# Enhanced understanding of factors affecting stream condition can improve restoration outcomes

**Issue:** The Chesapeake Bay Watershed Agreement has an outcome to improve stream health. Current restoration approaches have led to mixed improvements in stream conditions, indicating that some major stressors and their sources were likely overlooked. Managers could benefit from synthesized information on most reported stressors responsible for aquatic community impairment and their linkages to other stressors to improve restoration approaches.

**USGS Study:** Stream health can be affected by multiple interlinked stressors generated from various sources and land practices, as shown in Figure 1. This study synthesized information from the literature and state data to develop conclusions about stressors affecting the conditions of aquatic communities in streams in the Chesapeake Bay Watershed. Following the US EPA's structure for defining stressor categories for streams, nine stressors were considered: geomorphology, salinity, nutrients, toxic contaminants, acidity, riparian alteration, dissolved oxygen (DO), flow, and temperature. Geomorphology refers to altered streambed conditions and includes stressor subcategories of physical habitat and sediment. Toxic contaminants include mercury, metals, pesticides, and others. An extensive literature review was conducted, with 65 multi-stressor studies examined, and a subset of 33 used for a meta-analysis to determine the relative importance of the stressors. The jurisdictional impairment analysis focused on states that spanned the Chesapeake Bay Watershed and used the U.S. EPA's Assessment, Total Maximum Daily Load Tracking and Implementation System (ATTAINS) regulatory database.

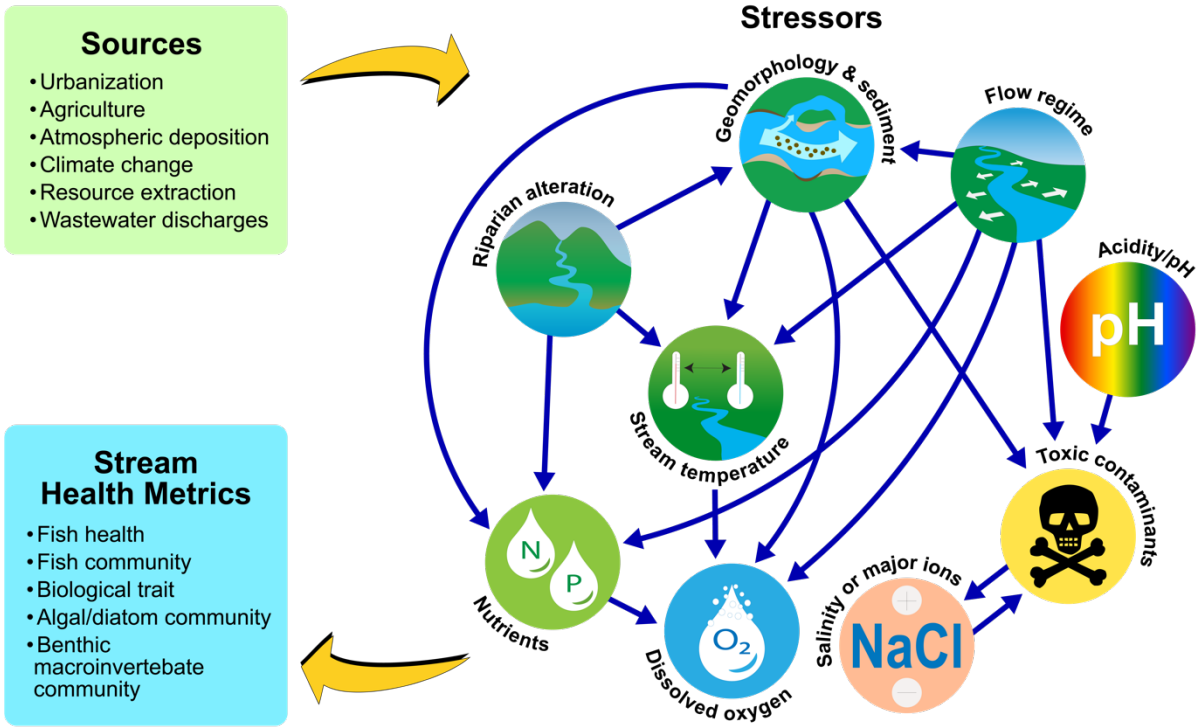


*Figure 1. Relationship among sources, interactions between stressors generated from these sources, and measures of stream health based on information provided in the US EPA 2017. Adapted from Fanelli et al. 2022 by UMCES-IAN*

**Major findings:** The findings are organized around the importance of different stressors based on the literature review and the jurisdictional impairment analysis. The study classified the importance of stressors as high, moderate, or low (Figure 2), and the primary impairments in each jurisdiction (Figure 3). Literature review identified salinity, geomorphology, and toxics as the most important stressors while jurisdictional impairment analysis identified geomorphology, salinity, and nutrients as the most reported stressors in the Chesapeake Bay watershed.

| Stressor category | Literature review | | Jurisdictional analysis |
|---|---|---|---|
| | Frequency of measurement | Frequency of importance | Watershed-wide ranking |
| Geomorphology | High | High | High |
| Salinity & major ions | High | High | High |
| Nutrients | High | Moderate | High |
| Toxic contaminants | Low | High | Moderate |
| Flow | Low | Moderate | Moderate |
| Acidity | Moderate | Low | Moderate |
| Riparian | Low | Low | Moderate |
| Dissolved oxygen | Moderate | Moderate | Low |
| Temperature | Moderate | Low | Low |

*Figure 2. Summary of rankings of stressors in literature review and the jurisdictional impairment analysis. Adapted from Fanelli et al. 2022 by UMCES-IAN*

- **Geomorphology and salinity were identified as having high importance** in both the literature review and impairment analysis. Overall, geomorphology is likely a primary regional stressor, especially in agricultural settings, whereas salinity and major ions are likely a regional primary stressor in urban and mining settings. Nearly 40% of aquatic community impairment was attributed to altered geomorphology. Altered geomorphology includes sediment that degrades stream conditions. Sediment is a known issue within the Chesapeake Bay watershed and has been identified as one of the top pollutants of concern for Chesapeake Bay health. For salinity, the primary sources were deicers, weathering of impervious surfaces or mined materials, or discharges from industry.

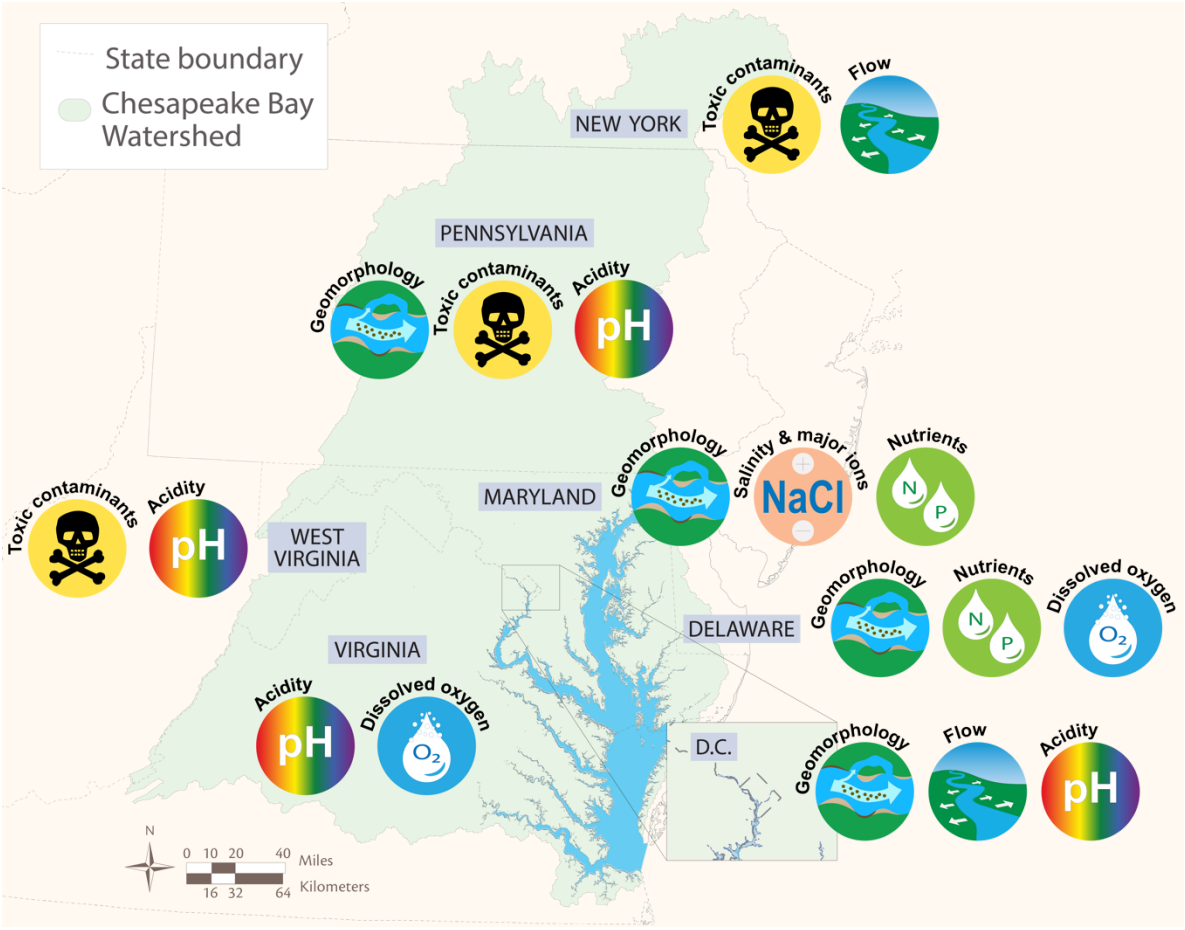


*Figure 3. Top reported stressors for each jurisdiction in the Chesapeake Bay watershed from Table 3 in Fanelli et al. 2022. Graphics by UMCES-IAN*

- **Nutrients were identified as having high to moderate importance.** The jurisdictional impairments rated nutrients as having high importance, with the literature review resulting in moderate importance. Nutrients may contribute to biological impairment but could also serve as a proxy stressor or co-occurring stressor. A proxy stressor is mechanistically related to the primary stressor, whereas a co-occurring stressor is correlated with the primary stressor but has no mechanistic relation. Nutrients contribute to biological impairment indirectly; whereby elevated nutrients cause decreases in DO levels and shift to more tolerant taxa. Nutrients also degrade the quality of food sources for macroinvertebrates and contribute to algal blooms.
- **Toxic contaminants were identified as important stressors but have limited data reported in the literature or by jurisdictions.** Although there was limited monitoring, toxic contaminants, especially pesticides, were important across multiple common land-use settings in the literature review meta-analysis. By contrast, pesticides and other organic contaminants were rarely reported in the jurisdictional impairment analysis. The only pesticide impairments were for legacy banned substances, suggesting that contemporary or emerging toxic contaminants are likely understudied across the region.

Overall, the importance of reported stressors that affect stream aquatic communities varied across different settings and among jurisdictions. However, uncertainties in the synthesized studies could impact stressor identifications and rankings in this meta-analysis. For example, a dominant stressor could be misidentified for a proxy or co-occurring stressor, thus, stressor interactions should be carefully considered. Another potential source of uncertainty is the differences in study designs and priorities among the jurisdictional approaches.

**Management, monitoring, and research applications:** Managers could benefit from detailed information on stressors resulting in biological impairment to adopt a more unified approach. This study highlights a mismatch between research and jurisdictional actions toward reporting stressors. Updated literature could help fill potential knowledge and management gaps regarding emerging and traditional stressors. Additionally, the study outlined key management, monitoring, and research suggestions for the nine stressors:

1. **Geomorphology**. Restored geomorphic function in the channel and floodplain can be achieved by focusing on upstream hydrological controls
2. **Salinity**. It is important to consider which activities lead to long-term elevated salinity. Maryland is the only jurisdiction that reports on salinity, so more monitoring is needed across the region.
3. **Nutrients**. The impairments caused by nutrients are often indirect, so it is important to consider co-occurring or proxy stressors.
4. **Toxic contaminants**. Toxic contaminants are underrepresented in stressor identification assessments. It would be helpful to expand monitoring to emerging toxic contaminants. Research suggestions include direct sampling of pesticides in stream reaches.
5. **Flow.** Flow may also need more monitoring given its impact on other stressors. Reducing flow variability may also improve altered streambed geomorphology and channel erosion. Research needs include direct monitoring of stage or discharge, which is best coupled with rainfall monitoring.
6. **Acidity.** Areas which are vulnerable to acidic inputs, such as from legacy acid mining or atmospheric deposition, could benefit from further monitoring.
7. **Riparian alteration**. Riparian alteration is a potential stressor in agricultural regions and can be improved through strengthening riparian buffers/zones.

*Impairments in Linganore Creek in Maryland (top) and Little Conestoga Creek in Pennsylvania (bottom) caused by altered geomorphology and high nutrients from sedimentation and agricultural runoff. Photos by Allen Gellis*

8. **Dissolved oxygen**. Reduced dissolved oxygen can be improved by focusing on areas with high nutrient inputs and/or altered thermal regimes.
9. **Temperature**. Stream temperature will become a primary stressor in more pristine waters with influences from climate change. Consistently monitoring the condition of such vulnerable streams may provide insight into temperature impacts on stream health.

The interrelationship among different stressors and different stream health metrics needs to be further studied to improve monitoring and inform restoration activities. Multi-stressor interactions are typically tested in flume or mesocosm studies, but extrapolation of findings from lab to field should be carefully considered.

Findings from different studies and jurisdictional analysis could be more generalizable by using common terminology, study and monitoring designs, statistical analysis, and understanding of source-stressor-response relationships. Establishing a unified approach for stressor identification is recommended, including use of EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS) and leveraging of common study designs.

**For more information:**

- Publication title: Identifying Key Stressors Driving Biological Impairment in Freshwater Streams in the Chesapeake Bay Watershed, USA
- Publication URL (with supplementary information): https://link.springer.com/article/10.1007/s00267-022-01723-7
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- This science summary was prepared in collaboration between the USGS and the University of Maryland Center for Environmental Science, Integration and Application Network. More information on UMCES-IAN can be found at: https://ian.umces.edu/
- Web version: https://www.usgs.gov/centers/chesapeake-bay-activities/science/enhanced-understanding-factors-affecting-stream-condition

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