to stumble into blue crab research when he found they were more plentiful. "I was so ignorant I didn't even know what a blue crab larva looked like," says Forward. "We got these things in our samples, and we said, 'Goodness! What species is this?' "

Fresh thinking often comes from outsider scientists, and Forward quickly came up with a simple, brilliant experiment. He created lab tanks with ocean water and lab tanks with estuarine water and then watched what larvae did. In ocean water the larvae swam towards the surface. In estuarine water, they swam down towards the bottom. "We can say their behavior changes," says Forward, "when they get into water near the estuary."

Those changes could help larvae enter estuaries. Megalopae could ride the bottom-water inflow that surges in from the ocean, or perhaps float in with nighttime flood tides. The chemical cues that kick off this behavior: yellow-looking humic acids that leak off the land whenever rainwater washes into rivers. Carried offshore by the outgoing plume, these cues off the land seem to be calling any would-be crabs to come home.

Working the day shift on the *RV Cape Henlopen*, Mike Roman was looking down at the net cable cutting through green, sun-spackled water. He's a wiry, weathered, low-key man who's stood on a lot of boat decks over the last 30 years. On several of those cruises, he found evidence that those chemical come-hithers could be carried far out to sea.

Working with Boicourt, he once measured outgoing freshwater plumes 24 miles off the mouth of the Chesapeake. Chemical cues carried that far out could draw in a lot of offshore megalopae, those tiny pre-crab life forms that look vaguely like a lobster and vaguely like a visiting extraterrestrial. It's like salmon smelling their home river, says Roman. "Larvae change their behavior and it helps ET get home."

When the big black net lands back on deck, Roman launched yet again into the endless routines of biological oceanography: haul in the net, unhook the canisters, pour the stuff through a sieve, rinse out the canister, close up the fruit jar. "See all the green stuff?" he asked a graduate student. "It's coastal stuff."

The *Henlopen* is right over the estuarine plume. The water in those fruit jars should hold plenty of chemical cues, perhaps plenty of larvae, perhaps a couple of answers. A north-flowing current gets these pre-crabs close, a chemical cue gets them ready. But what gets them across the threshold and back into the Bay?

A night time flood tide is one option, says Forward. Megalopae can rise up, ride one in, then wait on the bottom for

Michael W. Fincham

Hoping to find some blue crab larvae, *scientists Mike Roman (left) and Tom Wazniak open the collectors at the end of long plankton nets. It's a long way from home for Roman who grew up partly in Illinois and even went back there for college. "Farmers want to be fishermen," he says, "and fishermen want to be farmers." He became a biological oceanographer who specializes in the ecology of zooplankton, the seeds of fishery productivity.*

the next one. He calls this ploy "leapfrogging up the estuary." Another option is a hurricane. "Hurricanes are dynamite," says Forward. "You want to get larvae coming into the estuary? Bring a hurricane up the coast. The winds blow and all of a sudden you get lots of larvae."

It's a hurricane that ends North's cruise. Hurricane Ophelia wanders up the Atlantic, downgraded and upgraded between tropical storm and hurricane. The last upgrade is the cruise killer. Winds and high waves off the mouth of the Chesapeake. The net monster wouldn't work. There's not enough Dramamine on board. The *Henlopen* heads home.

It will be another year before North leads another crab cruise. And it will be another four years before all the larvae in all those fruit jars are identified and counted and crunched and correlated with flood tides and ebb tides, day and night cycles, winds and currents.

So how do crab larvae come home? According to Epifanio, it's an unlikely odyssey full of twists and U-turns. Crab larvae leave the Chesapeake, borne south along the coast — only to make a U-turn in July and August when they encounter a north-flowing current. The next twist comes from wind events like nor'easters in September and October. They drive water and larvae south — only to have the rotation of the earth shift everything westward, creating a right turn of sorts. The shift is called the Eckman effect, and it piles up water and larvae near the mouth of estuaries. Megalopae can now smell the estuary, and they react, moving down in the water column, getting ready to hitch a ride home.

"It took us a couple decades to nail all that down," says Epifanio. But it may not be completely nailed down yet. In her final cruise report, North finds little evidence that megalopae are riding in on flood tides. Her graduate student does cite data that megalopae do change their behavior near estuaries, swimming down during the day and up at night.

According to North, crab larvae can slip into an estuary during favorable wind events or episodes of low freshwater outflow and advantageous tides. Or they can be carried in by the bottom-water inflow.

And what drives the winds that drive the larvae? Could it be large-scale climate patterns like the Bermuda-Azores High? Or the North Atlantic Oscillation that shifts air masses between Iceland and the Azores? Or the Atlantic Multidecadal Oscillation in water temperatures?

"We don't understand that link between the large-scale weather patterns and what is happening at the mouth of estuaries to transport the blue crabs in," says North. "It is the forefront of where this kind of research is going."

The offshore odyssey of blue crab science seems headed even farther afield out over the Atlantic. And North is clearly excited by the prospect.

The old lightships with their drift logs are gone from the coast, replaced by flashing buoys or towers tall enough to be oil rigs. The Flagship Restaurant is closed. The old fishing boat that housed it stands abandoned, windows broken, its dining room vandalized. If you have $750,000, you can buy it. The exterior is chipped and peeling, but you can still see the blue crab that someone once painted on the hull.

The offshore hypothesis that was born in that boat has sprung some leaks, but it still remains afloat after three decades. Blue crabs still come and go every year in wildly varying numbers. But a big picture overview of their wanderings is emerging.

The frame of the puzzle is clearly outlined, and scientists are filling in more of the pieces in the middle, albeit with frequent disagreement. But a science-based snowball bush, a simple way to predict how many crabs are coming in next year, may still be a Holy Grail beyond their grasp.

That doesn't bother Boicourt, the oceanographer who supported the new paradigm from the start. "I'm not grumpy about the inconsistencies. I'm excited about the uncertainties, the unknowns," says Boicourt. He believes new technology will tell us where the crab larvae are. And new scientists will flesh out the theory. "We'll have young scientists fired up to figure it out."

— fincham@mdsg.umd.edu

The Value of Crabbing

State attempt to buy back crabbing licenses runs up against traditions, questions

Jeffrey Brainard

Rachel Dean and her husband Simon have a lively fishing business in Solomons Island, Maryland, switching between striped bass and crabs when they aren't taking tourists on the water and running a seafood company. Dean acquired two commercial licenses to catch blue crabs, one to run her business, and another with the next generation in mind.

She held onto this second license as a kind of family heirloom. Some months, the family used it to catch a few crabs. But Dean wanted to transfer it to her daughters one day so that they could join in the Chesapeake Bay tradition that she loves. This document would allow her oldest daughter, 16, to catch female "peeler" (ready-to-molt) crabs, which a Maryland recreational crabbing license would not. She kept paying the $50 annual fee to renew her license — and her dream.

"Even if my daughters don't go into the profession," Dean says, "that's the only way that they'll be able to get in the skiffs and go crab the way my family crabs."

So Dean was primed to say no when the state of Maryland asked in 2009 to buy hundreds of commercial crabbing licenses statewide. State managers had become worried that too many people held those licenses but, unlike Dean, weren't using them at all. Between 2004 and 2008, about a third of the 5,700 licensees didn't report catching a single crab. Fishery managers and scientists forecast that if those inactive crabbers went back out on the water, it would drive down profits for all crabbers and slow the nascent recovery of the Chesapeake Bay's crab population.

So the state made an offer it thought many inactive crabbers couldn't refuse: several thousand dollars to sell their licenses back to the state.

The results have been mixed. Hundreds of inactive licensees ended up taking the deal, but even more didn't. The project raises some compelling questions about how people think about Maryland's largest commercial fishery and the jobs that go with it. What are the best ways to make sure the fishery prospers? And can you attach a dollar value to a piece of paper that, for many people, symbolizes tradition and a way of life?

Rachel Dean

Down in Solomons Island, Maryland, *Rachel Dean and her husband run a fishing, crabbing, and tour business using the 40-foot boat* Roughwater. *She wants her two-year-old daughter Jamie (above with her mother in the crab shedding house) to have the option of following in her footsteps — which is why she refused a state offer to buy her crabbing licenses.*

Crabbers Who Don't Crab

For many years, the issue of inactive licenses itself lay dormant. The state capped the number of commercial licenses in the 1980s at a time when blue crabs crawled in greater numbers along the Bay floor. But then the crab population dropped off in the 1990s and into the 2000s. Under those circumstances, inactive crabbers were a good thing, at least from the state's perspective: less pressure on the crab population. But concerns over the inactive licenses grew in 2009, a good year for crabs. The population grew by about 30 percent in 2008, hitting the highest level since 1993 (see graph, p. 4).

State officials predicted that this upswing in crab stocks might entice licensees who had been sitting on the sidelines to get back out on the Bay. More crabbers would likely catch more crabs and the effect would be a slower recovery of the resource and less money for those who make a living crabbing.

"That free-for-all was not sustainable and wouldn't let us restore the fishery

back to a healthier condition," says Doug Lipton, an economist at the University of Maryland, College Park who specializes in fisheries. Plus, he says, "you want to have a situation where you can allow these fishermen to earn a decent living fishing."

To manage the risk posed by the inactive licensees, state managers even contemplated reducing the allowable harvest for all crabbers, including those who had worked the water all along.

Instead, the state in 2009 hit on the idea of buying back the licenses of those crabbers-in-waiting to keep them off the water. The hope was that the inactive licensees might be willing to take some cash for a privilege they weren't using anyway. Such exchanges had been tried before with some success in other markets, including the Pacific Northwest's famed salmon and New England's groundfish fisheries. For help in crafting the details of the Chesapeake program, state officials turned to a group of economists led by Lipton, who also directs Maryland Sea Grant's Extension program.

The economists came up with a design to give both the state and the watermen the best deal possible: a "reverse auction." Would-be sellers would submit their desired price in a sealed bid; the state then would buy as many licenses as it could, starting with the lowest bid, until the money ran out. In this case, the state budgeted $3 million in one-time federal funds it received when the blue crab fishery was declared an economic disaster zone in 2008.

The state sought at first to purchase only Limited Crab Catcher licenses. These licenses have a limit of 50 crab pots; the people actively using such licenses fish on a small, financially modest scale, and there were more inactive licensees of this type than of any other commercial crabbing permit (see table, below).

Sitting Out the Bidding

In the end, though, the reverse auction didn't seem like a great idea to either the state or the licensees. The state set a goal of buying 2,000 Limited Crab Catcher licenses; only 494 submitted bids, less than half of the inactive licensees. And those that did name their price asked for a lot: The median bid was about $4,900, a number at the upper end of prices advertised on the open market. So the state instead scrapped the reverse auction and offered a fixed price of $2,360 each — take it or leave it. This time, a total of 683 licensees said yes before the program ended in 2011. But that outcome still left unspent about half of the $3 million that the state had allocated to buy back licenses.

State managers had no better luck when they offered a second buy-back in 2010, this one targeting Tidal Fish Licenses. Of the licensees in this more-intensive category, 350 were inactive, and nearly 500 weren't breaking even at fishing, the economists estimated. A good number of potential takers, they thought. But only 99 accepted the offer.

"So then it became interesting," Lipton says. Why, he wondered, were so many people who never fished paying to renew the licenses? "It surprised us when we got such low participation, especially during a recessionary period."

To find out what people were thinking, the economists and graduate student Geret DePiper surveyed holders of both kinds of licenses. More than 2,000 people responded, and their answers revealed a lot about how people view the struggling profession of watermen and the future of the crab fishery in the Bay. Plenty of watermen vented their suspicion of government regulators, says Jorge Holzer, a Maryland Sea Grant Extension fisheries economics specialist. Many saw the buy-backs as simply a step by the state toward scaling down all commercial fishing.

"Quite a few said, 'I will never sell my license,' " Holzer says. " 'Don't send me any more offers.' " The fishermen expressed other doubts about the buy-back program. Why the emphasis on commercial crabbers, they wondered, but not recreational ones, whose effect on the Chesapeake Bay crab stock is poorly understood? Many commercial crabbers were also skeptical about the underlying rationale for the buy-back program, that inactive or "latent" fishing licenses were a threat to the blue crab population.

"Latent effort just doesn't scare me, it just doesn't," says Rachel Dean, who is secretary of the Calvert County Watermen's Association. "All [the buy-back] did was get rid of the people who were never going to use the license. …[Crabbing] is not as easy as it looks. It's not just 'Go throw the pot, just pull the trotline.' "

Maryland's Buy-Back of Commercial Crab Licenses: By the Numbers

License type	Maximum allowed crab pots	Total licenses before buy-back	Number inactive	Number purchased	Amount paid
Limited Crab Catcher (LCC)	50	3,767	1,046	248 active 435 inactive	$2,260 each
Tidal Fish License (TFL)	900*	2,064	~350	99 (about half inactive)	$7,000 to $12,000 each*

**Depending on license type.*

SOURCE: MARYLAND DEPARTMENT OF NATURAL RESOURCES.

In it for the Long Haul

Aside from those reservations, respondents indicated that their motivations mainly concerned their own wallets — but they were thinking of future, not present, gain. Only six of the Tidal Fish License holders said that the state's offered price was too low; 70 percent said they expected the license would appreciate in value over time. After all, some noted, the state's buy-back program was eliminating some of their potential competition. Or perhaps their optimism simply represented a vote of confidence in the prospects for a continuing comeback of the blue crab population in the Chesapeake.

Other survey respondents said they were holding onto their licenses because they wanted a fallback in case they became unemployed — a reasonable fear in this tough economy, Holzer says. There were respondents who wanted to hold on to the licenses as a possible nest egg to sell when they retired, another understandable concern for an occupation that typically doesn't offer pension plans.

"We learned a lot about why it's harder than it looks to buy out effort," Lipton says. For example, the state could have done more to persuade at least some of the doubters to participate in the initial reverse auction, Lipton says. Ever the economist, he notes that even if a license is attached to a dream, it is also attached to a dollar sign — its market value and the prospect of future earnings. The survey results indicated that a number of prospective bidders lacked information on how much they stood to gain and so concluded, "I'll just hold on to it because I don't know what it's worth," Lipton says.

But Dean says she had tracked those market rates. She just didn't consider the state's prices high enough. "You'd have to offer me enough for me to say, 'Hey, I'm not going to make that amount of money [by continuing to crab.]' This wasn't it."

"[Nevertheless], we made a pretty good dent in lowering the number of unused licenses," says Lynn Fegley, a fisheries official at the Maryland Department of Natural Resources who oversaw the buy-back. "[That] helps us to manage to maximize the economic value of the fishery for everyone because it's that many fewer people we have to account for when we set harvest limits."

Even today, the buy-back idea is not completely inactive. Her agency remains willing to buy back more of the Tidal Fish Licenses, and it may again offer to purchase the Limited Crab Catcher licenses, Fegley says.

Lipton adds that other steps will be needed to make sure the crab's tenuous comeback lasts: "Everything we did in Maryland was really designed to get the low-hanging fruit off the vine, so we could worry about the harder part down the road with other kinds of approaches."

To work on those next steps, state managers have met monthly with a committee of watermen for more than a year. The panel, the Blue Crab Industry Design Team, is discussing new ideas for ensuring that the Bay's blue crab fishery remains sustainable. For example, it's important to know just how much crab is harvested each season and when. So the state and watermen jointly came up with a new approach for commercial crabbers to report their harvests. It uses smart phones and tablets, tools that may improve the accuracy and timeliness of harvest reports. Volunteers will test it this summer on the Bay.

At the very least, this experiment won't wind up on the inactive list. More than 80 watermen volunteered to participate, filling all slots.

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Maryland Crab Coming to a Restaurant Near You

The future of the Maryland crab industry may depend in part on whether real Maryland crab makes it onto the menu at your local restaurant. That's the idea behind the "True Blue" campaign, a new marketing effort by the state of Maryland celebrating local restaurants that offer Chesapeake-caught crab.

The campaign aims to educate diners about a little-known reality in Maryland's hospitality industry: while crab cakes are a signature Chesapeake dish, many eateries in Maryland now make their cakes from imported, not local, seafood. "I know people who have lived in Maryland for a long time and go out all the time, and they've never eaten Maryland crab in their life," says Chad Wells, executive chef of the Baltimore-based eatery Alewife. After all, Asian crab meat costs restaurateurs dollars less per pound, and many customers never notice the switch. But Wells says that if you pay attention, the differences are clear. Chesapeake crabs come with a rich, buttery-sweetness, he notes, courtesy of the fat stores the animals build up to survive cold winters on the Bay. Asian crabs, he says, don't.

The True Blue effort is meant to educate restaurant-goers about which establishments sell locally harvested crab, says Steve Vilnit, the man behind the campaign. He's director of fisheries marketing for the Maryland Department of Natural Resources. Vilnit's plan is simple: restaurants like Alewife that buy at least three-quarters of their crab meat from local sources will be entitled to print the True Blue logo on their menus — a blue crab emblazoned with the Maryland state flag on its shell. As of late June, nearly 40 eateries, including Baltimore's Woodberry Kitchen and Washington's Dino, had submitted applications to the program. Roughly the same number of retail stores, such as some Whole Foods locations, will also participate.

Vilnit adds that there's more to the campaign than just promoting good taste. "It isn't just about the product that shows up at their back door," he says. "It's about the work that goes into it." To help chefs better understand the effort that goes into each pound of crab meat, he's given about three dozen tours of the Chesapeake Bay to Maryland epicures over the past 18 months. He encourages them to leave behind their busy kitchens and markets and spend the day on a working fishing boat, with a possible stop later at a seafood processing plant.

Many chefs seem to appreciate this introduction to seafood's supply-side, too. Wells, a True Blue participant, has traveled out to the Eastern Shore with Vilnit several times already. He keeps coming back because, like many foodies, he has an almost geeky need to know where the ingredients he cooks come from. This year, for instance, he saw for the first time crab pickers at work at the J.M. Clayton Company in Cambridge, Maryland — and, he admits, they put him to shame. "They can pick a crab in 10 seconds. …It's unbelievable to see," Wells says. "I can't even do it in 5 minutes."

— *Daniel Strain*

LOGO COURTESY OF STEVE VILNIT

Crab Processors Get High Tech

Daniel Strain

The crab pickers working today aren't just fast — they're so fast their hands blur. Dozens of them, mostly young, Hispanic women, crowd around the cafeteria-style tables lining the picking floor at Maryland's J.M. Clayton Company in Cambridge. This morning, they're working their way through overflowing mounds of cooked crabs. With curving strokes, the women slice off the crabs' legs, then backs, finally plucking out two, glistening pieces of lump meat from the now-open body cavities. For the best pickers, this gutting takes mere seconds.

Jack Brooks watches over the show, which looks feverish but is nearly silent except for the clinking of shells. "Here's where we pick crabs as we've done for 100 years — one at a time, with a knife," he announces. Brooks, who runs J.M. Clayton with his two brothers, Bill and Joe, and his son Clay, admits that his company is a mix of new and old. Its picking line still looks much like it did when his own great-grandfather, the original J.M. Clayton, opened his first seafood processing plant in 1890. But Brooks and his family have also embraced modern tools. Just recently, the company installed its first flash freezer, a device that makes it easier for the company to sell crab meat during the usually slow off-season, when freshly harvested crabs aren't available. "It enables us to keep buying and selling crabs" late into the fall, he says. "It's better for the fishermen; it's better for us, and it's better for our customers."

To get this new technique up and running, Brooks and his colleagues collaborated with Tom Rippen, a seafood technology specialist with Maryland Sea Grant Extension who is based at the University of Maryland, Eastern Shore in Princess Anne. Rippen and his fellow researchers haven't stopped at refrigeration: they're also working to develop other new technologies and best practices, including robotic pickers, to keep Maryland businesses competitive in a tough, shrinking industry.

Daniel Strain

A line of women, *most in the U.S. on guest worker visas, pick crabs at the J.M.Clayton Seafood Company in Cambridge, Maryland. These crabs — just recently steamed — represent only a portion of yesterday's harvest. The larger crabs, which bring a higher return sold live for the steamed hard crab market, have already gone to seafood markets and restaurants throughout the region.*

Rippen, a Michigan native who's worked with seafood processors for more than 30 years, is the go-to guy for the Chesapeake crab industry. This year, for instance, a Maryland company wanted help packaging and selling its famed crab soup to grocery stores. Today, that product is dished directly out of a small seafood market in Princess Anne. Rippen took packages of the soup to his lab where he slowly heated them in a large hot water bath that serves as a pasteurizer. The trick was to find the right amount of heat, just enough so that the seafood would be safe to store but not enough to tarnish the flavor. That company, called Beach to Bay Seafood, now plans to open a local plant dedicated to making crab soup, creating around 25 jobs in the process.

Small victories like this aside, Rippen notes that it's been a tough era for the Maryland crab industry. Many local businesses couldn't compete with the flood of cheap, imported crab meat that began streaming into the United States in the late-1980s. Of more than 50 crab-processing plants operating then, only about 25 survive today. The rest closed their doors.

The survivors quickly learned how to market their seafood to discriminating diners wanting to "buy local, buy fresh," Rippen adds. Marylanders, after all, take their seafood seriously (see "Maryland Crab Coming to a Restaurant Near You," p. 17.) Many local crab connoisseurs can even identify, solely by taste, the exact river where their crab was caught. Rippen's challenge is to connect such seafood aficionados to companies like J.M. Clayton. That's where flash freezing enters the picture.

Rippen explains that traditional freezing methods wreak havoc on succulent crab meat. That's because the slow rate of cooling imparted by a conventional freezer — like the ones kept in most

homes and businesses — causes the proteins in crab muscle to collapse. That, in turn, erodes their ability to hold in the meat's most tasty juices. After thawing, that fluid gushes out, taking flavor with it and turning fluffy jumbo lump crab into what Rippen calls a "bland, paper spit wad."

New Tools For the Industry

Flash freezers, on the other hand, don't suffer from the same flaws. Instead they cool so quickly — dropping down to -140 degrees Fahrenheit and even chillier with the aid of super-cold gusts of nitrogen gas — that the crab meat's proteins escape unharmed. In 2009, Rippen launched a pilot project to determine whether such freezers were right for the crab industry. For help, he turned to an engineer named Andrew Tolley.

Like Brooks, Tolley has crabs in his blood. His family had worked in the seafood processing industry since the 1920s and even owned their own plants in Toddville, Maryland. But they, like so many businesses at the time, wound up closing for good in the early 2000s following the imported crab boom. Out of the business, Tolley learned the basics of how manufacturing is done working for a local metal fabricator and eventually landed a position as a quality manager at a Maryland factory that made hospital beds.

Tolley says that losing the family business was hard, but he's still hoping to help keep alive the traditions surrounding Maryland seafood. "I did not want to get out," he says. "I am still interested in the people who live around here and who work on the water."

Tolley now works for a company that packages soup and other foodstuffs. He also takes on freelance projects. Teaming up with Rippen, he consulted with a freezer manufacturer to find the best design for local seafood processors. Flash freezing technology isn't new. But it hadn't yet been employed in the crab industry on a wide scale. So the team conducted some simple tests to see how local processors could best put these systems to use. How long should it take to cool a plastic carton full of crab meat, for instance, and how should it be thawed? Based on the group's recommendations, three of the Chesapeake's dwindling number of crab processors wound up installing their own flash freezers.

Back at J.M. Clayton, Jack Brooks opens his company's flash freezer. Wearing shorts and a white company T-shirt, he can easily fit inside this stainless steel contraption. Come the fall, Brooks's employees will begin freezing two to four batches of picked crab, each composing hundreds of pounds of meat, every day. That meat will be a nice sales cushion for the long winter months when crabs hibernate and the local harvest season is closed. And, once thawed, the flash frozen crab tastes virtually fresh, too, he adds.

Brooks notes that it's advancements like these that have helped to keep his business going even as other companies went under. "We lost a lot of our friends," he says. "[But] that's one thing the imports did do for us. …They made us improve our quality, and that's a good thing."

New freezers may be just the beginning, too. Andrew Tolley says he'd like to turn crab picking — the intensive slicing and plucking going on at J.M. Clayton — into an automated process. Most processors in Maryland, he explains, depend on foreign labor here on special visas to pick their crabs. And those visas can be very hard to come by, leaving some companies without an adequate workforce for entire seasons.

Tolley says it's possible to design robots that could size up individual crabs, then saw off their hard shells just like a human picker would. Questions remain, however, about whether local processors, which tend to be small, family operations, could afford such technology. Bill Sieling, executive director of the Annapolis-based Chesapeake Bay Seafood Industries Association, adds that "many of the companies take great pride that their product is hand-picked."

But, Sieling says, if those companies get the workers they need, they'll probably keep selling crab meat, much like they've done since J.M. Clayton opened his first plant more than a hundred years ago. "We're down to the hardcore…the real survivors," he says. "They're going to keep on doing what they can do for as long as they can."

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Asian Blue Crab: Are U.S. Imports Sustainable?

wikimedia Commons

Blue swimming crab
Portunus pelagicus

Distribution: Throughout the Indian and western Pacific oceans: Japan, the Philippines, Southeast and East Asia, Indonesia, eastern Australia, Fiji, and westward to the Red Sea and East Africa.

Key distinguishing markings: Males have brilliant blue-colored markings; females are olive green. Like the Atlantic blue crab, they have a set of paddle-shaped swimming legs.

Size: Adults up to 20 centimeters, or 7.9 inches (carapace).

SOURCE: UNITED NATIONS FOOD & AGRICULTURE ORG.

The Maryland crab industry's main competition is imported crabs from Asia, but fisheries there have shown signs of decline. Crabs harvested thousands of miles from here, in places like Indonesia and the Philippines, have come to supply the majority of all crab meat offered in restaurants and supermarkets across America, even in the Chesapeake Bay region. Large imports of the blue swimming crab from Asia have become big business during the past 20 years. But just as fishing practices and worsening water quality have threatened the Atlantic blue crab in the Chesapeake, the rapid growth of harvests in Asia is blamed for emerging signs of possible overfishing there. The average size of crabs has dropped, for example. Now seafood companies like Maryland-based Phillips Foods Inc. are studying and promoting the sustainability of those fisheries. Read more online by scanning the code below or going to: www.chesapeakequarterly.net/v11n2/asiancrab

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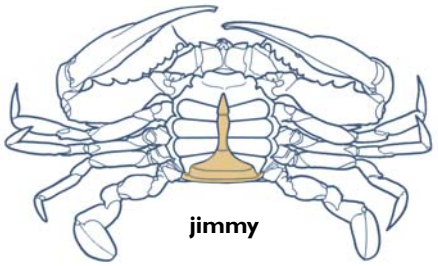
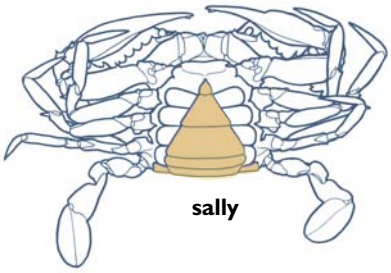
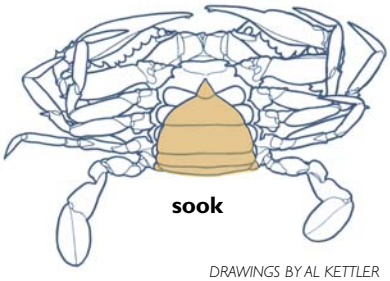
Glossary of Blue Crab Biology

apron The crab abdomen, which is folded under the body.
Atlantic blue crab Known by its scientific name *Callinectes sapidus*; in Greek "*Callinectes*" means "beautiful swimmer," and "*sapidus*" means tasty or savory.
backfin The swimming or paddle fin. The rearmost fin of the crab, which is a flat, oval-shaped swimming fin. Also a type of crab meat.
buckram crab A crab with a leathery, semi-hard shell, approximately 12 to 24 hours after molting; the stage past the paper shell stage.
buster Crab in an advanced stage of molting, wherein the old exoskeleton (hard shell) has cracked under the lateral spines.
carapace Top part of the shell of the crab.
Crustacea Class of invertebrates to which the Atlantic blue crab belongs; the crab is a crustacean.
dead man's fingers The gills, elongated, spongy-looking organs. The term probably refers to the fact that the gray "shriveled" gills vaguely resemble the fingers of a dead person. They are not poisonous but do have an unpleasant taste and texture. Remove and discard when cleaning crabs.
doubler Mating crabs; the male carries the soft-shell female crab, which has just completed its terminal molt, beneath it.
hard crab Crab with a fully hardened shell, from about four days after molting.
jimmy crab A male blue crab, distinguishable by its T-shaped apron. Regionally, the apron is said to resemble the Washington Monument.
megalopa (megalopae, pl.) Final larval stage between the zoea and juvenile stage.
molt The process by which a blue crab grows larger by periodically shedding its smaller shell. Blue crabs are invertebrates, meaning they lack a spinal column. Instead, crabs have rigid exoskeletons (hard shells). The shell grows in discrete stages through molting, while growth of internal tissue is more continuous. Unlike male crabs that continue to molt and grow throughout their entire lives, females stop growing when they reach sexual maturity, usually after about 20 molts. During this terminal molt, mating takes place.
mustard Yellow substance found inside a cooked crab. Contrary to popular belief, the "mustard" is not fat, rather it's the crab's hepatopancreas, the organ responsible for filtering impurities from the crab's blood. Although many find its flavor distinct and delicious, it is recommended that you do not eat this since many chemical contaminants concentrate in the organ.
paper shell A recently shed crab, approximately 9 to 12 hours after molting. It has a slightly stiff shell, but is still considered a soft-shell.
peeler crab Hard crab with a fully formed soft-shell beneath; it is ready to begin molting. Crab shedders can tell how soon a peeler will molt by looking at signs on the crab's shell that indicate two weeks (white sign), one week (pink sign), two days (red sign), or hours (rank peeler) prior to molt.
sally crab or she-crab Immature female, distinguished by a triangular-shaped apron.
shed Either the empty shell or the process of casting off the shell.
soft crab, soft-shell crab A crab immediately after shedding its old shell; its new shell is soft and pliable, and the crab is marketable as a soft-shell.
sook A mature female, distinguished by its bell-shaped apron. Regionally, the apron is said to resemble the dome of the nation's Capitol building.
sponge crab Female crab carrying an egg mass.
terminal molt The final molt, usually associated with the female. At the time mating takes place, she is in the soft-shell state and will not molt again after producing an egg mass. Males continue to molt throughout their lives.
zoea (zoeae, pl.) The larva that hatches from the female crab's egg; multiple zoeae stages are followed by the megalopa stage.







DRAWINGS BY AL KETTLER

The information in this glossary was drawn from the sources below. For more about the blue crab, visit their web sites:

- *Maryland Department of Natural Resources Fish Facts: Blue Crab – www.dnr.state.md.us/fisheries/fishfacts/bluecrab.asp*
- *The Blue Crab Archives – www.bluecrab.info*
- *Chesapeake Bay Program* – www.chesapeakebay.net/fieldguide/critter/blue_crab