NEW YORK STATE WATER RESOURCES INSTITUTE
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Does this taste salty to you?

Chronic effects of road salt application on stream food webs

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Content

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Executive Summary

Summary Points of Interest

1. Determine whether intra-annual salinity changes affect community composition and biochemical signatures of macroinvertebrates and periphyton.
2. Create baseline data for annual collections of macroinvertebrates and periphyton to allow future changes in community composition to be identified.

One understudied effect of climate change is reduced lake ice cover, which leads to greater lake-effect snow and may in turn cause an increase in road salt use. New York State applied over 900,000 tons of salt during winter 2020-2021, more than any other state. Excess salt in freshwater ecosystems can negatively affect critical organisms living there. Current studies have thus far examined salt effects on water chemistry and a few target organisms. One such study determined that high salinity is increasing the amount of omega-6 fatty acids in algae, which can have negative effects on consumer organisms. These organisms are sentinels of water quality, and elevated salinity is likely to have significant consequences for the fish and aquatic food webs within affected ecosystems. The purpose of this study is to investigate the effects of winter road salt throughout the year on stream algae and their invertebrate consumers in three regions across the state by investigating streams under various salting regimes.

Keywords
Road Salt, Surface Water, Water Quality

Policy Implications

This project targeted the following WRI Agenda Items:

- Theme A: Items 2, 3, 5, and 12
- Miscellaneous: Items 1, 3, 6, and 8

The outcomes of this project will be a first look into the consequences of excessive road salt application to streams and their biological communities. The lessons learned here can provide scientific evidence that will inform future updates to road safety practices. We will make these data available to management associations like the Lake Erie Watershed Protection Alliance, local governing entities like the City of Oneonta, and will contribute to a larger, state-wide Division of Water Data Portal with our collaborators at other institutions. Our partners are committed to both the protection of freshwater habitats as well as the training of the next generation of aquatic scientists.

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Introduction

"The purpose of this study is to investigate the effects of winter road salt on stream periphyton and macroinvertebrates throughout the year."

Chronic, long-term effects of winter road salt contamination of freshwater habitats are becoming increasingly apparent (1-3), and the impacts of climate change (less lake ice cover leading to more lake effect snow events) may increase road salt use (4). In the 2020-2021 winter season, New York state applied over 900,000 tons of solid salt which was more than any other state (5). Road salt application and deicing practices are of great concern to regional and local stakeholders in New York state. Stakeholder organizations such as Lake Erie Watershed Protection Alliance in the west and the city of Oneonta in the central region have expressed interest in this project and the need for this proposed work. The use of salt solids as a deicing agent can be particularly hard on aquatic ecosystems as they can persist in the environment and slowly infiltrate surrounding rivers (6). To help address this issue, stakeholder groups are working with research scientists at local institutions and agencies to monitor the impact of road salts on stream water chemistry.

Small streams are among the most numerous types of waterbodies and interact with the most people (7). Therefore, it is possible to use streams and their biotic communities as indicators of how human activity can impact water quality and ecosystem health. Most current studies have only examined chloride concentrations in water alone (e.g. 4) or related effects on abundance and life-history of select organisms (some fish species, *Daphnia*) (8). However, recent regional studies have determined high chloride concentrations are altering fatty acid production in stream periphyton by increasing the amount of omega-6 fatty acids (9), which has consequences for higher trophic levels (10).

The purpose of this study is to investigate the effects of winter road salt on stream periphyton and macroinvertebrates throughout the year. These groups of organisms have a long history of use in bioassessment and effects on these groups can have important consequences for higher trophic levels, including fish and terrestrial predators as well.

We expect organismal diversity will shift to more tolerant taxa and biochemical profiles will indicate lower food quality and stress. To accomplish this, we deployed chloride HOBO probes in streams across New York, focusing on the Lake Erie Watershed Management area, the Upper Susquehanna River basin, and Lower Hudson Valley. Each region will be sampled monthly for

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stream water chemistry, periphyton biofilms, and stream macroinvertebrates.

Methods

Across the Western New York region (WNY), the Upper Susquehanna River basin (CNY), and the Lower Hudson Valley (HUD), 30 streams were selected for the study, with 10 streams sampled in each region (see Appendix 1). Each site was equipped with a conductivity HOBO logger in May 2024, and stream sampling has been conducted monthly since then and will continue through April 2025. The HOBO loggers were installed following the manufacturer's recommendations. During each site visit, data from the HOBO loggers were downloaded, and organismal sampling was conducted downstream of the logger locations. Sampling methods closely adhered to the US EPA Rapid Bioassessment Protocol (11).

Stream water was assessed for additional condition and quality parameters, including in situ measurements (temperature, pH, dissolved oxygen [DO], and conductivity) and ex situ analyses (soluble reactive phosphorus [SRP], ammonium [NH_4^+], and nitrate [NO_3^-]). Field measurements were conducted using a YSI Professional Plus with multiparameter sondes. Calibration for pH, DO, and conductivity were performed according to the manufacturer's protocols.

Periphyton was collected at each site by scraping material from five fist-sized cobbles using stiff-bristle brushes. The cobbles were measured in situ according to specific geometric shapes, allowing colonizable surface areas to be calculated (12). The scraped material from the cobbles was pooled, and the total volume was recorded. A mixed subsample was stored in a 250-mL bottle and placed in an ice cooler for transport to the respective regional laboratories.

Macroinvertebrates were collected to assess biodiversity using a Surber sampler in representative areas of stream depth and flow. Samples were preserved in 70% ethanol for laboratory sorting and identification. Macroinvertebrates designated for fatty acid analysis were stored separately, and samples not preserved in ethanol were transported on ice.

All samples were either processed or frozen within 72 hours of collection before being shipped to partner institutions for further analysis. Periphyton analyses with measurements of biomass and stoichiometry, including chlorophyll content, ash-free dry mass, elemental carbon (C), nitrogen (N), phosphorus (P), and fatty acid composition. Periphyton was digested for diatom frustule identification (13) and was jointly assessed at Daemen and Fordham. Macroinvertebrate identification (14) occurred at Daemen and Oneonta. Ice-preserved (non-ethanol) macroinvertebrates were weighed to determine fresh biomass and analyzed for fatty acid composition at Daemen.

Conductivity data from the HOBO loggers were converted into salinity measurements (2–42 ppt) using Onset software, which was purchased alongside the loggers. Nutrient ion concentrations (SRP, NH_4^+, NO_3^-) in stream water were analyzed at

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Daemen University using an Astoria-Pacific rAPID-T nutrient analyzer, following the manufacturer's protocols.

Periphyton biomass and stoichiometric measurements were conducted at Daemen and Fordham. Chlorophyll pigments were extracted in 90% neutralized acetone, measured by spectrophotometry (15). Ash-free dry mass was measured by collecting periphyton material on a pre-ashed Whatman 47 GF/F then baking samples in a muffle furnace at 450 C for 2 hrs. Periphyton elemental P content was digested using a persulfate (16) method and analyzed as SRP at Daemen. Elemental C and N were measured using a ThermoFisher CHN Elemental Analyzer at Fordham. Fatty acids in periphyton and macroinvertebrates were extracted using a 2:1 chloroform:methanol solution (17) and, after transferring to hexane, were measured on a Shimadzu GC-MS 2010 using a Restek Rsi-5Sil capillary column at Daemen.

Results and Discussion

Stream Salinity Trends

While there are a few streams whose final salinity measurements have not been reported, many of our stream sites have concluded their sampling. Salinity measurements from the HOBO loggers were compiled into monthly averages for each stream and each region (CNY, HUD, and WNY). A few important patterns in stream salinity have emerged (Figure 1). Each region exhibited a distinct pattern regarding salinity, with the CNY streams maintaining consistently low levels of salinity, always below the US EPA threshold of chronic salinity pollution of 0.23 ppt. The HUD and WNY regions did have streams that were consistently below that threshold, but many streams and therefore regional averages were often between the US EPA chronic and acute (0.86 ppt) salinity pollution.

The late winter and early spring timeframe saw the highest salinity measurements in streams. We suspect this may be due to the consistently low temperatures experienced this winter that prevented snow and ice from melting and carrying road salt run off until the late winter and early spring periods. This effect was most drastic in some select streams in the WNY and HUD regions. Specifically, the Bronx River in the HUD region and the south branch of Smokes Creek in the WNY region. Both streams experienced a few days of >1 ppt of salinity during late February and early March.

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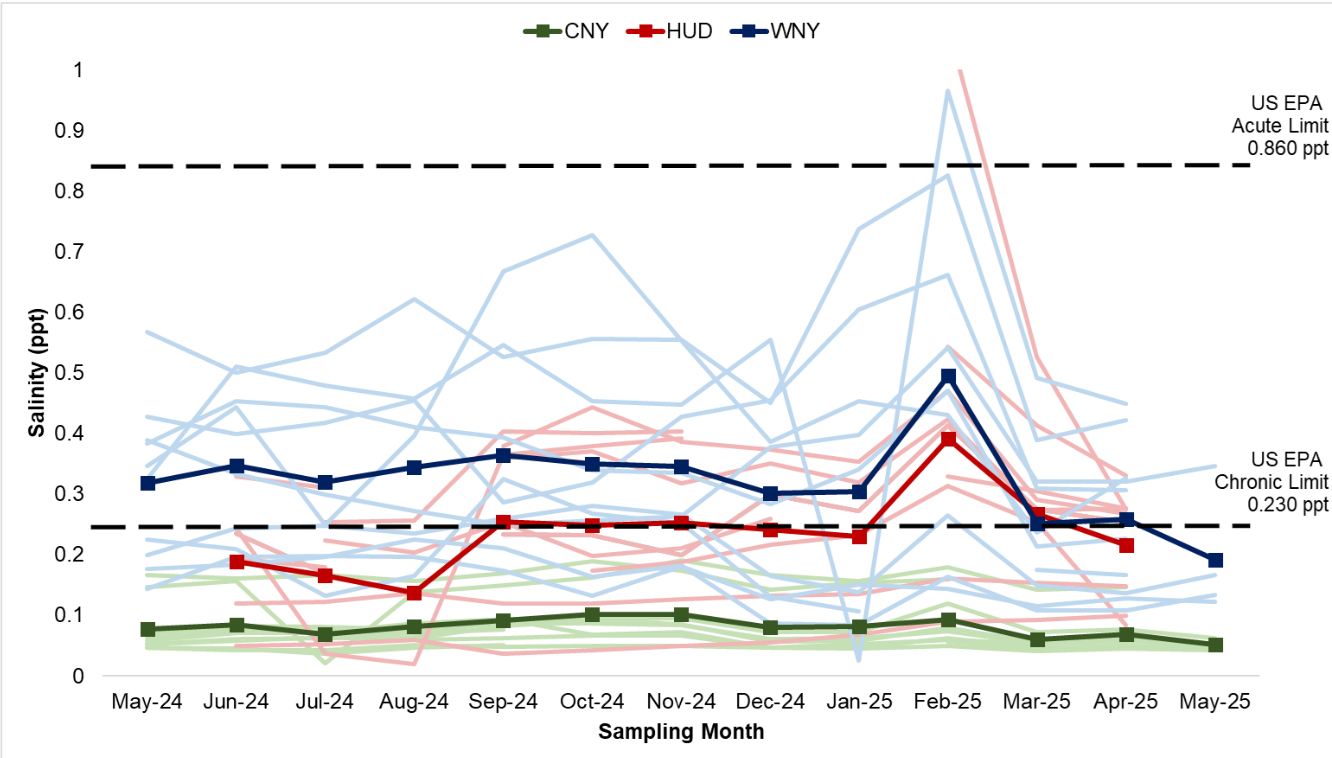

Figure 1: Monthly averages for each stream (faint lines) and for the overall region (solid lines). Gaps in lines are due to probes not being accessible due to ice or flooding and therefore lost data.

Periphyton Biomass

Chlorophyll (Figure 2) and Ash-Free Dry Mass (AFDM, Figure 3) responses to salinity were highly variable and are likely confounded by other landscape metrics yet to be evaluated. For this analysis, all streams within a region were combined into a monthly average to highlight regional trends in periphyton biomass responses to salinity. Generally, both Chlorophyll (R = 0.483, P = 0.017) and AFDM (R = 0.603, P = 0.005) were positively correlated with average monthly salinity measurements. Both metrics exhibited distinct regional patterns, generally following the stream salinity pattern above. The CNY region exhibited the lowest chlorophyll and AFDM compared to salinity, followed by HUD and finally WNY. The WNY region demonstrates the most variable of all measurements.

Periphyton in these streams have likely already experienced a period of selection for salinity tolerant taxa which may limit our ability to detect responses to increases in salinity. However, this may only be true for the biomass metrics presented here. Stoichiometric and macromolecule analyses have yet to be conducted and may yield different outcomes. Additionally, not all measurements for the CNY and HUD regions have been analyzed yet. The inclusion of this data may shift the trends presented here.

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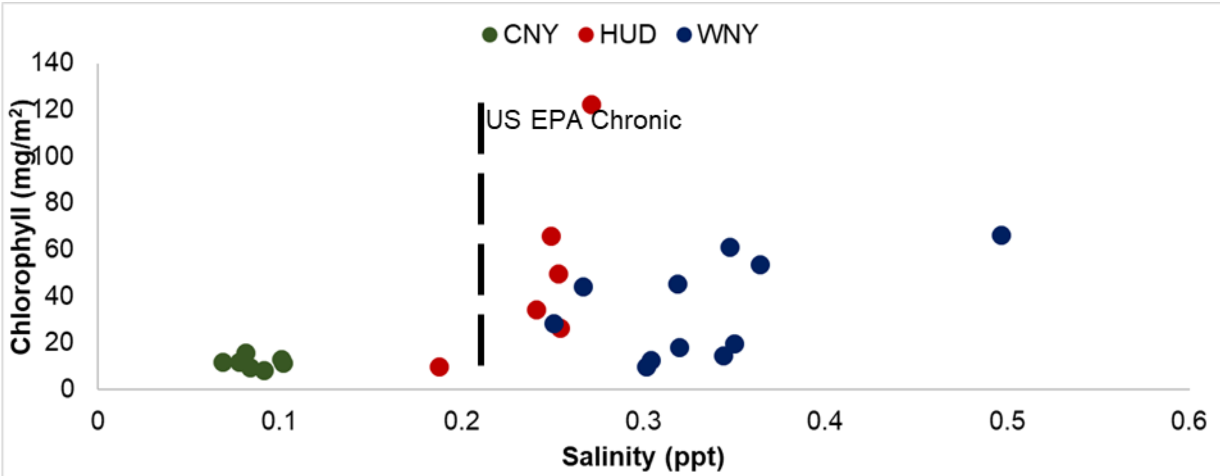

Figure 2: Monthly averages of chlorophyll and salinity within each region. A marker of the US EPA limit of chronic salinity pollution is indicated (0.23 ppt).

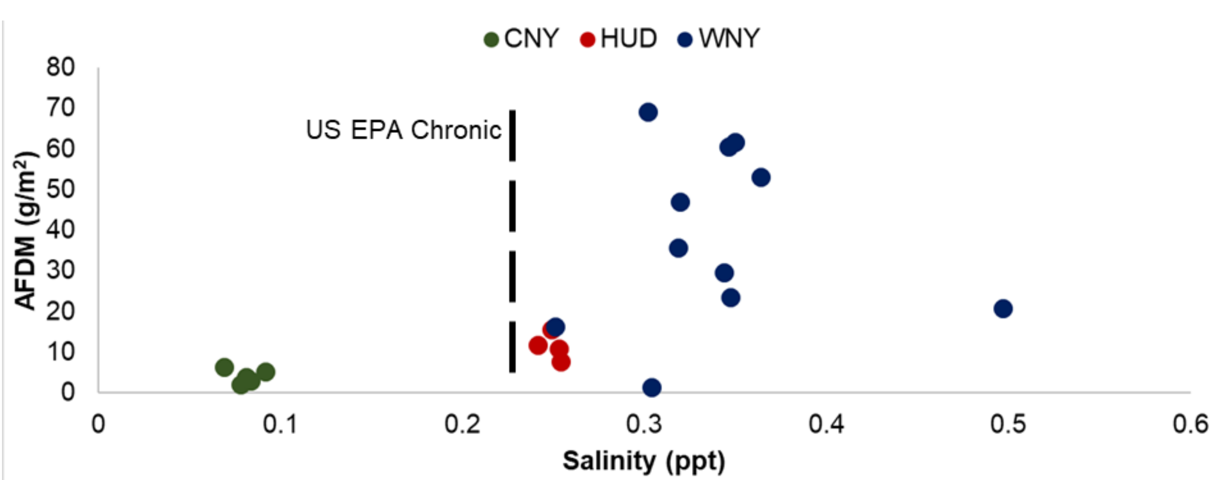

Figure 3: Monthly averages of Ash-Free Dry Mass (AFDM) and salinity within each region. A marker of the US EPA limit of chronic salinity pollution is indicated (0.23 ppt).

Macroinvertebrate Indicators

While we can examine some statewide trends regarding salinity and periphyton biomass, our macroinvertebrate analysis lags far behind. A limited analysis of indicator macroinvertebrate taxa within the WNY region is presented here. We have a focus on EPT larval insects. We calculated the percentage of EPT taxa present in WNY streams from May 2024 through October 2024. Across all streams and months, we found a negative correlation (R = -0.341, P = 0.012) of EPT taxa to salinity (Figure 4). Higher salinity was associated with lower amounts of EPT taxa. There is a notable exception to this trend. Specifically in the south branch of Smokes Creek, this stream regularly exhibited amounts of EPT insect larvae in line with extremely rural streams such as Sprague Brook.

We further analyzed EPT amounts based on the land use surrounding each of our WNY streams. We classified streams as being “agricultural” (Bull, Mud, Keg, 12 Mile), “residential” (East branch 18

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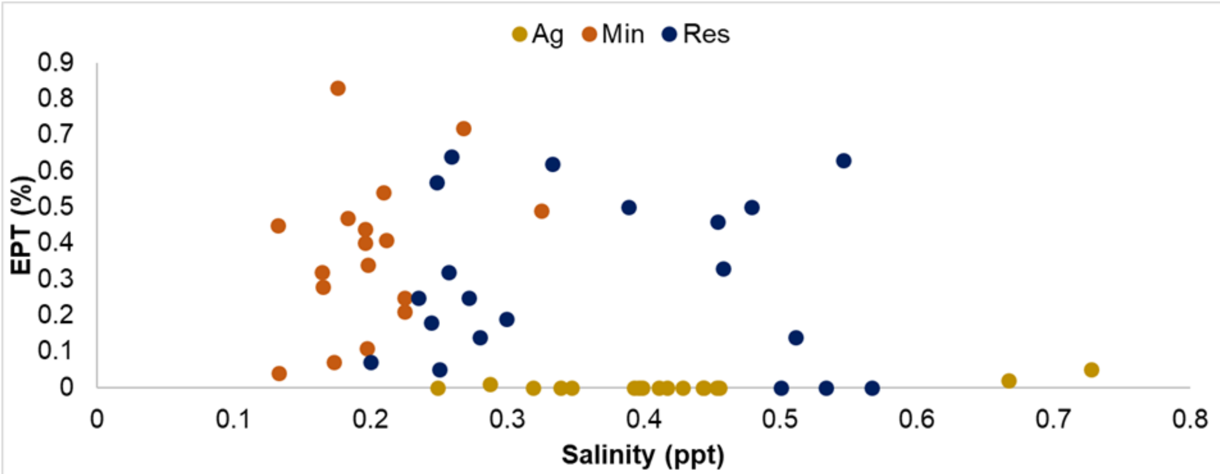

Figure 4: Percentage of EPT taxa in each stream compared to the associated salinity measuremnt. Points are separated by sampling-location land use categorization (Ag: Agricultural, Min:Minimal, Res:Residential).

Mile, south branch Smokes, Big Sister), or "minimal" (Buffalo, Elton, Sprague). When plotted based on these land use categories, these measurements form distinct clusters (Figure 4). Minimal and residential streams had similar amounts of EPT taxa, however they varied drastically in terms of salinity. Agricultural streams were regularly devoid of any EPT taxa, especially in Bull and Mud creeks, which are sediment-bottoms streams. Keg and 12 Mile are typical cobble-bottom streams however they had very few EPT taxa. It should also be noted that all agricultural streams were located in Niagara county.

Additional Measurements

Sample measurements are ongoing and are being posted to our project website as soon as they become available (https://sites.google.com/daemen.edu/nysaltstudy/home). Available data include the following:

- In situ stream measurements (temperature, pH, dissolved oxygen, conductivity, width, depth, velocity)
- Stream salinity daily averages
- Stream phosphate measurements (limited)
- Periphyton biomass (chlorophyll [a, b, c], AFDM)
- Periphyton phosphorous content (limited)

There are still several metrics remaining to analyze. We expect this data to be mostly complete by October 2025:

- Complete stream nutrients (phosphate, nitrate, ammonium)
- Completion of periphyton biomass
- Completion of periphyton phosphorous
- Periphyton carbon and nitrogen stoichiometry
- Periphyton fatty acid composition
- Periphyton diatom biodiversity
- Macroinvertebrate fatty acid composition
- Macroinvertebrate biodiversity

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Student Training

A project of this scale has provided ample opportunities for training future aquatic scientists. Importantly, this project provided summer funding for one graduate student and three undergraduate students. Many recent studies have shown that socio-economic factors often keep historically underrepresented students from participating in important, career-defining field work (18-20). All students involved in field collections will be offered the opportunity to be co-authors on resulting publications, provided they assist in the writing and editing process.

Students included in this research:

- Daemen University
    - Madelyn Casselman
    - Grace Covey
    - Daniel Dzierzewski (LEWPA)
    - Tyler Evans
    - Sage Sellers (WRRI)
- Fordham University
    - Evangeline Byers (WRRI)
    - Benjamin Gelman
    - Kate Laboda
    - Regan Phelan
- SUNY Oneonta
    - Benjamin Peterson (WRRI)
    - Gina Reinhardt
    - Eleanor Rettew (WRRI)

Further undergraduate training will occur through the integration into relevant courses such as Limnology (Daemen), Aquatic Invertebrate Ecology (Oneonta), and Algal Biology (Fordham).

Publications/ Presentations

This project will result in a number of publications and presentations of the collected data. Currently all publications are in preparation and have not yet been submitted for publication.

1. “Annual effects of road salt on stream periphyton and macroinvertebrate biodiversity” (Publication): Planned submission to Freshwater Science

2. “Annual effects of road salt on stream periphyton biochemical properties” (Publication): Planned submission to Journal of Phycology

3. “Annual effects of road salt on stream food webs using fatty acids” (Publication): Planned submission to Freshwater Biology

We have additional plans to present our preliminary findings at several scientific meetings upon conclusion of our field collection:

1. “Hold the salt! Effects of winter road salt felt all year by stream periphyton" IAGLR 2025, June 2-6. Milwaukee, Wisconsin

2. “Detrimental effects of road salt accumulation on the Light-Nutrient Hypothesis” IAGLR 2025,

June 2-6. Milwaukee, Wisconsin

Additional reports related to water resource research are available at: https://wri.cals.cornell.edu/resources/research-reports/

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Appendices

Appendix 1: List of stream sites included in this study

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