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Special Issue Featuring:

A Case Study on Black Gill in Georgia Shrimp

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The Mystery of Black Gill: Shrimpers in the South Atlantic Face Off with a Cryptic Parasite

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ABSTRACT

In the Southeast United States, an unidentified parasite is infecting shrimp and presenting new challenges for an already struggling industry. Emerging research in Georgia is investigating the resulting condition, known as Black Gill, to better understand this newest threat to the state's most valuable commercial fishery. Researchers, shrimpers, extension agents, and fishery managers are working collaboratively to gather baseline data on where, when, and how frequently Black Gill is occurring, as well as partnering to determine its epidemiology, dispersal, and possible intervention strategies.

Savannah, Ga. – In 2013, after years of intense competition from lower priced imports and financial pressures stemming from the rising cost of fuel and insurance, Georgia shrimpers were poised for a comeback as they looked forward to a profitable year. Shrimp prices had tripled, as a consequence of a bacterial disease infecting the supply of farmed shrimp from Asia (Loc et al. 2013).

Georgia shrimpers took to the water with high expectations, but soon realized that something was wrong. Far fewer shrimp were coming up in their nets, and a much higher than normal proportion that were caught exhibited a strange darkening of their gills, caused by a parasite and commonly known as Black Gill. At its peak in September 2013, shrimpers reported a prevalence of Black Gill in nearly all shrimp, though state monitoring observed an occurrence rate of 38.68 percent (DNR 2013). The autumn white shrimp fishery reported an 80 percent drop in volume compared to the five-year average (Deal 2014).

Shrimpers contacted the Georgia Department of Natural Resources (DNR), University of Georgia (UGA) Marine Extension experts, and coastal scientists for help in understanding the decline. Working together, researchers from Georgia and South Carolina have partnered with shrimpers, extension agents, and fishery managers, taking their investigation onto shrimp boats and into scientific laboratories.

Figure 1. A Georgia white shrimp displays symptoms of the Black Gill condition around its gills. Courtesy of Rachael Randall and Chelsea Parrish, 2015

A LANDMARK YEAR

Commercial food shrimp landings in 2013 were the lowest in recent history. Over the course of the year, shrimpers harvested 1.3 million pounds, down approximately 50 percent compared to the previous decadal average of 2.5 million pounds (DNR 2015). In Georgia, commercial food shrimp consist of two species, brown shrimp (*Farfantepenaeus aztecus*) and white shrimp (*Litopenaeus setiferus*) (Geer et al. 2014).

While increased rates of Black Gill likely contributed to the disastrous 2013 season, significantly higher rainfall and river discharge in the spring of 2013 also likely contributed to the fishery failure (Deal 2014). We speculate that abnormally high amounts of river discharge disrupted the movement of post-larval shrimp as they returned to their estuary nursery grounds, blocking an important development stage in the shrimp life cycle (see Figure 2 on page 3).

In February 2014, the state of Georgia requested a federal determination, from the Department of Commerce through the NOAA National Marine Fisheries Service, of a commercial fishery failure, citing a fishery resource disaster (Deal 2014).

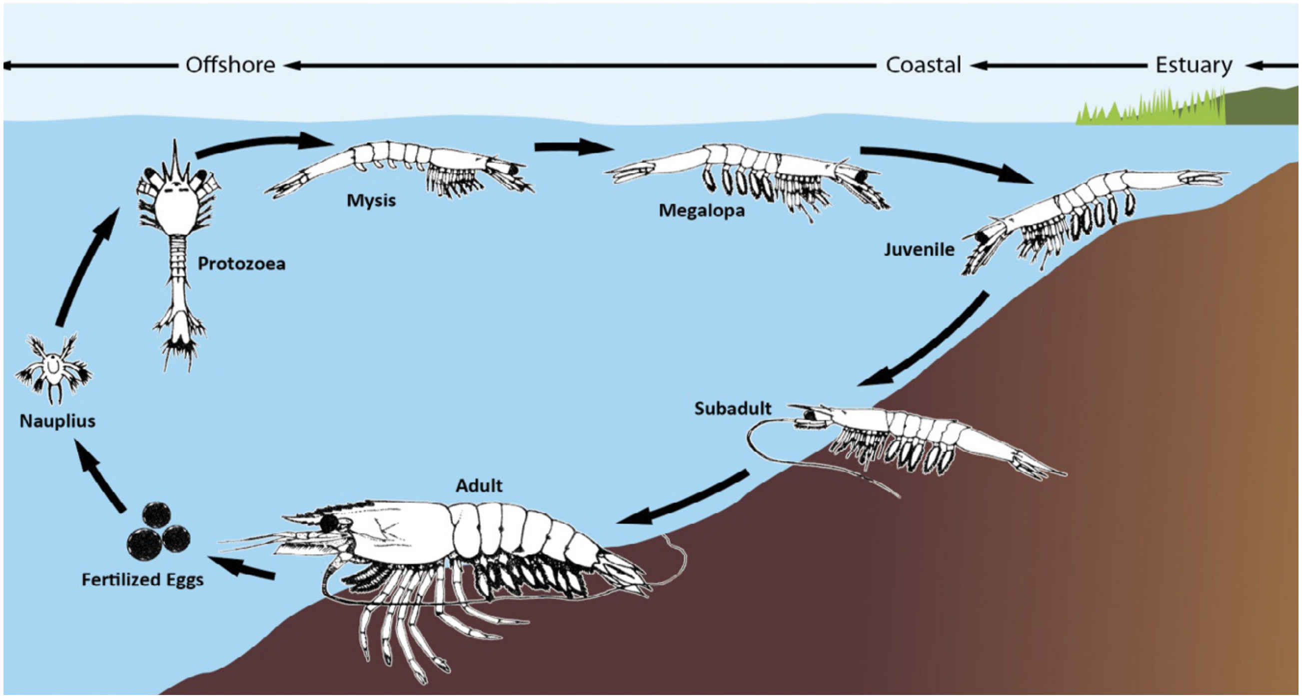

Figure 2. The life history of shrimp involves a migration of adults offshore where fertilized eggs are released and develop. Larval shrimp return to the productive estuary where they grow and mature. Black Gill or other environmental conditions could disrupt the complicated developmental life cycle. Figure adapted and courtesy of Marc Frischer and Anna Boyette after Baliey-Brock and Moss, 1992

The determination will afford shrimpers and small businesses affected by the failure eligibility for economic assistance and federal resources through congressional appropriations and small business loans. The successful acquisition of any funds is dependent on congressional support through Georgia representatives.

THE DECLINE IN SHRIMP LANDINGS

While the 2013 shrimping season brought severe reductions in revenue and landings, catching many shrimpers and their customers off guard, there was more to the story. This decline was part of a long-term trend involving factors other than a reduction in the quantity of shrimp off coastal Georgia.

In 1979, Georgia's shrimping industry was thriving, valued at more than $25 million (DNR 2012). By 2013, its value had dropped to roughly $5.8 million, primarily due to having less shrimpers out on the water, causing a reduction in overall efforts to catch shrimp (DNR 2015). For example, there were 1,471 commercial trawling licenses issued in Georgia in 1979. As of last year, this number had plummeted to only 253 (DNR 2014).

According to Geer and Roberson in their recent review of the history of the Georgia shrimp fishery and management program, a major decline in trawling licenses occurred in the early 1980s, when the DNR Commissioner began limiting shrimp trawling in the sounds and estuaries (Geer et al. 2014). This decision was made to protect the sounds as nursery areas for all species, but affected the smaller trawl vessels (the "mosquito fleet" of boats less than 30 feet in length) disproportionately. However, other economic factors have contributed to the reduction, including loss of infrastructure, aging vessels, rising fuel, and increased labor costs. The average age of Georgia's shrimping fleet is over 50 years old, demanding a higher investment in maintenance as the fleet ages.

Another reason for the decline in local shrimping since 1979 includes foreign imports driving down the cost of shrimp. Rising operating costs, coupled with an increase in cheaper, imported shrimp, have forced many shrimpers to leave the industry.

Ironically, throughout this period, shrimp in Georgia waters were bountiful. Using improved trawling equipment and techniques, shrimpers were actually catching more shrimp per voyage. Yet with the market driving the cost of shrimp down, these larger catches did not translate into greater profit. Many shrimpers went out of business.

A RESEARCH PUZZLE

From its economic and cultural impacts, to the simple scenic value of shrimp boats dotting the horizon, shrimping is part of Georgia's fabric. When shrimpers approached resource managers, extension agents, and coastal scientists with Black

Figure 3. Author Pat Geer separates shrimp from bycatch during a trawl to monitor for Black Gill in Georgia shrimp. Courtesy of Mike Sullivan, 2014

Gill, yet another challenge for the struggling shrimpers, they were met with multiagency cooperation and support.

Initial investigations have discovered startling new information about the causes and effects of Black Gill, while many more questions related to its epidemiology, including long-term impact on the fishery remain.

What is causing Black Gill in Georgia shrimp?

Research has revealed that Black Gill in Georgia shrimp is caused by a ciliate, a one-celled protozoan animal (Corliss 1979). Ciliates are common wherever there is water (such as oceans, lakes, and rivers) and are important members of coastal ecosystems. However, only a small fraction of ciliate diversity has been described. Recent estimates suggest that ciliate diversity is at least an order of magnitude higher than has been currently described (Foissner 2006). Sequencing the 18S rRNA gene, the ciliate that is causing Black Gill in shrimp has been tentatively identified as a species closely related to another ciliate (*Hyalophysa chattoni*) commonly found in shrimp and other crustaceans. Other studies based on electron microscopy studies have not confirmed this identification (Frischer and Walters et al. 2015).

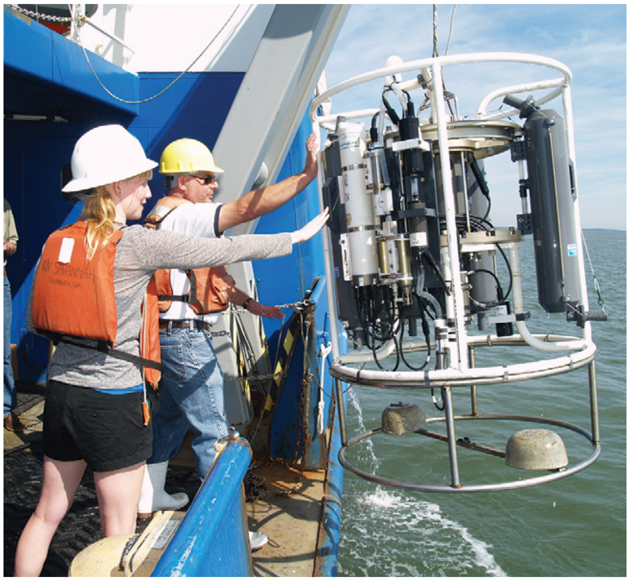

Figure 4. Author Marc Frischer and graduate student Ashleigh Price collect water and water quality data to investigate possible connections between Black Gill and water quality onboard the RV *Savannah*. Courtesy of Mike Sullivan, 2014

In cases of Black Gill, the ciliate invades the shrimp and can cause gill tissue to die. The presence of the invading ciliate stimulates an immune response in the shrimp. The darkened gills result from melanin production, a component of the shrimp's immune response. A dark protective layer of melanin forms around the ciliate on the gill tissue, possibly attempting to minimize the amount of tissue damage from the ciliate (Sönderhäll et al. 1992).

Where is Black Gill occurring?

Cases of Black Gill in shrimp have been identified along the U.S. eastern coast from Virginia to Florida (see Figure 5) (Frischer and Bulski et al. 2015). Black Gill appears to impact shrimp off Georgia and South Carolina most severely. Comparative testing indicates that a single species of ciliate is the infecting organism in all of these cases (see Figure 6).

When is Black Gill prevalent?

Shrimpers have reported seeing blackened gills on shrimp for years with increasing frequency. It was first officially detected by the Georgia Department of Natural Resources off the coast of Cumberland Island in 1996 (DNR 2013). There was variability in its prevalence, with active seasonal rates (August to December) in shrimp sampled by DNR ranging from zero detected in 1997, 1998, and 2001 to 45.7 percent detected in 2014 (Geer 2015). Many shrimpers perceive the rates of Black Gill that they observe at sea much higher than those reported by DNR. The University of Georgia Marine Extension is working with shrimpers to collect data on their trawls, training shrimpers to use unbiased sampling methods, and reporting styles in an effort to obtain a reliable, robust data set for statistical analysis.

While no clear trend has readily emerged related to the prevalence of Black Gill, a seasonal cycle has been detected (DNR 2013). The first reports of Black Gill typically occur in August, and peak in September and October, when many shrimp sampled by DNR have visible signs of the condition. Observed cases then decline to near zero by December. Higher sensitivity molecular and microscopy-based tests indicate that the Black Gill ciliate is generally present in shrimp from May through February (Frischer and Bulski et al. 2015). It is unclear where this ciliate originates, and why it is not detected March through May. Identifying the life cycle of Black Gill, including the vectors for transmission throughout shrimp stocks, is a key question. Answering this question may lead to new strategies for reducing transmission in the future. The variables affecting the prevalence and fluctuations of Black Gill are complex and not well understood.

How does Black Gill spread?

One of the most surprising findings has been the discovery that nearly all shrimp are infected by this ciliate during the late summer and fall period (Frischer and Bulski et al. 2015). It is not understood why some shrimp carrying the ciliate develop Black Gill and some do not. It is possible that the

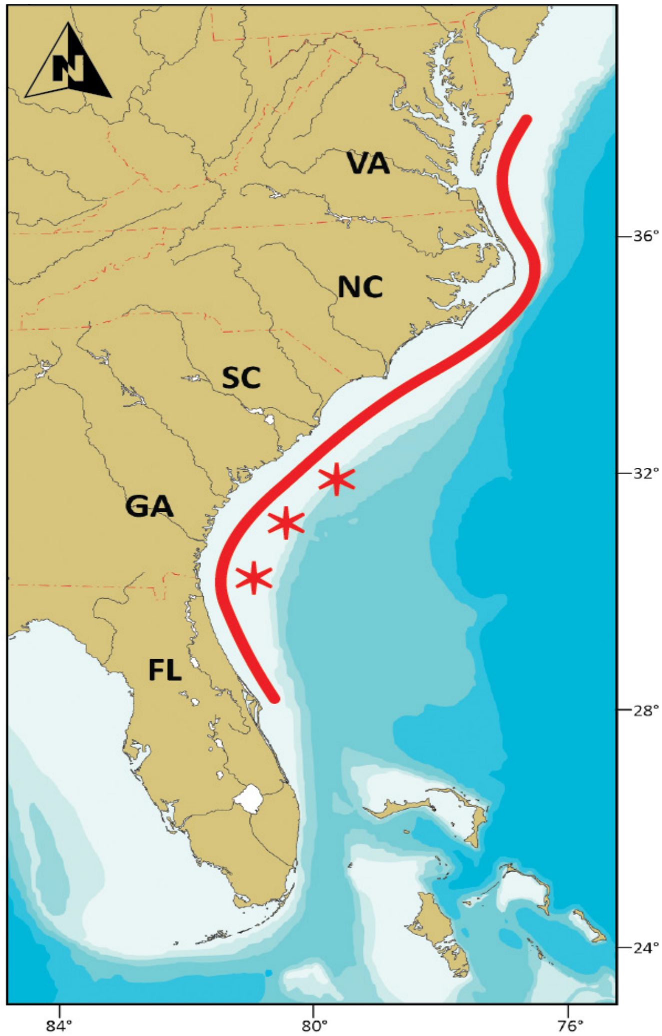

Figure 5. Documented range of Black Gill in shrimp in south-eastern coastal waters. Stars indicate location where the highest prevalence has been observed. Courtesy of Marc Frischer, 2015

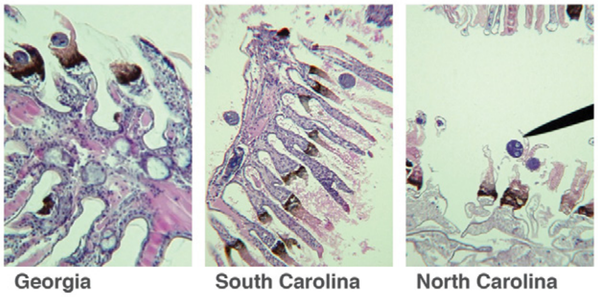

Figure 6. Samples from shrimp collected in Georgia, South Carolina, and North Carolina indicate that the same ciliate is causing Black Gill throughout the region. Courtesy of Anna Walker, MD, Mercer University School of Medicine, 2015

quantity of ciliates infecting a single shrimp may determine if infection is visually displayed as Black Gill. The discovery that all shrimp likely contain the ciliate has impacted laboratory tests significantly, as the control group in these experiments (the "healthy" shrimp) may not actually be free of the parasite.

Our studies have shown that the suspected ciliate becomes free swimming after a shrimp molts. Many shrimpers wonder whether common practices such as "heading" (removing the shrimp's head) at sea has caused Black Gill to spread. They posit that when the shrimp is headed or molts, the ciliate is not being nourished and, therefore, becomes a free-swimming agent to travel to another shrimp (Liguori). If the ciliate is the type that scientists have initially identified as the perpetrator, this could be true, (i.e. that particular ciliate typically becomes free-form when the shrimp molts, swimming to a new host and infecting the new shrimp) (Landers 2004).

Our ongoing studies have conclusively demonstrated that Black Gill can be spread when one shrimp eats the head of another shrimp that had Black Gill. Studies are currently underway using uninfected shrimp that were collected in the early spring and held in high health quarantine facilities to further investigate ciliate transmission. Because of the rate of transmission of Black Gill appearing in late summer, it is likely that whatever the mechanism, the condition spreads efficiently. Studies are also underway to investigate the mortality of shrimp stocks, seasonal and temporal correlations of the Black Gill season, and whether there is secondary mortality or morbidity events due to predation. Answers to these questions will be useful for predicting and attempting to manage Black Gill.

Is Black Gill harmful?

Black Gill is not harmful to humans, and shrimp displaying Black Gill are safe to eat (DNR 2013).

Black Gill may not kill shrimp directly but rather compromise individuals, making shrimp more vulnerable to predators and environmental pressures. For example, Black Gill may cause an increased number of molting events, which shrimp may be employing to remove a damaged gill. Molting is energetically taxing, detracting resources from growing, reproducing, and evading predators. Shrimp visibly impacted by Black Gill exhaust more quickly and have lower endurance compared with shrimp without visibly darken gills (Frede et al. 2015). This also could increase their chances of being captured by predators. Thus, Black Gill may indirectly affect shrimp mortality rates.

What can be done to stop it?

Additional field research and laboratory experiments, new testing methods, and ongoing collaboration with natural resource managers and shrimpers will help to better understand this issue. Many questions remain, with much on the line in terms of economic impacts for shrimpers who rely on this resource for their livelihoods.

Despite the threat that Black Gill poses to the shrimping fishery, dedicated funding by state and federal fisheries programs has been minimal. Scientists investigating Black Gill in Georgia have thus far found 195 different parasites in shrimp collected for study, although the only parasite that appears to harm shrimp health is the ciliate responsible for Black Gill. However, shifting environmental conditions could affect the ability of shrimp to defend against or co-exist with these other organisms. Surveillance and further research would increase the ability of scientists and managers to quickly respond to threats and mitigate their damage to fisheries. It would also allow the shrimping industry to adjust their business model and fishing practices accordingly.

ACKNOWLEDGEMENT

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Georgia White Shrimp Disaster Assistance Request

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CLASSROOM ACTIVITY – THE IMPORTANCE OF DATA

Imagine that you are a scientist and have been asked to investigate Black Gill, determining its cause, whether it is harmful to shrimp or people, and whether anything can be done to prevent it.

One of your biggest tools in approaching these questions will be data. For example, if Black Gill was at its worst in 2014, why might that be? What other circumstances could be contributing to its prevalence in peak years? Why does it flare up in certain months of the year?

However, what if your data starting point is false? The data that you are using to launch these other questions might give an incomplete story. Shrimpers and the Georgia Department of Natural Resources have different perspectives on the rates of Black Gill and its causes. GA-DNR's rate comes from fisheries surveys conducted on a monthly basis. This can lead to gaps in the data set. Shrimpers are out on the water much more frequently, but are relying on personal observation. This can be subjective and inconsistent.

Divide students into groups and assign each group a role: shrimpers, resource managers, restaurant owners, consumers, and scientists. Have students watch the "Black Gill in Georgia Shrimp" video, and then discuss how a person in their assigned role might feel about this issue. For example, as a scientist, who would you believe and why in regard to how widespread Black Gill is? How will you confirm which observations are correct?

Encourage students to conduct research online to learn about their role, so that they can better understand the different perspectives involved. As a class, discuss strategies for approaching the problem of Black Gill. Let us know what ideas or solutions your class comes up with! We will feature your ideas on the Georgia Sea Grant website.

Watch this video for more background.