The Road Map to Reduce Road Salt

Why using too much road salt has become a problem and how we can begin to fix it

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Acknowledgments

This booklet is a part of AdkAction's Road Salt Reduction Project. AdkAction is a 501(c)3 non-profit that has been working to reduce road salt pollution since 2011. AdkAction has co-hosted 4 Road Salt Conferences to bring to light the harmful environmental, economic, and health impacts of over-salting our roadways. We have worked with the New York State Department of Transportation to establish 6 road salt testing areas since 2011. AdkAction administers the Adirondack Road Salt Working Group, designed to engage regional stakeholders in identifying gaps in knowledge of road salt impacts and evaluate safe and effective alternatives that will lead to a reduction in the use of road salt. In 2018, AdkAction leadership was appointed to the Strategic Road Salt Working Group, a chartered committee consisting of decision-makers at NYS Department of Transportation, Department of Environmental Conservation, Department of Health, independent researchers, and advocacy organizations.

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AdkAction creates projects to address unmet needs, promote vibrant communities, and preserve the character of the Adirondacks. Current projects include preventing road salt pollution, increasing access to high-speed internet for all Adirondack residents, promoting local artists and arts institutions, conserving habitat for monarchs and other pollinators, and organizing Property Assessors Conferences to share best practices.
To learn more or to become a member, visit AdkAction.org.

New York State Pollution Prevention Institute

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Compiled by Adirondack Research
All photographs by Brendan Wiltse unless otherwise noted.
Cover art by Nip Rogers. Design by Kelly Hofschneider / Kindling Creative

There is a delicate balance between protecting the environmental resources of the Adirondacks and maintaining safe roads for motorists. For decades, the application of road salt (sodium chloride) has been used to maintain safe roads for the traveling public. Unfortunately, the use of road salt impacts aquatic and terrestrial ecosystems and has recently been shown to compromise groundwater.

Since 1980, roughly 6.5 million tons of road salt have been applied to roadways in the Adirondack Park. The Adirondacks contain about 6,000 miles of streams and 195,000 acres of lakes. Roughly half of streams and 75% of lakes in the Adirondacks are impacted by road runoff from paved roads, making them susceptible to road salt contamination.

Recent studies show that salt has infiltrated our groundwater, the source of drinking water for people with private wells. According to the federal Environmental Protection Agency, excessive sodium intake contributes to age-related increases in blood pressure, which carries an increased risk of developing coronary heart disease, stroke, congestive heart failure, renal insufficiency, and peripheral vascular diseases.

It is possible to reduce our collective dependence on road salt while maintaining a high level of service to keep the driving public safe. Best practices for winter road maintenance can be put in place that will protect the driving public and the environment. This booklet, "The Roadmap to Reduce Road Salt," provides scientific evidence on the impacts of road salt and outlines many best practices necessary to reduce the use of road salt in the Adirondacks.

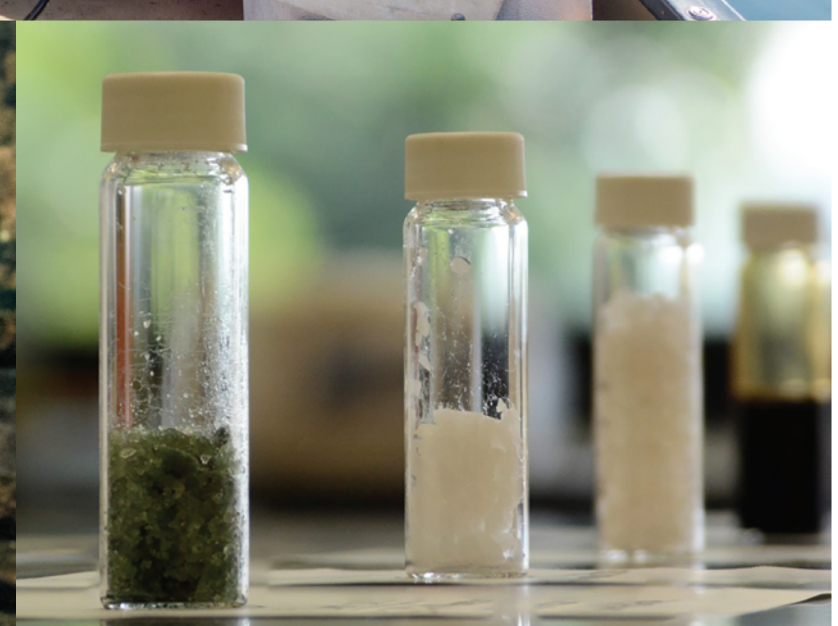
Road salt has been called the acid rain of our time, and like acid rain, we have the ability to correct the negative trend that science is showing to protect our communities and the fragile ecosystems critical to the overall health of our environment.

Best Practices

- Using **brine** for pre-storm anti-icing.
- The use of a **plow truck with a segmented plow blade** and other alternative blade technologies to mechanically remove as much snow and ice from the pavement as possible.
- Using **treated salt**, which is more effective at colder temperatures.
- Revisiting the **use of abrasives** in addition to or instead of road-salt where appropriate
- Using **Automatic Vehicle Location** equipment that can track salt application rates and regularly calibrating the salt spreading equipment.
- Closely **monitoring salt use during storms** while performing post-storm evaluations to review application rates and the performance of those rates.
- Evaluation of **abrasives** and **abrasive mixes**.
- Evaluation of **cutting back some trees** to allow sun to melt the snow and ice on portions of shaded roadways.
- Evaluation of **reduced speed limits** in pilot areas.
- Leveraging other **Maintenance Program Areas** (drainage, pavement, environmental) to see how they can be used to facilitate snow and ice operations, and subsequently reduce the dependence on road salt.
- Other and **emerging best practices** that may lead to a dramatic reduction in the use of road salt.

Research

Researchers in the Adirondack Park and throughout New York State are studying the environmental and public health impacts of road salt pollution. The research summaries below provide insight into recent scientific findings related to road salt pollution in our region, providing evidence for the need to reduce our collective dependence on road salt while balancing the safety of the driving public.

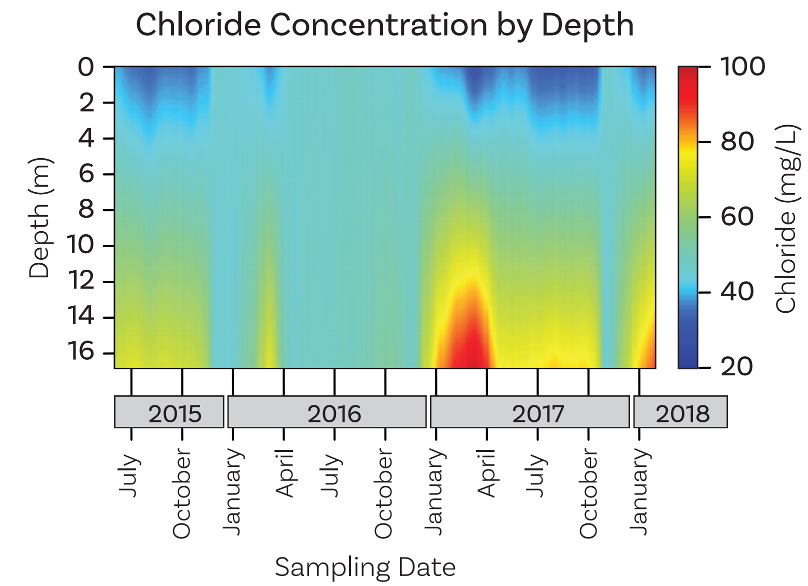


Photography (above and left) Brendan Wiltse, (right) Brian Mattes.

Road salt interrupts turnover of Mirror Lake

Brendan Wiltse et al. (*Ausable River Association and Adirondack Watershed Institute*)

INTRODUCTION AND BACKGROUND: Salt-laden runoff directly entering a lake or pond is often much denser than the water in the receiving water body. This density difference, depending on the size and basin shape of the lake, can cause the runoff to flow along the lake bottom and accumulate in the deepest part of the lake. The resulting density differences can increase the amount of energy required for the lake to mix in the spring and fall, a fundamentally important physical process in many temperate lakes. Interruption of lake turnover has been documented in several urban lakes.



RESULTS: Mirror Lake, in the Village of Lake Placid, is in the 97th percentile for surface water chloride concentrations out of all lakes monitored as part of the Adirondack Lake Assessment Program. Two-years of bi-weekly sampling of the water column of the lake has revealed salt accumulation at the lake bottom during the winter, and lack of spring turnover in 2017. Modeling the energy required to mix indicates the salt accumulation increases the energy required to mix the lake immediately after ice out by 75.5 times. Stormwater monitoring has documented runoff entering the lake has chloride concentrations as high as 2,400 mg/L.

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WIDER IMPLICATIONS: An interruption of lake turnover has the potential to produce a cascade of negative effects for a lake. The immediate and primary concern for a deep lake that supports cold water fish is the impact on bottom water dissolved oxygen concentrations. Incomplete mixing in the spring reduces the capacity of the lake to replenish deep water with oxygen, threatening the cold water fish that rely on that habitat during the summer. Resulting low dissolved oxygen concentrations can also increase internal nutrient loading, increasing the likelihood of harmful algal blooms.

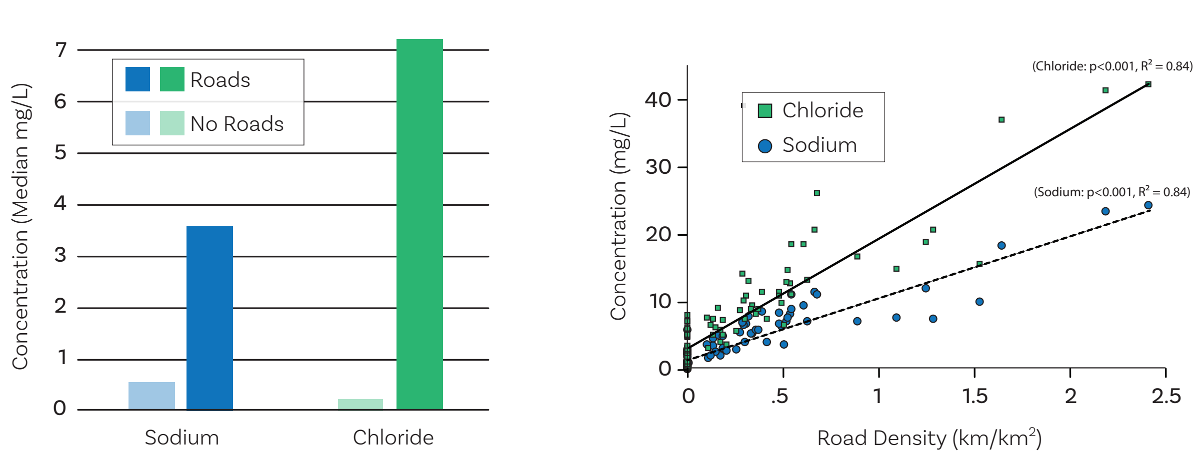
Reference: Wiltse, B., Yerger, E.C., Pionteck, N.C., & Laxson, C.L. 2018. Mirror Lake 2017 Water Quality Report. Ausable River Association, Wilmington.

Regional Salinization of Adirondacks Lakes by Road Salt

Dan L. Kelting et al. (*Adirondack Watershed Institute*)

INTRODUCTION & BACKGROUND: The New York State Department of Transportation (NYSDOT) applies 680,000 to 860,000 tons of sodium chloride to state roads every winter with application rates ranging from 16 to 23 tons per lane-mile per year. The purpose of our study was to develop baseline concentrations for sodium and chloride for lakes in watersheds without paved roads, and then determine the relationship between these ions and density, type and proximity of paved roads to shoreline. We used average summer (June–September) sodium and chloride data for 138 lakes combined in a watershed based analysis of paved road networks in the Adirondack Park of New York, U.S.A.

Sodium and Chloride Concentration



RESULTS: Median lake sodium and chloride concentrations in the 56 watersheds with no paved roads were 0.55 and 0.24 mg/L, respectively. In contrast, the median sodium and chloride concentrations for the 82 lakes in watersheds with paved roads were 3.60 and 7.22 mg/L, respectively. Paved road density (lane-km/km2) was positively correlated with sodium and chloride concentrations, but only state roads were significantly correlated with sodium and chloride while local roads were not. State road density alone explained 84 percent of the variation in both ions. We also successfully modeled the relationship between road proximity to shoreline and sodium and chloride concentrations in lakes, which allowed us to identify sections of road that contributed more to explaining the variation in sodium and chloride in lakes.

Paved road density (lane-km/km2) was positively correlated with sodium and chloride concentrations, but only state roads were significantly correlated with sodium and chloride while local roads were not.

WIDER IMPLICATIONS: Road salting has resulted in regional salinization of Adirondack lakes. Salt application on state roads is largely responsible for regional salinization, thus by extension, reducing salt loads on state roads should result in marked reductions in lake salt concentrations. Our model could be used as part of larger efforts to identify environmentally sensitive areas where alternative winter road management treatments should be applied.

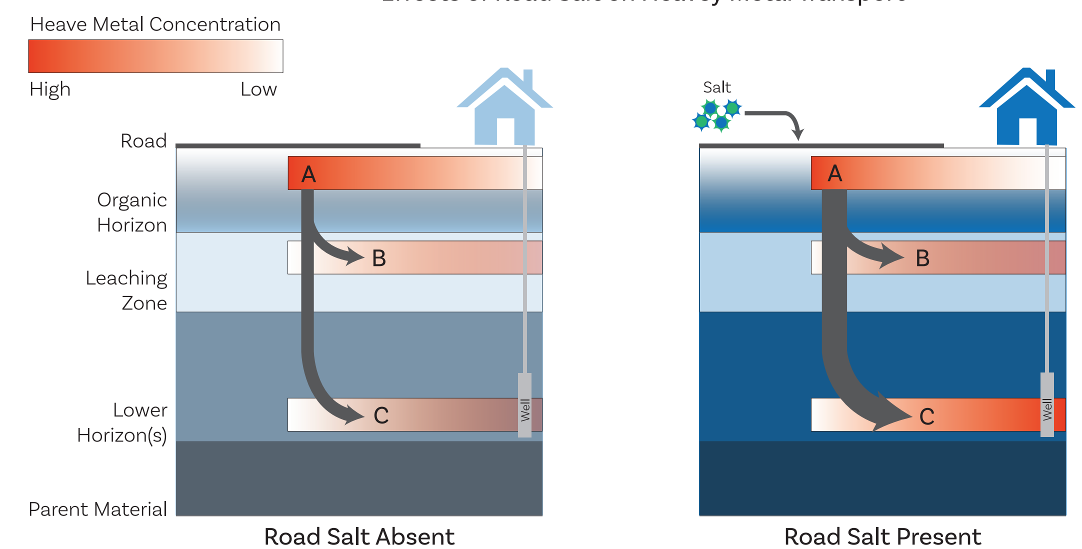
Reference: Kelting, D.L., C.L. Laxson, & E.C. Yerger (2012). Regional analysis of the effect of paved roads on sodium and chloride in lakes. Water Research, 46:2749-2758.

A review of the combined threats of road salts and heavy metals to freshwater systems

Matthew S. Schuler and Rick A. Relyea *(Darrin Fresh Water Institute at Rensselaer Polytechnic Institute)*

BACKGROUND: Roads are a major nonpoint-source of toxic pollutants, including heavy metals and road salts (i.e., deicers). Heavy metals can accumulate in roadside soils, but are easily mobilized by road salts into freshwater ecosystems. Increased heavy metal bioavailability could increase the concentrations of heavy metals in food webs. Despite numerous studies investigating the mobilization of heavy metals by road salts, few studies have investigated 1) the movement rate and fate of heavy metals mobilized by road salts, 2) how road salts alter the bioavailable fraction of heavy metals, and 3) how road salts and heavy metals interact to affect freshwater organisms or human health.

Effects of Road Salt on Heavey Metal Transport



RESULTS: Road salts increase the distribution and bioavailability of heavy metals. As heavy metals become more bioavailable and dissociated from organic soils, plants and algae would accumulate them in leaves and stems. Increased concentrations of heavy metals in the food web would lead to strong toxicological effects for organisms, especially top predators. Additionally, the concentration of heavy metals such as lead would increase in groundwater used for human consumption and agriculture. Improved monitoring of road salt use and modeling of heavy metal movement from soils into freshwater ecosystems would help inform consumers about potential groundwater contamination risks.

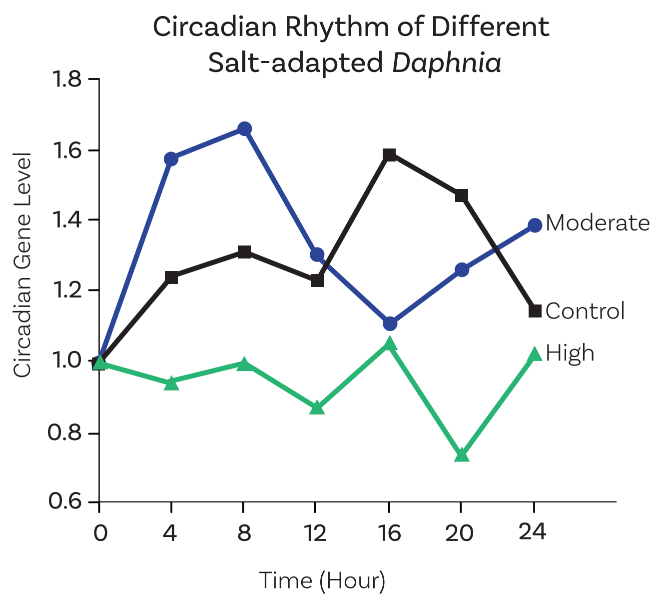
WIDER IMPLICATIONS: Heavy metals and road salts can accumulate in freshwater ecosystems, leading to increased toxicological effects and threats to human health. More research needs to be done to understand the effects that salts have on the bioavailability, mobility, and transport rate of heavy metals. Additionally, there should be a greater focus on the potential contamination of groundwater sources used for human consumption and agriculture.

References: Schuler, M.S. and R.A. Relyea. 2018. A review of the combined threats of heavy metals and road salts to freshwater ecosystems. Bioscience 68:327-335.

The circadian rhythm is affected by the evolution of salt tolerance

Kayla D. Coldsnow et al. *(Darrin Fresh Water Institute at Rensselaer Polytechnic Institute)*

INTRODUCTION AND BACKGROUND: Almost every organism completes cyclic, predictable behaviors such as sleeping, eating, mating, or migrating. Many of these behaviors can be explained by a circadian rhythm. A circadian rhythm is an internally driven cycle that is coded in our DNA. It has been shown that chemicals such as antidepressants and cigarette smoke can affect different cyclic behaviors and circadian-related genes. In nature, organisms are commonly exposed to novel environmental contaminants, such as road salt, that may be affecting their circadian rhythm at a molecular level, which may change behaviors and ecosystems. One group of organisms that are vital to freshwater ecosystems and participate in noteworthy cyclic behaviors are *Daphnia* (*Daphnia* are an important group of the tiny zooplankton that are critical for consuming algae and serving as the prey base for fish).



RESULTS: We investigated whether exposure, and the resulting evolution of tolerance to road salt, affected important genes involved in the circadian rhythm of a common *Daphnia* species. We found that *Daphnia* adapted to control, Lake George, NY conditions had normal circadian rhythms in the genes investigated. *Daphnia* adapted to moderate levels of the most common road salt, sodium chloride, showed moderate changes to their circadian rhythm such as shifts and shortening. Remarkably, *Daphnia* adapted to high levels of sodium chloride road salt showed abrupt changes to their circadian rhythm. Rather than the cyclic pattern expected, the circadian rhythm in *Daphnia* adapted to high levels appeared to flat line.

WIDER IMPLICATIONS
Circadian rhythms are thought to occur in every organism and are hypothesized to be responsible for a variety of functions. The consequences of circadian rhythm disruptions from road salt are unknown. *Daphnia* complete daily migrations from the bottom to the top of water bodies to avoid predators and feed on algae. A disrupted circadian rhythm may disrupt this behavior and community dynamics such as predator-prey interactions and algae abundance. This could affect the services freshwater systems provide to humans. Moreover, a common contaminant affecting the circadian rhythm of a common organism begs the question: What other contaminants are affecting what other organisms?

Daphnia adapted to high levels of sodium chloride road salt showed abrupt changes to their circadian rhythm.

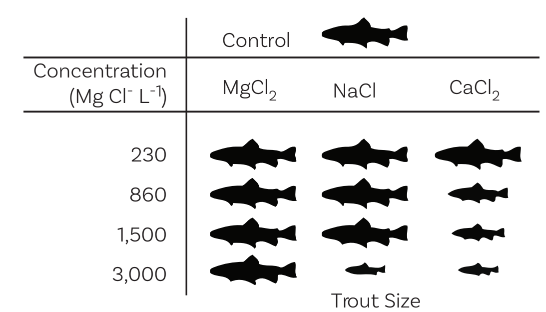
Reference: Coldsnow K. D., Relyea, R. A., Hurley, J. M. (2017) Evolution to environmental contamination ablates the circadian clock of an aquatic sentinel species. Ecology and Evolution, 7, 10339–10349.

Road salts negatively affect rainbow trout

William D. Hintz and Rick A. Relyea *(Darrin Fresh Water Institute at Rensselaer Polytechnic Institute)*

INTRODUCTION AND BACKGROUND: We wanted to know how common road salts affect young trout found in streams, and which salts were the most toxic. Three of the most common road deicing salts that are applied worldwide are sodium chloride, magnesium chloride and calcium chloride. Snow melt and stormwater runoff carries these salts off roads and eventually into streams. The contamination of stream ecosystems by road salts can negatively affect organisms in the streams. Given that a lot of young trout and salmon are hatching and growing in streams during the spring, it is important to know if road salts negatively affect the growth of newly hatched trout.

Rainbow Trout Grown and Development



RESULTS: Road salts had distinct effects on trout growth, but none of the salts affected trout development or resulted in death. The road salt magnesium chloride did not affect trout growth at any concentration, which was interesting because it is thought to be the more toxic deicing salt to fish. The most common deicing salt, sodium chloride, did not affect trout growth at the lowest three concentrations, but trout length was reduced by 9 percent and mass by 27 percent at the highest concentration, which is a concentration observed in highly contaminated streams. We found that calcium chloride had the greatest impacts on trout growth; trout growth was reduced at moderate concentrations (5 percent reduced length; 16 percent reduced mass). However, at the highest concentration of calcium chloride, trout length was reduced by 11 percent and trout mass was reduced by 31 percent.

Trout length was reduced by 9 percent and mass by 27 percent at the highest concentration, which is a concentration observed in highly contaminated streams.

WIDER IMPLICATIONS: Our findings indicate that sustained high levels of road salt in streams could lead to smaller young trout, which may have implications for the health of recreational trout fisheries.

Reference: Hintz, W.D. and R. A. Relyea. 2017. Impacts of road deicing salts on the early-life growth and development of a stream salmonid: Salt type matters. Environmental Pollution 223:409-415 DOI: 10.1016/j.envpol.2017.01.040

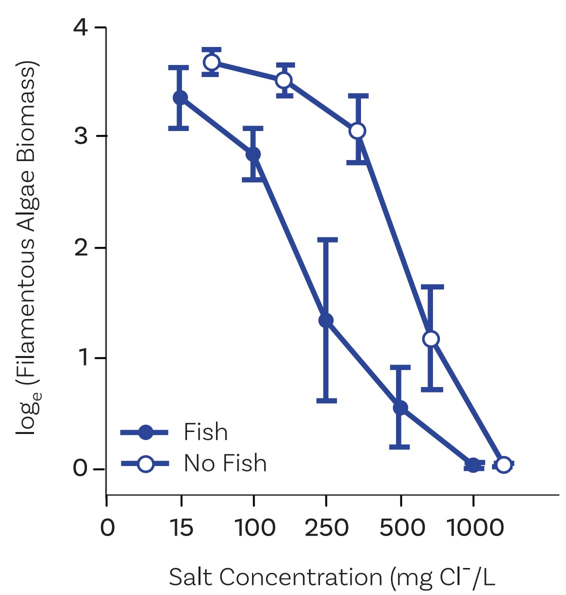
Road salt triggers a trophic cascade

William D. Hintz et al. (Darrin Fresh Water Institute *at Rensselaer Polytechnic Institute*)

INTRODUCTION AND BACKGROUND: We wanted to know how the most commonly used road salt, sodium chloride, affects organisms found in lakes. Many of the organisms in lakes contribute to ecosystems services important to humans like water clarity, drinkable water, recreation, and fisheries. These organisms are interrelated, and an impact on one organism can have a domino effect on other organisms. If organisms high up in the food chain are affected (e.g., fish or zooplankton), this may lead to changes in primary producers like algae. Scientists call this process a 'trophic cascade.' In our study, we wanted to know if sodium chloride triggered a trophic cascade in lake food webs and what implications this might have for ecosystem services.

We found that high salt concentrations in the presence of a fish predator induced a trophic cascade.

RESULTS: We found that high salt concentrations in the presence of a fish predator induced a trophic cascade. We observed a significant reduction in the types and abundance of zooplankton. A smaller, less diverse population of zooplankton, which eat algae, caused an increase in algae, which reduced water clarity. Moderate to high salt concentrations also reduced the abundance of filamentous algae, which can be important habitat for many lake organisms. In the highest salt concentration, we observed a 92% reduction in the abundance of amphipods, which are an important food source for many fish species. High



salt concentrations also increased the mortality of banded mystery snails and fingernail clams, but had a positive effect on pouch snails. Isopods were not affected by road salt and two of the highest salt concentrations had positive effects on the growth of a native fish species.

WIDER IMPLICATIONS: Although it took high concentrations (250–1000 milligrams of chloride per liter) of road salt to elicit an effect, our results indicate that globally increasing concentrations of road salt can alter food webs in lakes.

Reference: Hintz, W. D., B. M. Mattes, M. S. Schuler, D. K. Jones, A. B. Stoler, L. Lind, and R. A. Relyea. 2017. Salinization triggers a trophic cascade in experimental freshwater communities with varying food-chain length. Ecological Applications 27: 833-844. DOI: doi/10.1002/eap.1487/

Road salts and natural stressors in freshwater wetland communities

Devin K. Jones et al. (Darrin Fresh Water Institute *at Rensselaer Polytechnic Institute*)

INTRODUCTION AND BACKGROUND: Over 21 million tons of road salts are applied every winter in North America to manage roadways. Snowmelt and precipitation following winter road maintenance carries these deicing materials into adjacent aquatic habitats. Not only might this contamination cause direct toxic effects on sensitive species, it might interact with natural stressors (i.e., competition, predation) commonly experienced in aquatic systems. In our study, we investigated the direct toxic effects of road salts and their potentially interactive effects with competition and predation in wetland communities comprised of algae, zooplankton (water fleas), and tadpoles of two amphibian species (wood frog, American toad).

Increased road salt concentrations caused direct lethal effects on zooplankton

RESULTS: We did not find interactive effects of road salts and natural stressors in our study. However, each stressor affected our aquatic communities. Increased road salt concentrations caused direct lethal effects on zooplankton, leading to a bloom of floating algae (zooplankton food). Moreover, increased sodium chloride (NaCl) concentrations reduced American toad activity. Competition, created by doubling tadpole density, reduced the survival, time to metamorphosis, and mass at metamorphosis of wood frogs, but increased the time to metamorphosis of American toads. Predation, simulated by exposing tadpoles to predator (dragonfly nymph) cues and kairomones (e.g., chemical signals released by predators), reduced the activity of both tadpole species.

American Toad photograph by Larry Master

WIDER IMPLICATIONS: Our results suggest that road salts affect freshwater wetland communities through direct toxic effects on sensitive aquatic species. However, changes in the behavior or abundance of sensitive species can lead to indirect effects on other members of the food web that interact with the sensitive species. Given the increasing chloride concentrations found in temperate freshwater systems, it is important to continue to investigate how ecosystems, beyond our experimental communities, respond to the threat created by road salt contamination.

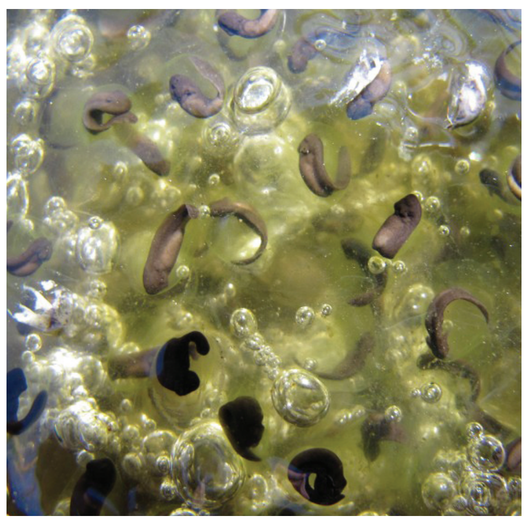
References: Jones, D.K., B.M. Mattes, W.D. Hintz, M.S. Schuler, A.B. Stoler, L.A. Lind, R.O. Cooper, R.A. Relyea. 2017. Investigation of road salts and biotic stressors on freshwater wetland communities. Environmental Pollution 221:159-167. https://doi.org/10.1016/j.envpol.2016.11.060

Road salt contamination alters the sex ratios of wood frogs

Max Lambert et al. *(Yale University and Darrin Fresh Water Institute at Rensselaer Polytechnic Institute)*

INTRODUCTION AND BACKGROUND: There is increasing evidence that natural and man-made chemicals can alter the sex ratios of animal populations. Such chemicals likely interfere with hormonal regulation during development. In this study, we explored how road salt influences amphibian development. Since it is also known that chemicals in leaf litter (an important food resource for tadpoles) can influence amphibian sex ratios, we also asked how road salt interacts with leaf chemistry. We analyzed the sex ratios of wood frogs reared from egg to metamorphosis with different combinations of salt concentrations (114 and 867 mg Cl- L-1) and leaf species (none, maple, and oak).

Salt has a masculinizing effect on tadpole sex ratios.



Tadpoles and wood frog photographs by Larry Master

RESULTS: We found that salt has a masculinizing effect on tadpole sex ratios (i.e. creates more males), whereas oak, but not maple litter, feminizes populations. In addition, road salt contamination eliminates size differences among oak-reared male and female frogs, but enhances such size differences in maple-reared frogs, specifically producing larger females.

WIDER IMPLICATIONS: We are the first to show that road salt and native tree leaf litter manipulates vertebrate sex ratios and sex-specific development. Human land use might therefore influence the sex expression of animals directly from contamination by road salt and indirectly by changes in the species composition of forests.

Reference: Lambert, M. R., Stoler, A. B., Smylie, M. S., Relyea, R. A., Skelly, D. K. (2017). Interactive effect of road salt and leaf litter on wood frog sex ratios and metamorphic sexual size dimorphism. Canadian Journal of Fisheries and Wildlife Science 74:141-146, DOI:10.1139/cjfas-2016-0324

Call to Action

*Towns and Villages in the Adirondack Park that are willing to make an effort to reduce the use of road salt are encouraged to sign the **"Pledge to Reduce Road Salt"** Memorandum of Understanding. The Pledge can be found at AdkAction.org/pledge*

Individuals looking to support regional salt reduction efforts are invited to email info@adkaction.org with their mailing address to request a "Hold the Salt" car magnet.

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Special thanks to our partners in the Adirondack Road Salt Working Group.

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