1. ADMINISTRATIVE.

Name: Lydia Olander

Contact: lydia.olander@duke.edu

Institution: Nicholas Institute for Energy, Environment, and Sustainability, Duke University

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2. PUBLIC SUMMARY.

The Eastern Hellbender is a large salamander that depends on fast and clear streams of the Appalachian Mountains. Hurricane Helene struck western North Carolina in late September 2024 at the peak of breeding season. The catastrophic flooding displaced adult hellbenders, flipped rocks, and carried eggs downstream.

To understand what Helene did to hellbender habitat and where recovery efforts should be prioritized, we partnered with the North Carolina Wildlife Resources Commission (NCWRC) and the Aquatic Conservation Research Lab at Appalachian State University. We analyzed over a decade of stream habitat data from 62 survey sites across three drainages (New, Nolichucky, and Watauga) and examined each site against four types of storm damage: flooding, vegetation damage, infrastructure damage, and landslides.

Flooding has the most widespread impact with 97% of study sites affected. We identified 15 high-priority sites for post-Helene field visits based on the overlap with Helene damage layers (flooding, vegetation damages, landslides, and infrastructure failures) to assess habitat conditions and hellbender populations. Habitat measurements at three Nolichucky sites revealed that streams are now wider and deeper, with increased fine sediment accumulation. This is alarming for hellbenders because they depend on clean, clear water.

These findings are directly actionable for NCWRC wildlife biologists planning recovery efforts to assess habitat and population changes at high-priority sites most affected by

Helene damages. As climate change increases the frequency and intensity of extreme storms, maintaining long-term habitat data will be essential for protecting species like the Eastern Hellbender.

3. **TECHNICAL SUMMARY.**

Hurricane Helene struck western North Carolina in late September 2024, causing catastrophic flooding during the peak breeding season of the Eastern Hellbender (Cryptobranchus alleganiensis alleganiensis), a species currently under consideration for federal endangered status. This project had two primary goals: (1) synthesize available pre-Helene stream habitat baseline data from researchers working in hellbender regions, and (2) conduct a prioritization analysis to help North Carolina Wildlife Resources Commission (NCWRC) biologists prioritize post-Helene habitat assessment and hellbender population monitoring.

We compiled stream habitat data from 62 survey sites across three HUC8 watersheds (New, Watauga, and Nolichucky) and overlaid study site locations with four post-Helene impact layers: flooding extent polygon layer from NC Emergency Management, severe vegetation damage raster layer (based on NDVI changes) from US Forest Service, infrastructure failures (likely repair and likely replace infrastructure projects) from NCDOT, and landslide impact areas from USGS. A weighted sum prioritization analysis was done with 40% weight for flooding extent, 30% weight for severe vegetation damage, 20% weight for infrastructure failures, and 10% for landslide impact area. Of the 62 sites assessed, the top 33rd percentile was considered as high-priority and a total of 15 sites were high priority sites.

Most of the high priority sites are in Nolichucky drainage with a few in New and Watauga drainages. Three sites in the Nolichucky drainage have long term pre-Helene data as well as post-Helene data collected in 2025. These three sites showed that stream depth increased for all three sites, stream width, stream velocity, and percent fine materials increased in two of the sites, and we found unclear pattern for mean and median substrate size.

The project synthesized baseline habitat information and demonstrated that the existing ecological monitoring data can be used as post-disaster baseline information. The stream habitat data collection approach used by the Aquatic Conservation Research Lab at Appalachian State University provided a standardized approach, which would be helpful to other aquatic ecologists in the region to investigate the changes in stream habitat for other focal species.

4**. PURPOSE AND OBJECTIVES.**

The original objectives were to (1) assess available pre-Helene stream habitat data from stakeholders working in Helene-impacted areas and (2) analyze that data to guide post-Helene data collection planning. Both objectives were achieved. One modification was made to how hellbender life history literature was incorporated. The original proposal intended to use published literature to categorize study sites by habitat suitability; however, the existing literature does not provide direct quantitative thresholds for the stream habitat metrics collected at our study sites. Instead, we incorporated hellbender occurrence records from the NC Natural Heritage Program as an additional prioritization criterion. Sites already ranked as high priority based on Helene damage severity were further elevated in priority if they also had confirmed pre-Helene hellbender occurrence records, ensuring that post-Helene assessment efforts would be concentrated where both habitat disturbance and species presence had been documented.

5. **ORGANIZATION AND APPROACH.**

Task 1: Assess availability of baseline habitat data. We consulted with wildlife biologists from NCWRC to determine whether pre-Helene stream habitat data had been collected in hellbender survey areas. Those conversations confirmed that the Aquatic Conservation Research Lab at Appalachian State University held the relevant baseline dataset.

Task 2: Understand data collection methods. We worked with Dr. Michael Gangloff at App State to obtain documentation of field data collection protocols, including sampling periods, number and length of transects, particle selection methods, and measurement approaches for stream depth, width, velocity, percent fine materials, and substrate size.

Task 3: Clean and organize baseline data. Habitat data had been collected across multiple years in varying formats and measurement units. We standardized and reorganized records across all three HUC8 drainages to prepare a consistent dataset for analysis.

Task 4: Prepare site location data. We worked with the App State team to retrieve geographic coordinates for each study site and match location information to the corresponding habitat records.

Task 5: Spatial analysis. We overlaid four spatial layers representing Helene damage, including flood extent, vegetation damage, infrastructure damage, and landslide impact area, with buffers of study site locations to quantify the degree of overlap at each site.

Task 6: Prioritization analysis. We consulted with Lori Williams and Kendrick Weeks from NCWRC to finalize damage indicator weights and apply them to calculate a composite prioritization score for each site.

Task 7: Pre- and post-Helene habitat comparison. For a subset of sites where post-Helene field data were collected by the App State team in 2025, we visualized long-term trends in stream habitat metrics to characterize change before and after the storm.

Task 8: Spatial analysis of Helene damage with Hellbender EO. In addition to evaluating the study sites from the Aquatic Conservation Research Lab at App State University, we also evaluated the extent of spatial overlay of Helene damage (flood extent, vegetation damage, infrastructure damage, and landslide impact area) with the hellbender element occurrence layer (at stream segment level).

6. **PROJECT RESULTS.**

Data synthesis. Stream habitat data were processed and cleaned for 62 study sites across three drainages: 26 in the New, 25 in the Nolichucky, and 11 in the Watauga. Site geographic coordinates were obtained and verified in collaboration with the Aquatic Conservation Research Lab at App State.

Spatial overlay. Intersecting study site locations with four Helene damage layers revealed that 60 of 62 sites (97%) fell within flood extent. In addition, 28 sites showed severe vegetation damage (large canopy gaps), 17 sites were in proximity to damaged infrastructure identified by NCDOT as likely requiring replacement or repair, and 11 sites were affected by landslides.

Prioritization analysis. Sites with a weighted composite prioritization score in the top 33rd percentile were classified as high priority for post-Helene assessment. This threshold yielded 15 high-priority sites: 12 in the Nolichucky drainage, 2 in the New drainage, and 1 in the Watauga drainage.

Pre- and post-Helene habitat comparison. Of the 15 high-priority sites, 6 were visited by the App State team in 2025. Three sites in the Nolichucky drainage had sufficient long-term pre-Helene data to support a before-and-after comparison. The remaining three visited sites (2 in the New drainage, 1 in the Nolichucky drainage) had only a single year of pre-Helene data, limiting the depth of temporal comparison at those locations.

EO overlay. Of the 49 hellbender occurring stream segments in western NC, 22 of them overlaid with severe vegetation damage (percent overlap range: 0.05% to 18.90%), 28 overlaid with flooding extent (percent overlap range: 9.61% to 99.98%), 22 overlaid with likely repair or likely replaced infrastructures (range: 1 to 32 failed infrastructures), and 12 overlaid with landslide impact area (percent overlap range: 0.33% to 29.62%).

7. **ANALYSIS AND FINDINGS.**

Pre- and post-Helene habitat comparisons at three long-term monitoring sites in the Nolichucky drainage revealed consistent directional changes in stream channel conditions. All three sites showed increases in stream depth, two sites showed increases in wetted width, and two sites showed increases in stream velocity. Fine sediment accumulation increased notably at two sites, with percent fine materials measuring 35% and 41% in 2025 compared to pre-Helene averages of 26% and 21% at those respective sites. This increase is ecologically significant for hellbenders because sand and silt can fill the interstitial spaces between and beneath streambed rocks that the species relies on for shelter and nesting. No consistent directional pattern was detected for mean or median substrate size, likely reflecting high natural variability in those metrics across pre-Helene sampling periods.

8. **CONCLUSIONS AND RECOMMENDATIONS.**

Both project objectives were completed successfully. The primary challenge encountered was in the data cleaning phase, where inconsistencies in site naming conventions across more than a decade of field surveys created difficulties in correctly matching habitat records to their corresponding site coordinates. These discrepancies were resolved through direct communication with the Aquatic Conservation Research Lab at App State to verify site identities.

The logical next steps are for Lori Williams and other NCWRC wildlife biologists to conduct field visits to the high-priority sites to assess post-Helene habitat conditions and estimate hellbender occurrence and abundance. Continued monitoring at the three Nolichucky sites with long-term data would also be valuable for tracking whether fine sediment levels persist, worsen, or recover over time.

9**. MANAGEMENT APPLICATIONS AND PRODUCTS.**

The prioritization analysis and site-level habitat assessment developed through this project are intended to directly inform NCWRC's hellbender recovery planning in Helene-impacted areas of western North Carolina. The ranked list of high-priority sites provides wildlife biologists with a data-driven basis for allocating limited field survey capacity across a large landscape in the aftermath of a major disaster.

Key collaborators and stakeholders on this project included:

- Lori Williams, NCWRC Wildlife Diversity Biologist: co-developed the research plan, provided input on damage indicator weights, and will use project deliverables to guide post-Helene hellbender survey planning.

- Kendrick Weeks, NCWRC Western Wildlife Diversity Program Supervisor (now Assistant Chief of Species Monitoring and Restoration in the Helene Restoration Division of NCWRC): provided input on project design and deliverables.
- Dr. Michael Gangloff, Appalachian State University: contributed baseline stream habitat data and post-Helene field survey data collected by his lab.
- Hutch Whitman, Appalachian State University: conducted post-Helene field surveys at priority sites in 2025.

The primary decision support product developed through this project is the weighted composite prioritization scores, which ranks hellbender survey sites by estimated Helene impact severity across four damage categories.

Stakeholder feedback confirms the management utility of these products. Lori Williams noted: "These deliverables will be extremely helpful as we continue to prioritize hellbender reaches for inventory/monitoring and assessing post-Helene status." Kendrick Weeks added: "Your products have been helpful, and I can see them continuing to be useful as we work to restore watersheds and monitor Hellbenders going forward."

10. **OUTREACH AND COMMUNICATION.**

Project findings were communicated to agency partners and the public through the following activities:

Stakeholder presentation. A preliminary results presentation was delivered via Zoom to Lori Williams and Kendrick Weeks (NCWRC). Jin Bai presented the prioritization methods and findings in detail and addressed questions. Feedback from this meeting was incorporated into the final prioritization analysis before deliverables were prepared.

Deliverables to NCWRC. Finalized project deliverables were shared directly with Lori Williams and Kendrick Weeks and included: (1) a spatial dataset of the 62 study sites with prioritization scores, (2) an attribute table spreadsheet with a dedicated data dictionary tab describing each field, and (3) an updated slide deck summarizing project finding. These materials are intended for use in ongoing hellbender survey planning and species recovery efforts.

Public outreach. A public-facing article summarizing project findings was published on LinkedIn, reaching 1,320 LinkedIn members as of 6/26/2026. The article presents the prioritization work and habitat metric comparison findings in accessible language for a general audience.

Bai, J. (2025, June). How did Hurricane Helene reshape hellbender streams? LinkedIn. https://www.linkedin.com/pulse/how-did-hurricane-helene-reshape-hellbender-streams-jin-bai-lbzye/