

Effects of Tropical Storm Helene on Eastern Hellbender Populations in the Upper French Broad River Watershed, North Carolina

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Abstract

The eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) has experienced widespread declines due to anthropogenic effects. Extreme hydrologic events have recently increased in severity and frequency due to climate change, posing a threat to stream ecosystems; however, there is a lack of research on how these events, such as major floods and hurricanes, impact aquatic species such as eastern hellbenders. In the fall of 2024, Tropical Storm Helene devastated Western North Carolina, bringing floods up to 20 feet above base flow, washing debris and pollutants through waterways. This study assessed pre- and post-Helene eastern hellbender populations from nine reaches across the Upper French Broad Watershed. Sites were sampled prior to the storm in 2023 and 2024 and after in the summer of 2025. All substrates six cm or larger were checked using diurnal snorkel surveys, ensuring all life stages were considered. Pre- and post-Helene population estimates were analyzed using paired t-tests to compare estimated

abundances of hellbender age classes across all sites, as well as total estimates by site. The adult abundance significantly declined, with an average of one less adult per site. Adult decline raises concern about reproductive and recovery rates. The effects of Helene were site-specific, indicating that further investigation is necessary to identify factors responsible for population changes. Our results suggest that disturbances like Helene may decrease populations, threatening species already at increased risk. This data provides a baseline understanding of hellbender response; however, more research must be done to track population change over time and expand on the different factors influencing populations.

Introduction

Extreme hydrologic events such as high precipitation, flooding, and hurricanes have increased globally and are predicted to continue in frequency and intensity as global warming progresses (IPCC et al., 2023), posing a major threat to freshwater ecosystems (Talbot et al., 2018). The IPCC reported that the increase in frequency of heavy precipitation will be nonlinear, with heavy precipitation likely doubling and tripling in the frequency of 10-year and 50-year events, respectively, leading to an increase in flood frequency (IPCC et al., 2023). Regular and predictable flooding is a common disturbance that many ecosystems depend on (Dolloff et al., 1994). Extreme flooding events are historically destructive, with heavy precipitation increasing erosion and sedimentation, and high winds sweeping trees into waterways, obstructing or redirecting flow. These effects can severely alter river channel morphology, lead to habitat loss, and introduce alien species (Anufrieva & Shadrin, 2017; Dolloff et al., 1994). Increased flooding is another threat contributing to the biodiversity crisis, leading to rapid declines in biodiversity and populations (Talbot et al., 2018; Western, 1992). As anthropogenic impacts increase, habitat loss is raising concerns for biodiversity due to competition for limited resources. When alien species are introduced, endemic populations are at risk of being outcompeted for habitat or food. Extreme events can occur naturally, but anthropogenic climate change has increased their frequency and intensity (Ledger & Milner, 2015; Talbot et al., 2018).

As climate change projections continue to grow, it is necessary to understand the impacts these events may have on riverine ecosystems (Talbot et al., 2018). Much of the research on flooding follows events, lacking pre-flood reference data (Poff & Zimmerman, 2010). From the available research, macroinvertebrate populations decline in diversity and abundance as flooding rates from precipitation events increase (Poff & Zimmerman, 2010; Strickland et al., 2024). Fish have been found to display a similar trend of lower diversity and abundance following flooding events (Dolloff et al., 1994; Talbot et al., 2018). All

studies indicate that pre-disturbed stream conditions were relevant in predicting response time and resilience to flood events (Poff & Zimmerman, 2010; Strickland et al., 2024). While research exists about generalized organisms, there is little research available on how specific and rare species respond to floods.

A prime example is the eastern hellbender (*Cryptobranchus a alleghaniensis*). The eastern hellbender is North America's largest fully aquatic salamander that grows up to 70cm long. This long-lived (up to 29 years) late reproducing species breathes through its skin, requiring clear, cool streams for habitat (Nickerson & Mays, 1973). Ranging over 13 states, hellbender populations have been declining and have been reported extirpated from their historic range in Alabama, Illinois, Indiana, and Ohio (Phillips and Humphries 2005; Burgmeier et al., 2011; Freake & DePerno, 2017). Hellbenders are considered indicator species for healthy freshwater habitats due to their sensitive skin and are currently at great risk of population decline (Foster et al., 2009; Nickerson & Mays, 1973). Another major factor shown to impact population rates is the lack of recruitment (Wheeler et al., 2003). Studies have found populations predominantly or completely composed of adults with little to no indication of younger generations to replace them (Burgmeier et al., 2011; Freake & DePerno, 2017). There is little to no data reporting on how hellbenders respond to extreme weather events. It is understood that long-lived species with delayed maturation and low annual recruitment rates are particularly vulnerable to anthropogenic exploitation and extinction (Congdon et al., 1994; Musick, 1999; Unger et al., 2013). Unpredictable recruitment allows catastrophic events to rapidly decrease their population size (Coulson et al. 2001; Unger et al., 2013). Hecht et al. found that while studying population structure in the Little River, larval rates were lower in years with high flooding (2009). They compared these results with Nickerson et al.'s findings of low to no sightings of hellbenders after the flood in 2003 in the Middle Prong of the Little River (2007). They predicted that the increase in precipitation events may lead to higher hellbender mortality or passive transport (Hecht-Kardasz et al., 2012; Nickerson et al., 2009). Both articles indicate a strong need for further research to continue analyzing how increased flooding may continue to influence hellbender populations. They predicted that the increase in precipitation events may lead to higher hellbender mortality or passive transport (Hecht-Kardasz et al., 2012; Nickerson et al., 2009). Both articles indicate a strong need for further research to continue analyzing how increased flooding may continue to influence hellbender populations.

In the fall of 2024, Tropical Storm Helene swept through Southern Appalachia. Helene's destructive path broke through riparian buffers, increasing debris and sediment in waterways, and raising water levels 18 feet above base flow within the French Broad River (USGS Rosman). My goal was to understand how Tropical Storm Helene affected eastern hellbender populations. The specific objectives of this study were 1) to estimate

hellbender populations within the Upper French Broad Watershed, 2) to analyze population differences pre- and post- Helene to predict population impact. To achieve these objectives, we sampled sections of the Upper French Broad watershed after major Tropical Storm Helene. This data was compared to pre-Helene samples at the same sites to analyze population differences before and after the major flood event.

Methods

Study area

The field research team and I conducted our survey in the Upper French Broad River Watershed (UFBRW), Transylvania County, NC. The UFBRW has a drainage area of about 1190 square kilometers and flows north through the Blue Ridge ecoregion. Based on the 2011 USGS data, the land cover is 88% forest cover, 6% development, and 5% crops (USGS, 2011). It is important to mention that there has been some expected land use change over the past 15 years, following the USGS report.

We surveyed at nine sites over 16 days between June 4th and July 29th, 2025. Two passes were conducted at each site on multiple days within a week. To ensure continuity, we modeled our sampling protocol after pre-Helene data collection in 2023 and 2024 and selected dates to align within a week of the previous year's dates.

At each site, we found the survey reach using GPS coordinates. We then marked the 30-meter reach, dividing it into three 10-meter subsections. Snorkeler team size ranged from four to ten. Snorkelers lined up across the zero-meter transect line and assigned lanes to survey, guaranteeing the whole width of the river was covered. Regardless of team size, all available habitat was checked. Rocks six cm or larger were lifted to check for hellbender presence and ensure detection of all hellbender life stages. We returned all rocks to their previous locations after lifting. To reduce invasiveness, we used divelight to check for hellbender presence under large rocks with crevices without lifting the rocks when possible to prevent unnecessary disruption.

Any hellbenders we captured were placed into a dip net or mesh bag and processed. We measured the total length of the individuals using a ruled half PVC pipe, and weighed their mass using mesh bags and spring scales appropriate for the size of the animal. We defined age class by larvae: pre-metamorphic (still with gills), juvenile: ungilled metamorphs <20cm, subadult metamorphs: 20< 30cm (before sexual maturity), adults: >30cm, considered sexually mature (Bodinof and Hopkins, 2018; Diaz et al., 2022). Age classifications are separated into four classes to most accurately understand the population age. When visible, sex and sex characteristics were recorded. Adult

hellbenders were checked for passive integrative transponder (PIT) tags from previous years. If no PIT tags were found, one was implanted behind the back, left leg, along the tail. All captured hellbenders were returned to capture sites, and coordinates were recorded.

Statistical Analysis

We estimated population size using the larger of the two estimates from the passes. Due to the low recapture with PIT tags, mark and recapture population estimates could not be used. We tested for differences in the means before and after Helene using a paired T-test (Gillette et al. 2006). Due to reduced statistical power from low replications, we used an alpha value of 0.10 to decrease the likelihood of a type II error (Dayton, 1998; Gido et al., 1999).

Results

Over the 2025 summer surveys, 36 individuals were found across nine sites compared to the 42 from the 2023-2024 studies. Using a PIT tag scanner, we identified two individuals for recapture between passes and one identified from 2024 at the original tag site.

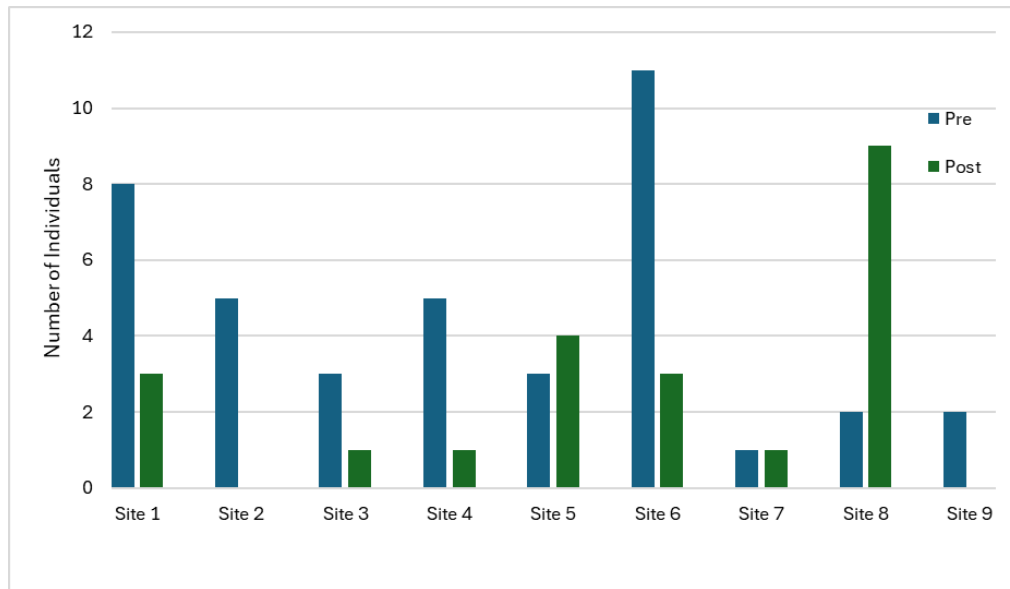


Figure 1. Overall mean hellbender population estimates across sites. Mean population estimates did not statistically decline from pre- to post-Helene ($P = 0.206$)

Across all sites, total hellbender population size did not significantly decline pre- and post-Helene ($P = 0.206$, Figure 1). The mean and standard deviation population of hellbenders per site was 4.44 ± 3.06 pre- and 2.44 ± 2.67 post-Helene. Most of the sites

show a decline in populations; however, sites five and eight show an increase in population, indicating variance in site resilience. To further understand populations, we analyzed overall populations by age classification.

Adult populations significantly declined from pre- to post-Helene estimates ($P = 0.069$, Figure 2), with a pre-Helene mean of 1.67 ± 0.77 and a post-Helene estimate of 1.15 ± 1.03 . All other age classes, larva, juvenile, and sub-adult, showed a decline in estimates, but no significant difference in populations (all $P \geq 0.19$, Figures 3, 4, 5).

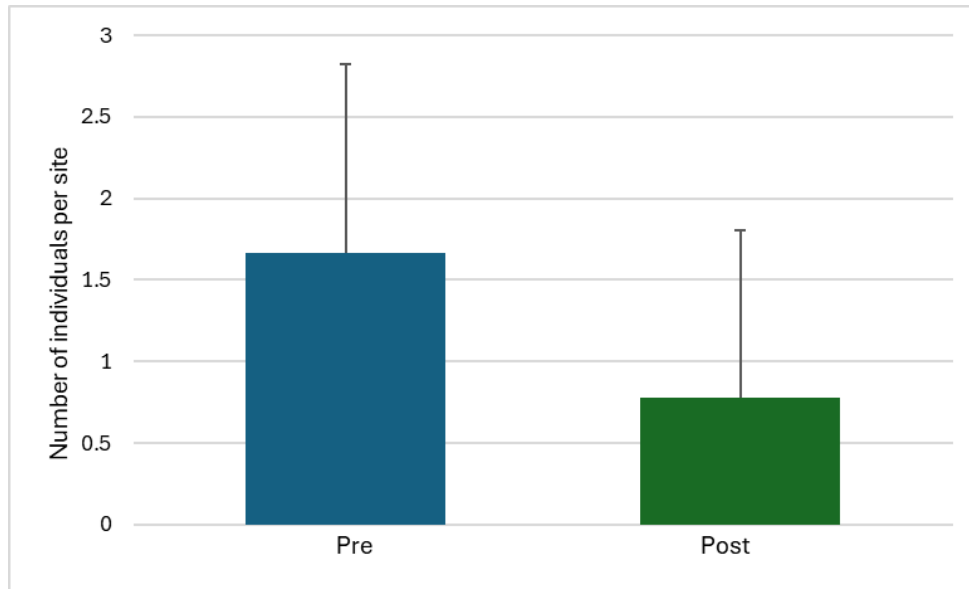


Figure 2. Mean and standard deviation of adult hellbender population estimates pre- and post-Helene. Average population significantly declined from pre- and post-Helene ($P = 0.069$).

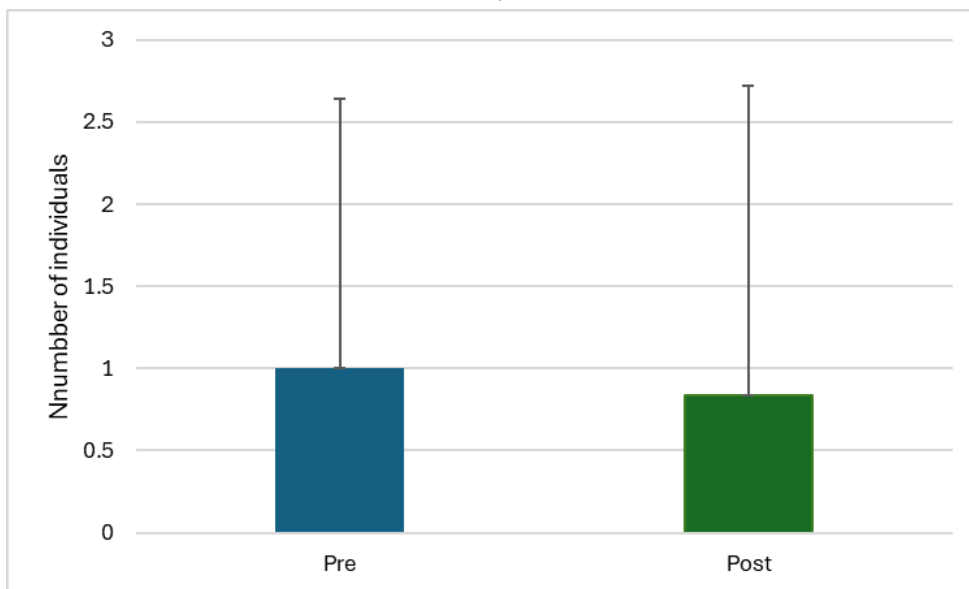


Figure 3. Average larva populations pre- and post-Helene show no statistical significance ($P = 0.645$)

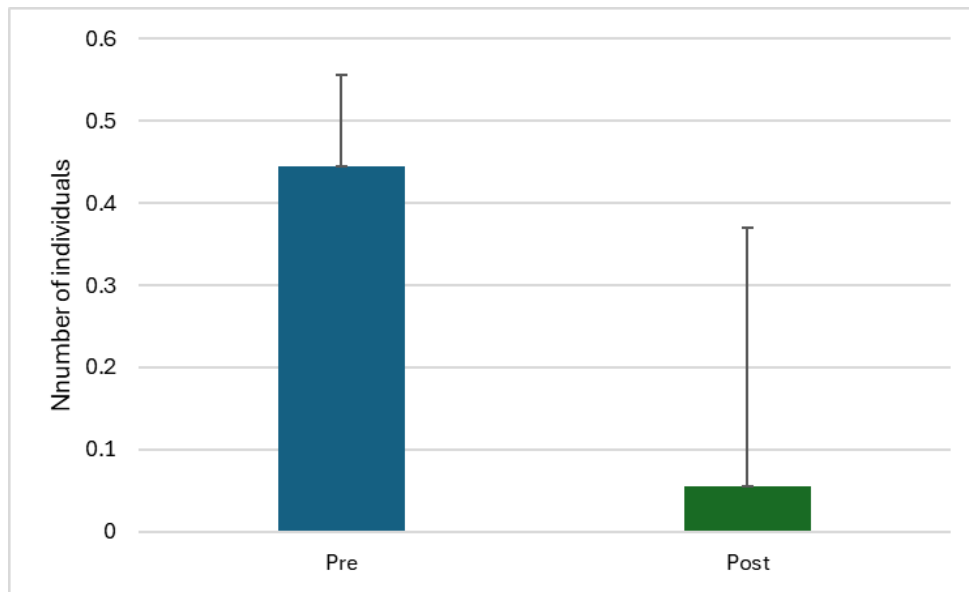


Figure 4. Average juvenile populations demonstrate a decline from pre- and post-Helene but no statistical significance ($P = 0.19$)

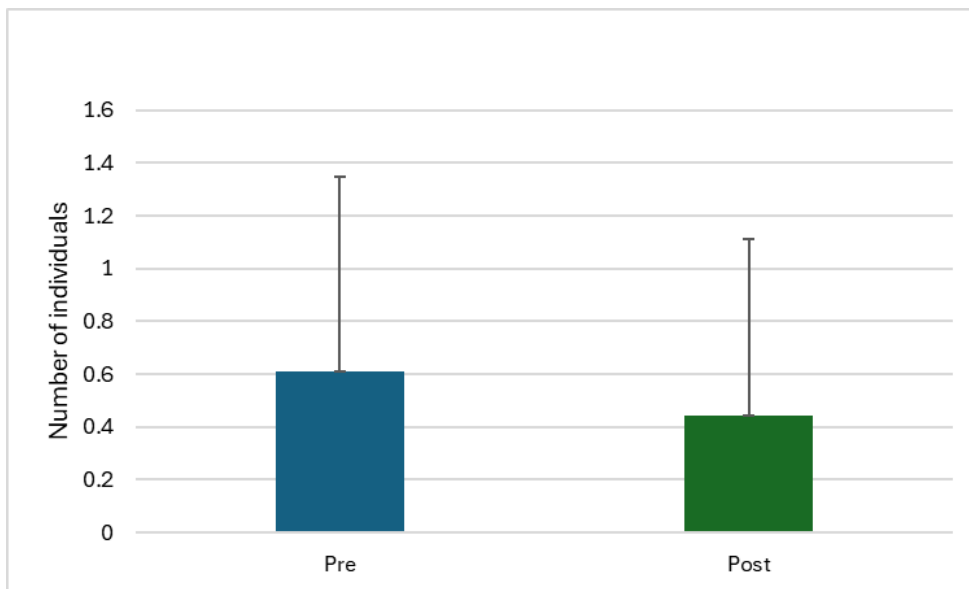


Figure 5. Average sub-adult populations show a slight decline pre- and post-Helene, but no statistical significance ($P = 0.51$)

Discussion

My results suggest that adult populations significantly declined after Tropical Storm Helene, raising concerns for future populations. While there was no statistically significant decline in other life stages, the decline in adults alone has the potential to critically harm

these populations. Hellbenders are considered adults when reaching sexual maturity at approximately five years old (Nickerson & Mays, 1973). The presence of younger age classes brings hope for the population to be replenished and recover from Helene; however, Freake & DePerno found that larva population survival rates are about 10% in the first year (2017). With low survival rates, younger populations may not reach adulthood to replenish populations. Additionally, recent studies have found that many populations are composed of older and larger adults, signaling a lack of successful recruitment and possible extinction (Diaz et al., 2022; Unger et al., 2013; Wheeler et al., 2003). With recruitment rates reaching concerning low levels and a loss in the reproductive population, there is reason for concern that if other age classes do not successfully reach maturation, we may see serious declines in recruitment.

Surprisingly, the larva populations did not show a significant decline in population after Tropical Storm Helene. While there was a slight trend, there was no clear decrease in populations, contradicting previous research conducted by Nickerson et al., who found larva populations decreasing after major flooding due to high conductivity and flow (2009). The lack of statistical significance may be due to low capture rates overall; with increased sample sites, we may see clearer trends. Another factor impacting statistical significance was the difference in site populations and responses to the storm.

Population estimates differed across sites, indicating a need for further research on additional factors impacting populations by site. The natural flow of rivers leads to a more optimal habitat for specific species and overall resilience to natural fluctuations and storms (Dolloff et al., 1994). Some additional factors impacting populations at varying levels by site include habitat loss, debris removal, movement rates, and riparian damage. When comparing sites, it is necessary to mention the presence of machine debris removal visible at four of the nine sites. There were visible impacts of these machines, including cracked rocks and tire tracks spanning the river. Because we were unable to sample after Helene, but before the machinery and after the machinery, we are unable to confirm what damage was caused by what factors. This makes it difficult to extrapolate the degree of impact when comparing populations among sites with or without debris removal. The debris removal creates an additional factor in analyzing populations that must be continually monitored to understand their impacts and make recommendations for potential future efforts for our rivers.

Biological significance is crucial to consider when examining rare species, particularly those with already declining populations. Overall, we are observing a decline in populations at most study sites, which is concerning, particularly in adult populations. As extreme hydrological events continue to increase, this data provides a baseline understanding of hellbender response to major flooding events.

Recommendations

We recommend monitoring of the populations at these sites to track age class and reproduction rates to better predict how populations respond. Additionally, factors such as riparian damage, riparian size, and land use should be researched to determine how sites respond differently to flooding. If factors can be identified, restoration practices can be focused on the correlated factors to attempt to build stream resilience to protect populations. These specific sites have a unique additional factor of heavy machinery debris cleanup. While we were unable to analyze the impact of debris removal due to a lack of post-Helene pre-debris cleanup data, these sites provide a location to track habitat and population changes following debris cleanup, providing data to inform future restoration efforts.

Acknowledgments

I want to express my absolute gratitude to my mentor, Dr. David Gillette, for his constant support and guidance. Thank you to Reed Rossell for being an amazing field advisor and help. This project would not exist without the previous research of Ben Dalton with the North Carolina Wildlife Resources Commission, the financial support from Defenders of Wildlife, Center for Biological Diversity, the North Carolina Collaboratory, and the UNCA Undergraduate Research Program. I also want to thank Tess Bryant, Halle West, Zach Grady, and all our volunteers for their tireless work in data collection.

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