BROOK TROUT BEHAVIOR

Genetics Could Help Populations Adapt to Habitat Change

photo-Shannon White

by Amanda Yeager

When we look at a wildlife species like Brook Trout, we may not immediately recognize whether a diversity of behavior and characteristics exist in their populations. It's a question that fisheries researcher Shannon White, a Ph.D. student in Penn State's ecology program, is examining to identify whether certain traits and behaviors may help Brook Trout populations adapt to habitat pressures including warming climate conditions.

"If we get a better understanding of Brook Trout ecology, we may get new answers for management," said White, who is studying the behavioral traits, movement habits, heat tolerance and genetics of wild Brook Trout, as a member of the Pennsylvania Cooperative Fish and Wildlife Research Unit fisheries lab coordinated by Penn State adjunct associate professor of fisheries, Tyler Wagner.

"Brook Trout conservation is a priority, because they're a valued fish species and the only native stream dwelling species of trout in the eastern United States (Lake Trout are native to some lakes in the eastern United States)," said White. "There are important economic and ecological conservation factors tied to Brook Trout. They net billions of dollars in angling revenue from recreationists who travel and buy gear and fishing licenses to enjoy this increasingly rare and beautiful fish, so if they become less prevalent, the states will see a revenue loss. They also have a unique role as a consumer of specific stream invertebrates, and as a food source for birds and other predators, and that niche can't be perfectly filled by other trout species."

Survival pressures

The Brook Trout, *Salvelinus fontinalis*, is an important native trout species that is declining across its eastern United States range due to the loss of quality stream habitat. In Pennsylvania watersheds, more than a third of historic Brook Trout populations no longer exist, and another 39 percent of the state's watersheds host Brook Trout populations now less than half their original size.

Brook Trout have specific habitat needs, requiring clean, cold waterways or lakes to thrive. Optimal habitats have been reduced over time with land use changes and the loss of cool, forest-shaded stream corridors. In many areas, Brook Trout also experience competition for food and other habitat resources from non-native Brown Trout, which have developed naturalized populations in many streams, are stocked for angling and have a higher tolerance for disturbance than Brook Trout. Expectations for warming stream temperatures suggest a future of growing pressures for remaining Brook Trout populations in Pennsylvania and the eastern United States.

"The question is, how are Brook Trout going to survive these compounding threats? With climate change, many terrestrial species like birds can relocate—with fish, and especially with Brook Trout, they often get trapped," said White.

With temperatures varying within many river systems, Brook Trout must seek out the coldest locations to meet their thermal requirements. While she sees potential for both sport fish to be managed, White explained that Brown Trout competition often pushes Brook Trout higher into small headwater tributaries, restricting them to limited areas and resources. In some cases, Brook Trout also benefit from upwellings of cold groundwater that occur in small pockets in some streams. The challenge for Brook Trout populations often comes down to the capability of individual fish to locate and occupy the habitats that best ensure their survival and successful reproduction—while the challenge for fish ecologists and managers centers around how best to leverage the species' survival strategies with matching conservation practices.

White is adding to the knowledge available on this species, using several laboratory and field experiments that examine the connections between Brook Trout and the behaviors they employ to adapt to habitat changes or to move to more suitable habitats.

"We need to consider if there are specific genes or behaviors that create adaptable and moving fish—we'll want to conserve that genetic content in the populations," said White. "We want to discover the factors that will create robust and moving populations of Brook Trout that can survive climate change a bit better."

Behavior and adaptation

To investigate how behavior affects Brook Trout responses to habitat changes, White has employed two laboratory experiments in constructed aquatic environments. In the first, Brook Trout were introduced to a maze environment with a food source situated near visual cues such as a plant or rock. Once they acclimated, the maze was rearranged to see if fish could relocate their food near the same environmental cues. The behaviors of the fish were also recorded before they were introduced to the maze. Fish can generally be categorized as either "bold" or "shy," and readily demonstrate their behavior when placed in a small personal tank. Shy fish remain still or cower in a corner while bold fish actively seek an escape by swimming in circles or jumping.

The study results, which White and her colleagues have submitted for upcoming publication in the journal Behavioral Processes, showed significantly different responses. Shy fish learned to relocate their food source based on the position of environmental cues while bold fish traveled the maze without locating food.

"Bold fish aren't as good at forming small spatial maps, but they do move around more—so they go looking for new locations when their habitat changes while shy fish stay close to home and try to solve the problems they encounter," said White. "It's good to have a mix of these behaviors. Bold fish can colonize new areas if a population is wiped out by a natural event like a flood; shy fish, following their safer life strategy, will stay put in their original area and maintain a trout presence in that area. If you wipe out either, you have problems."

In a second lab experiment, White examined the behavioral responses of Brook Trout exposed to thermal changes. Bold and shy fish were introduced to environments with multiple tanks at varied temperatures, with one tank holding food and one containing water with an optimal cold temperature, equivalent to what wild Brook Trout could locate in streams with upwellings of cold spring water. Movement behavior was tracked for each fish, including the time spent at the cold area and food source, examining choices between temperature and feeding. Data is still being analyzed, but cold temperature areas seemed to be a clearly limiting factor, especially for large-sized fish with greater sensitivity to high temperature. These Brook Trout prioritized cold pools over food. The study suggests both total population and body size will decrease for Brook Trout living in habitats that lack optimal cold water and plentiful food resources. Whether the ability of individual fish to locate cold upwellings comes from social cues, or a keen sensitivity to environmental changes, still remains to be seen. White hopes relevant information on adaptive behaviors and their source will also be found in the ecological and genetic information collected on Brook Trout in her field studies.

"Behavioral data are hard to collect in the field, which is why much of that information is conducted in labs. Science is now starting to expand these studies more into the realm of field ecology," said White.

Behavior and movement in wild populations

The field portion of White's study is taking place in three tributaries to Loyalsock Creek, Lycoming and Sullivan counties. Her ongoing research in the Loyalsock Creek watershed is being conducted in partnership with Susquehanna University, which has provided grant funding and student technicians to assist with data collection. Local residents in the Loyalsock Creek Watershed Association are also assisting with monitoring watershed habitats and other contributions to the project.

Using electrofishing to catch and release fish, White has assessed the behavior of 300 wild Brook Trout. She has also collected blood and tissue samples and implanted radio-telemetry tags in 150 trout to follow their movements. Twice a week, she records the newest locations of the tagged trout and monitors environmental conditions such as the stream temperature in locations they are occupying. A few trends are appearing in her initial results.

"So far, behavior in this natural population has really varied," said White. "Some localized populations show boldness in 80- to 90-percent of fish; others have only 10 percent. So, our working theory is that behavior is variable, and there's not a set proportion of bold or shy fish that's standard in all populations."

According to White, analyzing the data on site conditions for each population's locale could provide some explanations on why boldness and shyness levels differ greatly among the populations, and there are some observable differences in the sites.

"One driver could be the presence of Brown Trout," said White. "The expression of behavior has genetic and environmental drivers. In areas where Brown Trout limit Brook Trout from exploring habitats, it could be driving shy behavior. Brown Trout also grow faster and could be eating bold, young Brook Trout that are actively moving and easier to predate, which means fewer bold Brook Trout will survive and reproduce in the population."

The level of tracked movement has varied to some extent depending on which of the three stream tributaries the fish occur in—some have

photo-Tyler Wagner

Shannon (left) at a study site with Penn State student research assistants.

colder temperature and higher quality habitat than others. During warmer seasonal temperatures or drought conditions, all of the tagged Brook Trout tended to move less, but when rainfall returned to an area, stream levels and trout movement both picked up.

"Stream flow is definitely a trigger for Brook Trout movement," said White. "Climate change is not just about temperature, it is also projected to cause drought and less snowfall. If there is less precipitation, or if the watershed is developed and that changes the stream flow, these factors will influence movement and may cause behavioral changes. You need two things for Brook Trout to move—the genes and the environmental triggers that prompt movement. If there isn't an environmental cue, the fish may not move anyway."

White is looking forward to analyzing trends in the overall movement behaviors recorded for the fish she has tagged.

"Movement is one of the most critical behaviors to study if these fish are going to survive, because the species needs individual fish that can find specific habitats," said White. "We need to conserve genetic groups that know how to move to the right temperature habitat like cold-water upwellings, or areas where they can avoid Brown Trout competition. When we look through the data, I think we'll see these fish are behaving in ways we haven't thought about before, such as moving between tributaries to find optimal habitat, which is important for any Brook Trout population living in connected river systems like Loyalsock Creek."

Genetic factors

In addition to tracking movement and measuring personality characteristics in Loyalsock Creek's Brook Trout, White will also utilize the tissue and blood samples she has collected to add genetic data to what we know about the species. White is interested in the role genetics play in Brook Trout movement and other behavioral traits and heat tolerance. Cataloging the genetic make-up of the samples will take time and may produce separate research studies. White hopes to pair initial genetic data with her field study to see which of the watershed's fish are related and to identify fish who traveled from other locations, bringing outside genes that may be expressed in movement behaviors and tolerance to changes like warming conditions.

One of the key Brook Trout questions centers around which genes generate the proteins that help fish preserve healthy cells during warmer conditions and what environmental influencers prompt the trout to turn those genes on or off. So far, research has suggested Brook Trout express the protein-making genes under not only thermal increases but other environmental stressors such as low water levels. The genes are also being expressed at an early age and when fish are still occupying temperatures several degrees below the upper-end of their thermal tolerance.

"It could mean they could adapt to warming water temperatures better than expected," said White. "If they are producing the proteins readily, they may have a chance to develop some resistance and survive longer, at least if stream temperatures are warming at a slow pace."

Management implications

Now at the mid-point of her research, White is beginning to see potential for her studies to add tools to Brook Trout conservation plans.

"In a lot of management strategies, we may think in terms of conserving Brook Trout as a species, or Pennsylvania's Brook Trout or a watershed's Brook Trout," said White. "The idea of conserving specific behaviors isn't always something we consider, or it may not always seem manageable. But, it's something we may insert into a management plan if we know the important factors for individuals. It's a management tool on a different scale. It's also about determining where it may be appropriate—we don't know yet, which is why we're pursuing it."

White hopes her findings on behavior, movement and thermal tolerance may help conservationists focus their efforts. When local managers plan conservation practices for the high-quality streams in their areas, adding smaller-scale data may help them focus efforts first on stream reaches that also contain trout populations with essential genetics or behaviors. And, new information on trout heat tolerance and movement behavior could identify moderate-quality habitats that could be remediated by replanting streams edges or removing waterway barriers in areas with actively-moving Brook Trout.

"One of the goals of this research is to show the importance of considering behavior and genes in wildlife conservation. My specific goal for Brook Trout is to demonstrate the value of looking at different habitat units and thinking about scales of management, so we begin to consider behavior, genetics, individuals, populations, everything—and create a more holistic strategy."

Since Brook Trout are a species that generates interest among the general public, and in particular with conservation organizations like Trout Unlimited and local watershed groups, White regularly conducts outreach presentations to community groups and to students who are considering studies in fisheries or other science fields. She shares online updates on her Brook Trout research at **www.TheTroutlook.com**.

"Brook Trout conservation does come down to people protecting this resource in their backyards," said White. "I try to share the science and research with interested people in an approachable format, since the general public can't do anything without that information. Planting trees and limiting watershed development are essential for Brook Trout, but people first need to know what's important for them to be advocates for those local decisions."

photo-Shannon White

Researchers extract a gill filament from an adult wild Brook Trout. Taking tissue samples like these allow analysis of gene expression to determine traits that best allow fish to survive.