2022 Sport Fish Restoration Project Award – Research and Surveys

Overview.—The North Carolina Wildlife Resources Commission (NCWRC), in partnership with the Southeastern Cooperative Fish Parasite and Disease Lab (SCFPDL; Auburn University), led the discovery of three exotic-invasive trout pathogens in the Southeastern United States. These pathogens comprised the causative agent of salmonid whirling disease (*Myxobolus cerebralis*; *Mc*) and the pathogenic gill lice *Salmincola californiensis* and *Salmincola edwardsi*. Each is of high concern for coldwater resource managers regionally. An intended overarching outcome of this agency-university partnership was the creation of region-specific management tools. This work, conducted using funding provided through the Sport Fish Restoration program (SFR; 2018-2021), forged the primary research on these pathogens for our region and shared critical results with numerous partners. It also raised practical awareness of the importance of fish disease diagnostics and inter- and intra-state biosecurity; including interactions between private trout producers and fisheries managers. Nine graduate students (4 MSc and 5 PhD students) gained critical insights on applied fish health management in a fisheries context and at a regional scale, resulting in over 20 platform scientific presentations and 9 peer-reviewed publications in international journals.

Need.—Trout are a significant biological, cultural, and economic entity for North Carolina. As the State's only native salmonid, the Brook Trout is a species of conservation importance and has provided local fisheries for generations. In addition to self-sustaining populations of Brook Trout, the NCWRC also manages stocked Brook Trout and self-sustaining and stocked Brown Trout and Rainbow Trout fisheries through its Public Mountain Trout Waters program (PMTW). These diverse resources are popular with anglers. In 2014, 149,000 anglers fished in PMTW and had a total effect of approximately $383 million to the State's economy. Trout also serve as an important agricultural commodity for North Carolina, with the State often ranking among the leaders in United States sales.

In 2015, we discovered *Mc* in Watauga River, North Carolina (the first detection in the Southeastern United States); however, it was known to exert deleterious population-level effects on salmonids elsewhere in North America and abroad for decades. Soon thereafter, the exotic invasive gill lice (*S. californiensis* and *S. edwardsi*) were detected in Rainbow Trout and Brook Trout. As such, these pathogens fell within a geographic area where potential biological threats to coldwater resources including native Brook Trout were indeterminate. Thus, such knowledge gaps made it difficult to achieve informed decisions on behalf of resource managers.

Objectives.—Our objectives were to 1) determine the spatial and temporal distribution of these pathogens in North Carolina's trout waters and trout species, 2) explore life history characteristics of *Mc* in its invasive range, 3) provide critical information to support our portfolio of trout management activities, 4) disseminate scientific results to adjacent resource managers likewise concerned with these salmonid pathogens, and 5) engage in public outreach that targets anglers and other citizens.

Procedures.—We collected 655 Brook Trout, 1,155 Brown Trout, and 1,811 Rainbow Trout representing 112 localities across North Carolina. All microscopy and molecular (nested PCR) analyses were performed at SCFPDL. Extensive communication between NCWRC and SCFPDL ensured that the information produced could be directly applied to support management needs and disseminated among partners, staff, and members of the public.

Results.— This project generated groundbreaking information to support management and conservation efforts in North Carolina and abroad. We conducted the most comprehensive study of trout health in North Carolina, while developing a robust dataset for *Mc* epidemiology. We discovered a new species of *Myxobolus* infecting Brook Trout that is evidently not routinely pathogenic but morphologically nearly identical to *Mc*, which could have led to false positives in diagnostic tests for *Mc*. We also confirmed that *Mc* has a distinct life cycle in the Southeastern

United States, infecting an oligochaete other than *Tubifex tubifex.* This result was transformative to global understanding of the epidemiology and life cycle of *Mc* because the distribution of the pathogen is linked to the abundance and distribution of the definitive host. The project generated pioneering information on parasitic species undescribed previously in the region: the parasitic copepods (aka "gill lice") *S. edwardsii* (in Brook Trout) and *S. californiensis* (in Rainbow Trout).

Our SFR project has contributed substantively to the understanding of trout health across North Carolina and the United States, while providing a model for other state and federal agencies have followed. The scholarly outputs (Rash et al., 2017; Ruiz et al., 2017a, b; Ksepka et al., 2019; Ksepka et al., 2020a, b; Ksepka and Bullard, 2021; Ksepka et al., 2021; Truong et al., 2022) and presentations (state, regional, and national American Fisheries Society meetings, Southeastern Society of Parasitologists, American Society of Parasitologists, Wild Trout Symposium) and numerous public lectures (individual Trout Unlimited chapter meetings, national Trout Unlimited meeting, individual Federation of Fly Fishers meetings, Western NC Fly Fishing Expo) were delivered; helping spread insights gained through the course of the project.

Benefits and Public Impact.—While gathering and planning to collect information, the NCWRC communicated effectively with management partners (something that is critical given the transient nature of pathogens). This is especially important in North Carolina, where there are numerous waters and watershed boundaries that are shared between states, municipalities, the Great Smoky Mountains National Park, Eastern Band of Cherokee Indian Reservation, and private aquaculture facilities. With this in mind, the NCWRC kept all aware of the progress this SFR project was making in researching these newly-discovered coldwater pathogens.

In the case of both *Mc* and gill lice, the NCWRC has utilized angler reports to identify infected trout populations. As such, increasing public awareness has been an important part of the NCWRC's response to these and other aquatic nuisance species (ANS). Press releases and social media posts conveyed relative findings, while a webpage devoted to whirling disease compiled media and provided additional information. On-stream signage was also placed along waterways where *Mc* was documented. Furthermore, the NCWRC has developed an ANS message (Clean, Drain, Dry, and Never Move) that staff can utilize to promote minimal efforts to prevent the spread of ANS.

The NCWRC has also been working to prevent the spread of ANSs via its review of stocking permit applications. In North Carolina, individuals must obtain a permit from the NCWRC to stock any fish in public waters. During permit review, the NCWRC confirms that the trout slated for stocking are pathogen-free. Furthermore, the NCWRC conducts the same screening for its stocked fish and self-sustaining Brook Trout that are to be translocated in restoration projects.

Evaluation.—Raising awareness about biosecurity and fish health in a fisheries management context as well as hastening communication between aquaculturists and fisheries biologists was a broader impact of this SFR project. This subject has not received adequate attention historically in the Southeastern United States. Our work has helped reinforce the critical importance of conducting fish health checks on both wild and captive fishes given that one affects the other. This activity has built some resiliency in our ability to manage invasive pathogens and diseases in hatcheries and wild trout populations by 1) informing management decisions, 2) disseminating scientific research findings to adjacent resource managers who are likewise concerned with these salmonid pathogens, 3) hastening inter- and intrastate biosecurity measures, and 4) engaging in public outreach that targets anglers and other conservation-minded citizens.

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