Assessing Impacts of Lyngbya and Algaecides on Tidewater Mucket (*Atlanticoncha ochracea*) in Lake Gaston, NC/VA.

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Prepared By:

North Carolina State University

Aquatic Plant Management Program

Raleigh, NC 27607

Submitted To:

Lake Gaston Weed Control Council

Littleton, NC 27850



NC STATE UNIVERSITY

Introduction

The tidewater mucket (*Atlanticoncha ochracea*) is a North Carolina state-threatened freshwater mussel native to the Roanoke River drainage that is known to be well established within Lake Gaston, NC/VA. Currently, the lyngbya treatment program at Lake Gaston is restricting the minimum depth allowed for application within treatment areas to reduce the potential exposure of tidewater mucket to chelated copper-based algaecides used to control lyngbya. However, the current treatment protocol has the potential to allow unregulated growth of benthic lyngbya mats in shallow water areas, decreasing the overall efficacy of the treatments. While the toxicity of copper to aquatic organisms, especially freshwater mussels, has been well documented (Keller and Zam 1991, Jacobson et al. 1993, and Jorge et al. 2013), the impacts of co-occurrence between this listed species and lyngbya is poorly understood.

The original goal of this project was to determine the potential for mapping tidewater mucket distribution within areas that are receiving directed lyngbya treatments from the Lake Gaston Weed Control Council. Understanding the distribution and abundance of tidewater mucket within these areas would assist in developing proper application techniques that would maximum treatment efficacy while minimizing contact with freshwater mussel beds. The originally proposed objectives of this project were to 1) determine if side-scan sonar can be utilized for locating freshwater mussel beds in Lake Gaston, 2) determine if mussel beds can be properly identified and mapped within lyngbya treatment zones, and 3) determine overall distribution patterns and habitat preferences of tidewater mucket populations within Lake Gaston.

Due to unforeseen logistic issues, outlined below, the original project objectives could not be fully achieved. In response, the project was restructured to focus directly on the interaction between tidewater mucket, lyngbya presence, and lyngbya control methods. The revised objectives continue to support the overarching goal of this project, which was to develop effective lyngbya treatment protocols that minimize negative impacts to native tidewater mucket populations. Understanding how lyngbya presence and control efforts affects tidewater mucket populations is critical to both mussel conservation and lyngbya control. The knowledge gained from this project will aid resource managers of both species in making balanced, data-driven management decisions.

Objectives

Objective 1

The first original objective of this project was to determine if side-scan sonar could be utilized for locating freshwater mussel beds in Lake Gaston. Side-scan sonar has been shown to be an effective tool for identifying individual mussel beds by successfully delineating mussel shells located in sand and clay substrates (Powers et al. 2015). The goal for this objective was to utilize Lowrance side-scan technology to develop reference images of known mussel beds at Lake Gaston. Therefore, confirming that tidewater mucket beds could accurately be delineated utilizing this technology.

Methods

North Carolina State University Aquatic Plant Management Program (NCSU) purchased a Lowrance HDS LIVE 12 Fish Finder/Chartplotter and an active imaging transducer to complete this objective.

Prior to scanning, reference mussels were obtained by gluing together empty tidewater mucket shells collected from Lake Gaston. On July 24th, 2023, researchers from NCSU and aquatic wildlife diversity biologists from the North Carolina Wildlife Resources Commission (NCWRC) deployed a plethora of reference mussels within a series of three sites located in water depths ranging from 1 to 1.5 meters of water. At each site, 1m x 1m metal quadrats were deployed in which biologist buried 5 mussels in to the substrate such as to mimic natural freshwater mussel behavior. Lowrance side-scan technology was used to scan these locations at 455 kHz, 800 kHz, and 1075 kHz frequencies at distances that varied from 1.5 meters to 9 meters. On July 26th, 2023, established natural mussel beds were also scanned at the same aforementioned frequencies and distances.

Results

After extensive scanning, it was determined that the Lowrance side-scan technology could not effectively identify tidewater mucket beds within Lake Gaston. Side scan images were greatly influenced by rocky substrates and corbicula shells creating rendering the images too complex to differentiate substrate, mussel shells, and other materials. Throughout the multi-day process, researchers were unable to confidently identify a single mussel shell located within the metal quadrats or the established mussel bed locations.

Objective 2

The original objective 2 focused on determining if mussel beds could be properly identified and mapped within areas receiving directed lyngbya treatments. However, due to the inability to identify tidewater mucket in objective 1, this objective was unable to be achieved.

Objective 3

The original objective 3 focused on determining overall distribution patterns and habitat preferences of tidewater mucket populations within Lake Gaston. Due to the inability to achieve results in objective 1, objective 3 was modified to address questions related to the possible direct impacts lyngbya presence and its associated management strategies had on tidewater mucket populations. The revised objectives were to 3.1) quantify impacts (lethal and sub-lethal) of lyngbya and associated treatment protocols on propagated tidewater mucket and 3.2) document impacts resulting from direct exposure to a high density level of lyngbya on tidewater mucket.

These restructured objectives also continued to facilitate the original objective of developing a collaboration with the NCWRC that would promote balanced management decisions based on sound science.

Methods

Mussels

All mussels stocked during this study were acquired from the Harrison Lake National Fish Hatchery in Charles City, VA where they were propagated from Lake Gaston broodstock. Prior to stocking, tidewater mucket were individually identified using Hallprint tags and all lengths measured. These mussels were then deployed in a series of mesh cages and exposed to multiple conditions detailed below in objectives 3.1 and 3.2.

Mussel Cage Design

All mussels were stocked into a 0.5 m x 0.5 m x 0.25 m plastic mesh cage. Cages were filled with 15 gallons of playground sand to provide ample room for mussels to burrow and position related to substrate was used as a general proxy for mussel behavior. Cages had a mesh lid flap that allowed for easy access to mussels within the cage and prevented live mussels from moving out or dead mussels from floating away from the cages. Within each cage, 15 mussels were placed into the substrate and an additional 15 were stocked in substrate directly adjacent to the outer edges of the cages (Figure 1). All cages were deployed in 1-1.5 m of water and were located parallel to the shoreline. At each site general habitat descriptions were recorded. Hobo data recorders were deployed in both Poplar and Hubquarter Creeks to autonomously record hourly water temperatures.



Figure 1. Images of propagated tidewater mucket being stocked into cages at Lake Gaston. The image on the left was the first reported mortality of the project.

Objective 3.1

A total of 24 cages were deployed at 12 site locations within both Poplar and Hubquarter creeks. Each individual site location contained two cages that were exposed to one of three conditions 1) lyngbya was present but not actively receiving direct lyngbya treatments, 2) area was included in the lyngbya treatment program and receiving direct algaecide applications, or 3) lyngbya was not present and area was not receiving direct lyngbya treatments. Each of the aforementioned conditions were represented by two sites within each creek. Mussels were stocked in March 2024, prior to initiation of the 2024 lyngbya treatment season in April, and monitored monthly through October (Figure 2). The only exception was the month of September, in which no sampling occurred due to unfavorable weather conditions and logistical issues. Cages were also assessed in January 2025 to target a period of suppressed lyngbya growth outside of the lyngbya treatment season. Each month, mortality events and mussel position within the substrate (surface / sub-surface) were recorded.

Objective 3.2

A total of 5 cages were deployed at a single cove within Poplar Creek to evaluate the response of tidewater mucket to direct exposure to a high density level of lyngbya. Site selection was based on the historical presence of a very robust and dense lyngbya infestation in the area (Figure 3). Of the five cages, researchers physically inundated three with 1,000 grams of

measured, fresh lyngbya that was sourced from the existing established mat. Mussel response in these three lyngbya cages were compared to two control cages that were placed on an adjacent shoreline and were void of lyngbya. Mussels were stocked in May of 2024 and monitored monthly through October. The only exception was the month of September, in which no sampling occurred due to unfavorable weather conditions and logistical issues. Cages were also assessed in January 2025 to target suppressed lyngbya growth in a time period that was outside of the lyngbya treatment season. Each month, mortality events and mussel position within the substrate (surface / sub-surface) were recorded.



Figure 2. Images of survey efforts monitoring tidewater mucket stocked in cages at Lake Gaston.



Figure 3. Image of past lyngbya infestation level at site selected for objective 3.2.

Results

Mortality

Overall, there were no significant mortality events reported in 2024 or 2025 for either objective (Table 1).

Table 1. Survival rates of tidewater mucket stocked into cages at Lake Gaston, NC/VA.

Creek	Sites	Mortalities Reported (Oct 2024)	Percent Alive (Oct 2024)	Mortalities Reported (Jan 2025)	Percent Alive (Jan 2025)
Objective 3.1					
Hubquarter	**Control**	**0**	**100**	**0**	**100**
	Lyngbya	**0**	**100**	**0**	**100**
	Treatment	**0**	**100**	**0**	**100**
Poplar	**Control**	**1**	**98**	**0**	**100**
	Lyngbya	**1**	**98**	**0**	**100**
	Treatment	**1**	**98**	**0**	**100**
Objective 3.2					
Poplar	**Control**	**0**	**100**	**0**	**100**
	Lyngbya	**6**	**87**	**0**	**100**

For objective 3.1, there were a total of 3 mussel mortalities reported in 2024, all of which occurred in Poplar Creek sites. Of those 3 mortality events, a single event was recorded at a site exposed to lyngbya, a single event at a site exposed to algaecide treatments, and a single event at a control site void of both lyngbya and treatments. All mortality events that occurred were recorded in either August (treatment site) or October (control site and lyngbya site). It should be noted that of the four sites where tidewater mucket were expected to be exposed directly to lyngbya, site wide infestation levels were highly variable. Within each creek, one of the lyngbya sites was heavily inundated outside the cage early season and by October lyngbya was observed inside the cage, while another site had only trace amounts of lyngbya observed in relation to the cage. Due to this variability, the placement of the cages exposed to trace amounts of lyngbya will be reevaluated for the 2025 monitoring season. There were no mortality events reported within Hubquarter Creek.

For objective 3.2, there were a total of six mortality events recorded in 2024 and all occurred in cages inundated with lyngbya (Table 1). These mortality events were reported in June (4) and August (2). No mortality was reported for control cages in which tidewater mucket were not directly exposed to lyngbya.

Growth

For objective 3.1, growth varied by site and was generally greater in Hubquarter Creek than Poplar Creek. For unknown reasons Control Site 1 in Poplar Creek displayed much slower growth than all other sites. This site should be considered an outlier because growth rates in all other sites, regardless of treatment, were not significantly different.

For objective 3.2, mean growth for mussels located in control sites was greater than the mean growth of mussels located in lyngbya inundated cages (Control = 18.4 mm; Lyngbya = 14.1 mm) (Figure 4).

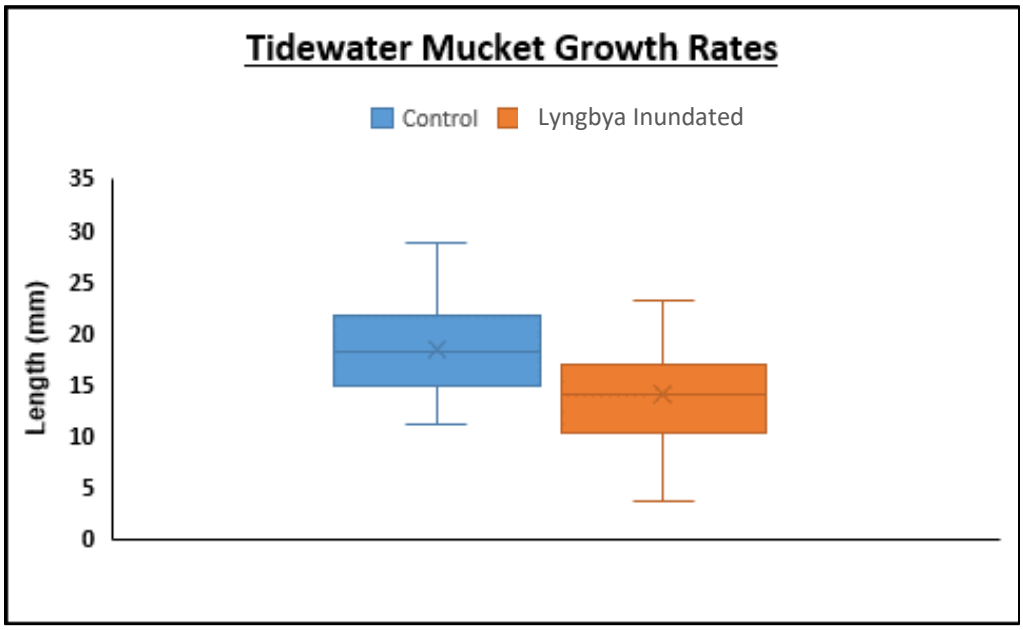


Figure 4. Growth rates of tidewater mucket that were directly exposed to lyngbya versus those that were not directly exposed. Blue represents growth rates of mussels that were held in control site cages void of lyngbya and orange represents mussels in cages directly exposed to dense lyngbya mats.

Behavior

The presence of dense lyngbya mats did appear to have an impact on overall tidewater mucket behavior. When lyngbya density was high in cages, mussels were either located on top of the substrate or had made a vertical movement up into the lyngbya mats and were suspended off the substrate. Unlike mussels located in cages with no lyngbya or trace amounts, very few of the mussels that were inundated with lyngbya were buried in the substrate which could be an indication of stress. Potential factors that may be influencing this behavior include micro-water chemistry differences (i.e., low DO, pH fluctuations, others).

Relocation of mussels stocked outside of cages was minimal. In most cases, no recaptures were reported after the initial stocking event and the fate of those mussels is unclear at this time.

They likely, migrated out of the immediate study area. Following May monitoring, the only reported recapture occurred in June at a lyngbya exposure site located in Hubquarter Creek.

Discussion

While the original objectives were unable to be achieved, this project has succeeded in providing further understanding on the interactions of tidewater mucket with lyngbya and lyngbya directed control methods.

Of the two scenarios tidewater mucket were exposed to, the toxicity of copper exposure to freshwater mussels has been well described (Keller and Zam 1991, Jacobson et al. 1993, Jorge et al. 2013). With this toxicity in mind, the Lake Gaston lyngbya treatment program has been designed to reduce negative impacts to freshwater mussels by decreasing copper concentrations and restricting application of algaecide to areas that avoid potential interaction with tidewater mucket beds. However, freshwater mussel populations are known to have natural environmental stressors such as water quality and temperature, sedimentation, and habitat alterations (Augspurger et al. 2003, Wang et al. 2007a, Wang et al. 2007b, Wagner et al. 2017) which can compound the effects of copper and increase mortality rates (Pandolfo et al. 2010 and Wagner et al. 2017). In 2024, neither direct application nor compounding natural stressors produced increased mortality within those mussels exposed to lyngbya directed control methods. The high survival rate is a positive indicator that the Lake Gaston algicide applications are being properly designed for minimal negative impacts to tidewater mucket. The second potentially stress inducing scenario that tidewater mucket were exposed to was direct exposure and inundation with lyngbya mat material. While the impacts of direct exposure of lyngbya to freshwater mussels are unknown, large diurnal variations in temperature and pH have been associated with established lyngbya mats (Metz et al. 2022) and are potential stress factors to tidewater mucket populations. It was hypothesized that there would be near 100% mussel mortality in cages that were highly inundated with lyngbya, so the low rate of observed mortality was unexpected. However, mussels that were not exposed to any stress scenarios were found burrowed in the substrate and displayed little sign of stress, while some mussels inundated with lyngbya were observed gaping, which is a sign of stress. Along with gaping, mussels were also observed making vertical migrations and were found suspended within the lyngbya mat formation. This could be an indication of increased stress and a sign that they were trying to avoid a harsh microenvironment presented to them between the lyngbya mat formation and substrate.

Although we observed low mortality rates during 2024, we were not able to address long-term impacts related to the interactions of tidewater mucket, lyngbya and lyngbya directed control methods. Like our results, studies that have focused on the impacts of total suspended solids (TSS) and freshwater bivalves have found no acute response in terms of mortality (Zhu et al. 2023). However, similar to the results we found with exposure to high concentrations of lyngbya, studies that examined impacts of exposure to high TSS concentrations found that

growth was negatively impacted (Zhu et al. 2023). Negative impacts of high concentration of TSS have also been found for suspension feeding and reproductive success of freshwater mussels (Landis and Stoeckel 2016, Tuttle-Raycraft et al. 2017). Physical interference with sperm capture, and compromised gill function have been identified as possible driving forces for low reproductive success in freshwater mussels (Landis and Stoeckel 2016 and Landis et al. 2013). Mussels feed by creating currents to draw water in through the incurrent siphon and decrease growth could be attributed to the energy used during the process of particle selection and rejection (Tuttle-Raycraft et al. 2017). While it is unclear if increased filament particles would have the same impact as suspended particles, it is reasonable to assume that robust filamentous mat formations could present physical interference with mussel functions and have similar negative impacts on feeding and reproductive success.

Conclusion

This project successfully developed a study design to evaluate the acute responses of tidewater mucket to lyngbya-related factors. To build on this work and assess long-term exposure impacts, NCSU and NCWRC will continue monitoring the established cages and associated tidewater mucket through 2025. Ongoing monitoring will help identify any year-to-year variations between the 2024 and 2025 lyngbya treatment seasons and evaluate the effects of prolonged lyngbya exposure to tidewater mucket. This continued collaboration with NCWRC will also enhance the management of both tidewater mucket and lyngbya in Lake Gaston by integrating sound science into decision-making processes.

To further understand long-term impacts of extended exposure with lyngbya, future research should focus on the potential effects of robust lyngbya mat formations on feeding, growth, and reproduction success of tidewater mucket. Focus is also needed with other life stages that could be impacted by these interactions, such as juveniles which are inherently more vulnerable than adults.

References

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope, and F.J. Dwyer. 2003. Water Quality Guidance for Protection of Freshwater Mussels (Unionidae) from Ammonia Exposure. Environmental Toxicology and Chemistry 22: 2569-2575.

Jacobson, P.J., D. S. Cherry, J.L. Farris, and R.J. Neves. 1993. Juvenile freshwater mussel (bivalvia: unionidae) responses to acute toxicity testing with copper. Environmental Toxicology and Chemistry 12: 879-883.

Jorge, M.B., V.L. Loro, A. Bianchini, C.M. Wood, and P.L. Gillis. 2013. Mortality, bioaccumulation and physiological responses in juvenile freshwater mussels (*Lampsilis siliquoidea*) chronically exposed to copper. Aquatic Toxicology 126: 137-147.

Keller, A.E., and S.G. Zam. 1991. The toxicity of selected metals to the freshwater mussel Anodonta imbecillis. Environmental Toxicology and Chemistry 10: 539-546.

Landis, A.M.G., W.R. Haag, J.A. Stoeckel. 2013. High Suspended Solids as a Factor in Reproductive Failure of a Freshwater Mussel. Freshwater Science 32: 70–81.

Landis, A.M.G. and J.A. Stoeckel. 2016. Multi-Stage Disruption of Freshwater Mussel Reproduction by High Suspended Solids in Short- and Long-Term Brooders. Freshwater Biology 61: 229–238.

Metz, T.T, S.P. Putnam, G.L. Scott, and J.L. Ferry. 2022. Shoreline Drying of *Microseira* (Lyngbya) *wollei* Biomass Can Lead to the Release and Formation of Toxic Saxitonin Analogues to the Water Column. Environmental Science and Technology 56:16866 – 16872.

Pandolfo, T.J., W.G. Cope, and C. Arellano. 2010. Thermal Tolerance of Juvenile Freshwater Mussels (Unionidae) Under the Added Stress of Copper. Environmental Toxicology and Chemistry 29: 691-699.

Powers, J., S.K. Brewer, J.M. Long, and T. Campbell. 2015. Evaluating the use of side-scan sonar for detecting freshwater mussel beds in turbid river environments. Hydrobiologia 743: 127-137.

Tuttle-Raycraft, S. T.J Morris, J.D. Ackerman. 2017. Suspended Solid concentration Reduces Feeding in Freshwater Mussels. Science of the Total Environment 598:1160-1168.

Wagner, J.L., A.K. Townsend, A.E. Velzis, and E. A. Paul. 2017. Temperature and toxicity of the copper herbicide (Nautique ™) to freshwater fish in field and laboratory trials. Cogent Environmental Science 3:1339386.

Wang (a), N., C.G. Ingersoll, D.K. Hardesty, C.D. Ivey, J.L. Kuntz, T.W. May, F.J. Dwyer, A.D. Roberts, T. Augspurger, C.M. Kane, R.J. Neves, and M.C. Barnhart. 2007. Acute Toxicity of Copper, Ammonia, and Chlorine to Glochidia and Juveniles of Freshwater Mussels (Unionidae). Environmental Toxicology and Chemistry 26: 2036-2047.

Wang (b), N., C.G. Ingersoll, I.E. Greer, D.K. Hardesty, C.D. Ivey, J.L. Kunz, W. G. Brumbaugh, F. J.Dwyer, A.D. Roberts, T. Augspurger, C. M. Kane, R.J. Neves, and M.C. Barnhart. 2007. Chronic Toxicity of Copperand Ammonia to Juvenile Freshwater Mussels (Unionidae). Environmental Toxicology and Chemistry 26: 2048-2056.

Zhu, W., J. Kunz, E. Brunson, C. Barnhart, H.Brown, S. McMurray, A.D. Roberts, C. Shulse, K. Trauth, B. Wang, J.A. Steevens, and B. Deng. 2023. Impacts of Acute and Chronic Suspended Solids Exposure on Juvenile Freshwater Mussels. Science of the Total Environment 905:167606.