Do Road Salts Cause Environmental Impacts?

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Introduction

Hundreds of reports and scientific papers have examined potential environmental problems associated with the use of salt to de-ice roads. Appendix A provides a list of some of the most pertinent recent literature. This document is a brief review and summary of some of that literature. Our document also describes results from the Maryland Biological Stream Survey (MBSS) data that are relevant to this topic. The MBSS is led by Maryland Department of Natural Resources (DNR) staff with support from the University of Maryland Appalachian Laboratory staff. Along with this summary, we recommend three other documents because they offer useful information. For a thorough technical review of ecological literature on the effects of salt, Miguel Cañedo-Argüelles et al. (2013 in *Environmental Pollution* volume 173) "Salinisation of Rivers: an Urgent Ecological Issue" is recommended. For a non-technical report, we recommend the one written by staff at The Cary Institute of Ecosystem Studies (December 2010) titled "Road Salt: Moving Toward the Solution". Along with general information about road salt impacts, the Cary Institute report offers solutions, costs, and alternatives. The Canadian Council of Ministers of the Environment (2011) provides a report titled "Canadian Environmental Quality Guidelines for the Protection of Aquatic Life: Chloride". This report describes chloride toxicity in a regulatory context and presents justification for the water quality guidelines used in Canada.

According to The Cary Institute of Ecosystem Studies (www.caryinstitute.org), salt was first used in the United States to de-ice roads in New Hampshire in 1938. By the winter of 1941-1942, a total of 5,000 tons of salt were spread on highways in the U.S. annually. Between 10 and 20 million tons of salt are used today. This increase in the use of road salt has caused an increase in the salinity of the Nation's ground and surface waters that threatens our drinking water and environment. Concentrations in surface and groundwater will continue to increase, perhaps for decades, even if road salt use is completely stopped because there is a lag between salt application to roads and salt showing up in groundwater (Jackson and Jobbagy 2005; Godwin et al. 2003) . In most areas, concentrations of salt in surface waters near roads exceed ambient stream and groundwater concentrations. The rate of export (flushing) of salt from ground and surface waters is usually slower than the rate of input. Ambient salt concentrations will likely continue to increase until input concentrations approximately equal ambient concentrations (Kelly et al. 2008; Harte and Throwbridge 2010; Perera et al. 2013) or road salt application is reduced substantially.

Although other alternatives exist, the most commonly used "salt" for road de-icing is sodium chloride. Some studies summarized here directly examined the environmental effect of this salt from road run-off. Many studies focused only on the chloride ion and other studies used the specific conductance of water as a surrogate for salt in areas where de-icing occurred. Since specific conductance is a measure of dissolved salts in solution, it tends to be higher in water with salt compared to water without it. However, specific conductance can be high due to the presence of other naturally occurring and anthropogenically dispersed ions such as calcium and bicarbonate ion. Therefore, there is no way to directly adjust specific conductance values to determine sodium chloride concentrations. Although the chloride ion occurs in compounds other than those used to de-ice roads and other salts are sometimes used for de-icing, sodium chloride used for road de-icing is the most common anthropogenically dispersed salt found in ground and surface freshwater. Thus, chloride concentration typically provides an accurate representation of water's sodium chloride content. Figure 1 shows the relationship between specific conductance and chloride concentrations from 2,482 samples taken from Maryland streams as part of the MBSS.

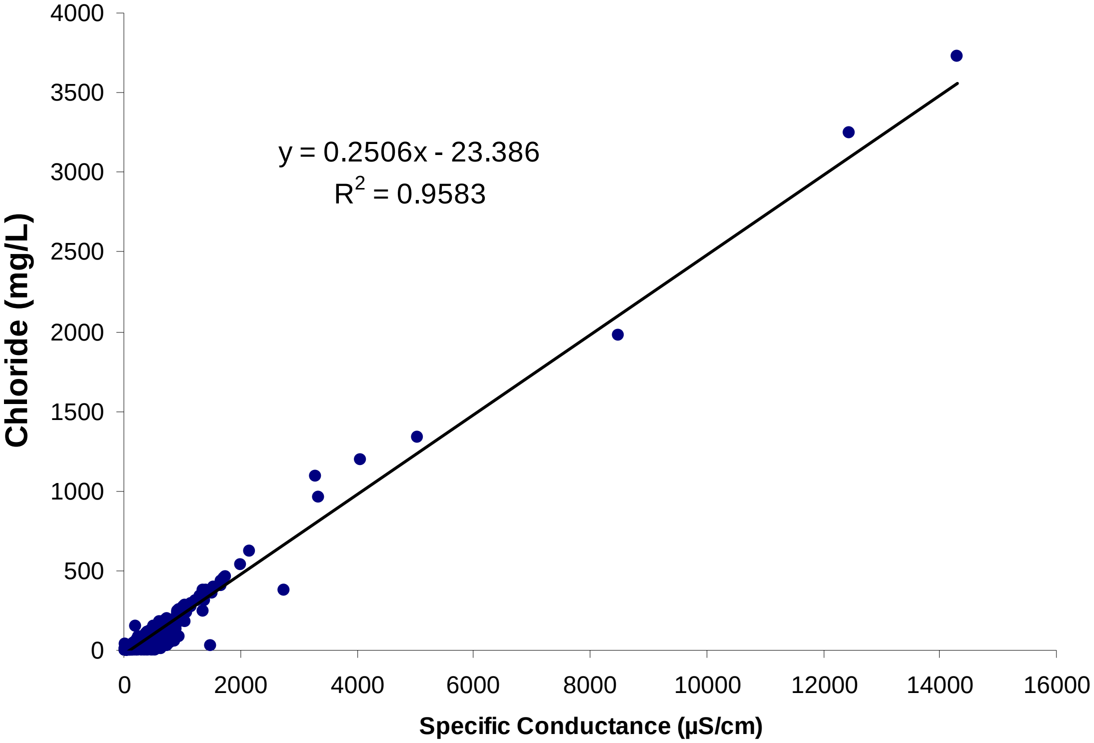

Figure 1. Chloride concentrations and specific conductance measured at 2,482 Maryland Biological Stream Survey sites.

The natural salinity of aquatic environments varies widely. Sea water typically contains about 35,000 mg/L salt and about 19,000 mg/L chloride. In estuarine waters, the ratio of chloride concentration to the total salinity is consistent regardless of total salt concentrations. Therefore, total chloride concentrations can be easily calculated in estuaries if the total salinity is known. Water that is considered "freshwater" typically contains less than 500 mg/L salt and less than 300 mg/L chloride, but the ratio can vary widely (Kaushal 2009). The average salinity of inland ("fresh") waters environments is about 120 mg/L (Kaushal 2009). In Maryland, there is evidence that chloride concentrations in freshwater streams have been increasing (due to salt accumulation) over the last 40 years, including streams that enter Liberty Reservoir, a drinking water reservoir for Baltimore City (Kaushal et al. 2005). Figure 2 from that document is shown here with permission from the authors. Recent estimates from MBSS data of chloride concentrations in wadeable streams with minimal anthropogenic influence vary by ecological region and range between about 4 and 19 mg/L (Morgan et al. 2012). DNR's long-term non tidal monitoring data show a statistically significant increasing trend in conductivity at 43 of 54 (80%) stations sampled (Figure 3).

Salt concentrations in freshwater rivers and streams are likely related to stream size. Small streams tend to have higher concentrations than larger streams due to reduced capacities for dilution. Distance and position in relation to salt-treated roads also influences salt concentrations in rivers and streams. In Adirondack streams, (New York State), concentrations of salt downstream from roads were up to 31 times higher than upstream (Demers and Sage 1990).

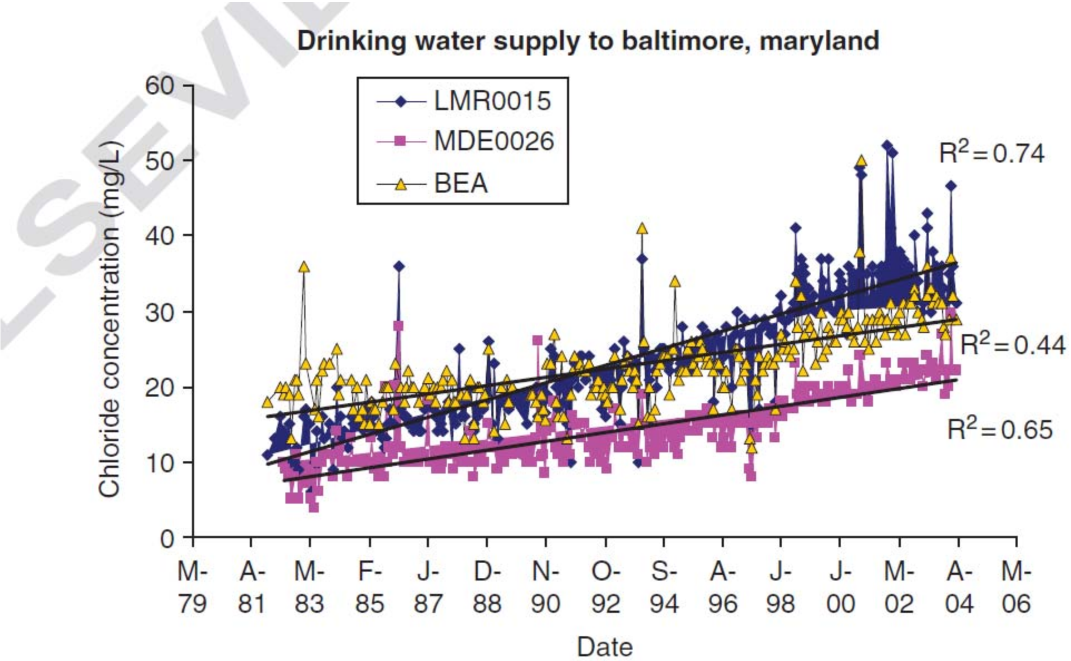

Figure 2. Chloride concentrations of three tributaries to Liberty Reservoir (a drinking water reservoir) in Maryland. Taken by permission from Kaushal et al. (2005).

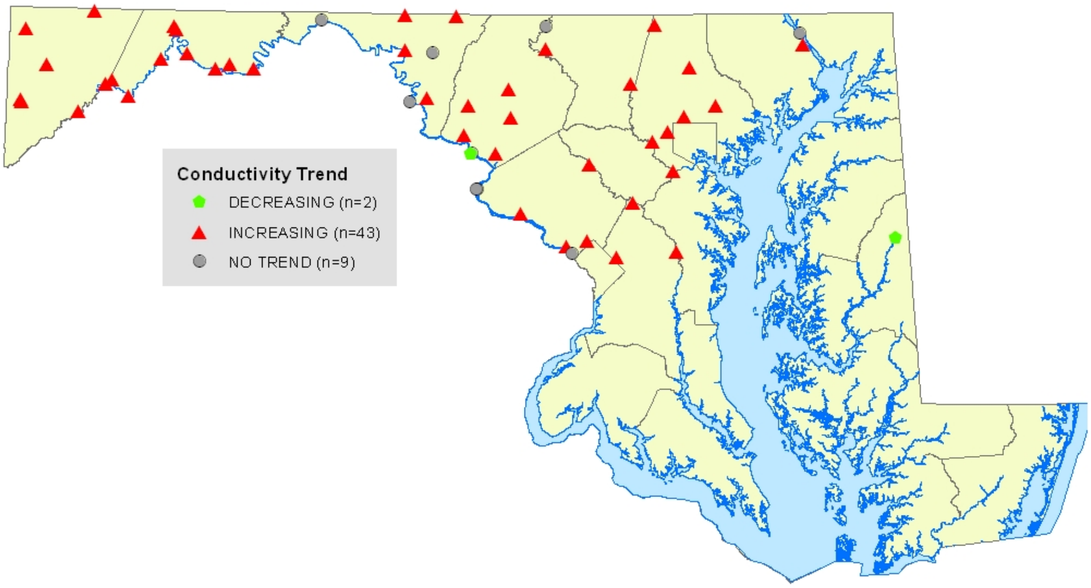

Figure 3. Map of conductivity trends from Maryland DNR’s long-term non tidal monitoring.

Beginning in September 2011, DNR personnel deployed instruments that record stream conductivity (specific conductance) every hour in several Garrett and Allegany County streams. These conductivity loggers, which were deployed both upstream and downstream from roads, show vastly different specific conductance (specific conductance is temperature-corrected conductivity). Baseline concentrations for western Maryland streams are typically less than 100 *u*S/cm (Morgan et al. 2012). Specific conductance levels measured using a conductivity logger deployed by DNR in the Savage River approximately 8.1 kilometers downstream from Interstate 68 frequently exceeded 500 *u*S/cm (Figure 4). Interstate 68 is a major roadway running through Garrett County that is treated with salt in the winter. The Savage River specific conductance readings tended to be highest following snow fall events and were lowest when stream flow was higher (presumably due to dilution). During summer low flow periods (when the potential for dilution is at its lowest), the average conductivity remained above 330 *u*S/cm (Figure 5). Specific conductance was also recorded from a small tributary to the Casselman River in Garrett County upstream of any roads. Throughout the year, the specific conductance in this stream remained lower (less than 200 *u*S/cm) and less variable compared to the Savage River below Interstate 68.

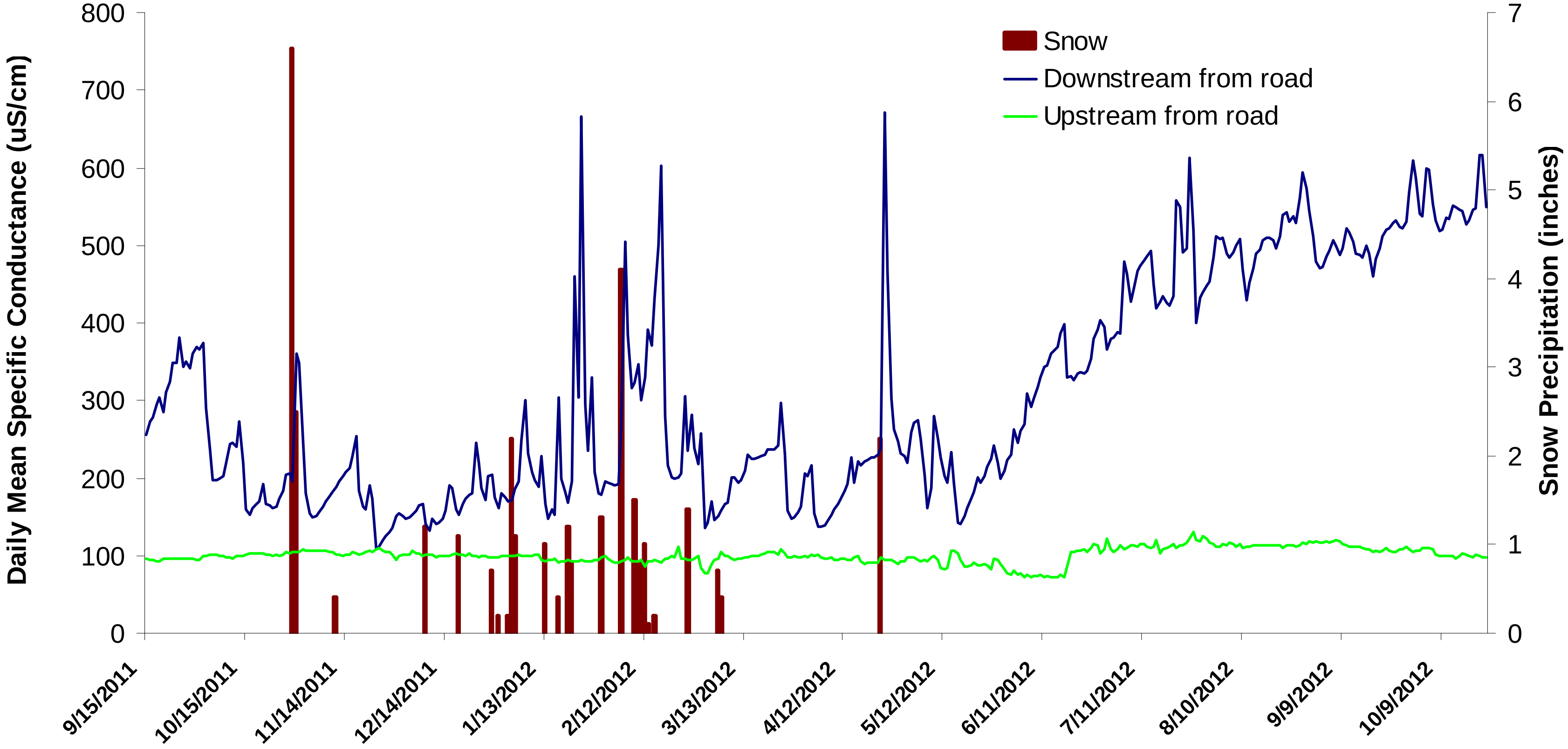

Figure 4. Hourly measurements of specific conductance from two sites in the Savage River watershed - one upstream and one downstream of Interstate Route 68 in Garrett County, Maryland. Bars represent snowfall in inches of precipitation.

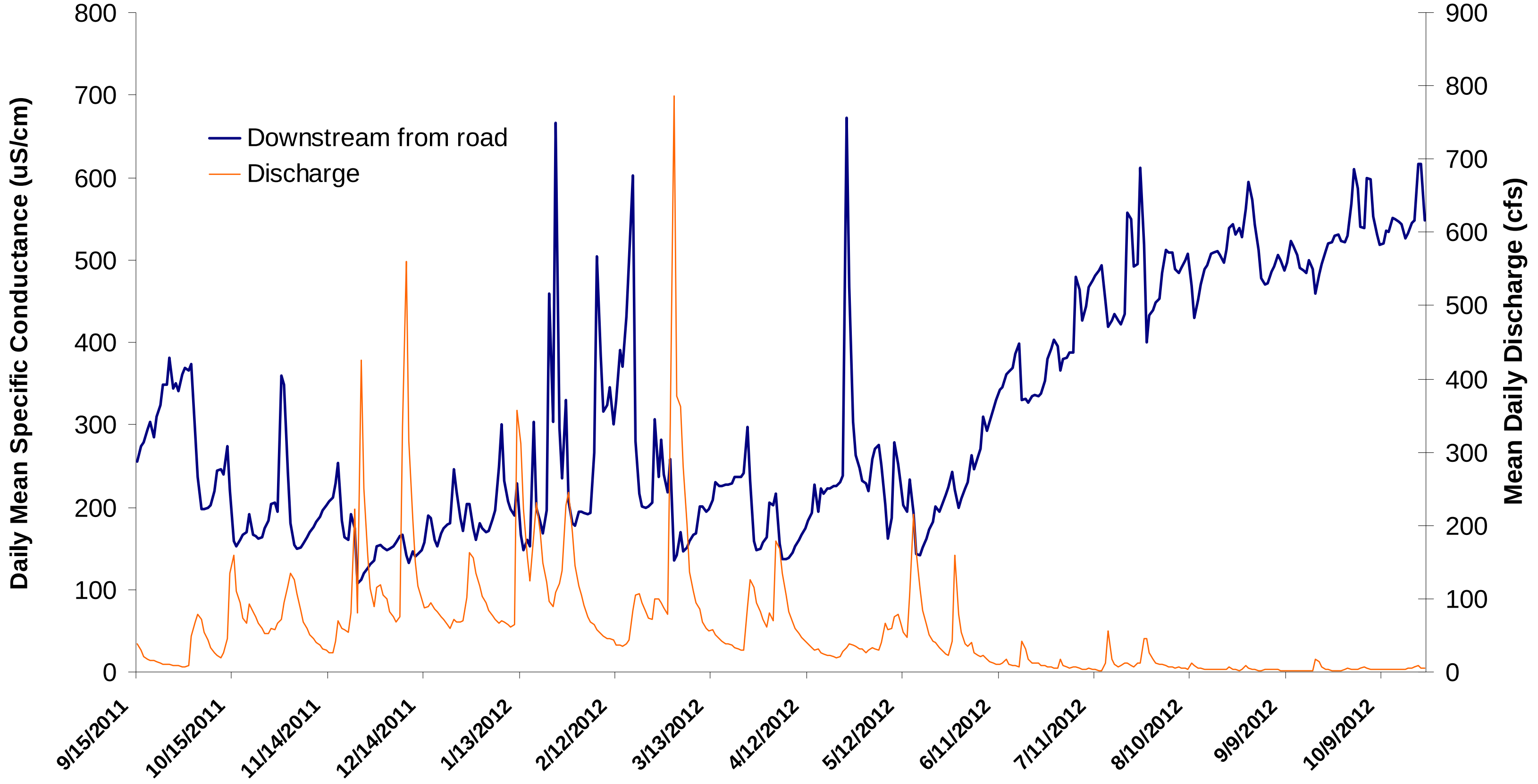

Figure 5. Hourly measurements of specific conductance from the Savage River downstream from Interstate Route 68 in Garrett County, Maryland, and stream discharge showing higher conductivities during the lowest discharge.

In addition to the ecological effects of road salt on freshwater streams, road salt also influences the potential of soil along roads to perform denitrification (Green et al. 2007). According to Endry et al. (2012), salt concentrations in stormwater as low as 80 mg/L had a significant influence on soil bacteria (compared to deionized water) and soil bacteria had a significant effect on effluent concentrations of nitrate, phosphate, copper, lead, and zinc. Thus, greater salt concentrations in roadside soils have the potential to increase nitrogen loading into nearby waters. The magnitude and extent of roadside soils containing salt could be an important factor to consider for meeting Maryland's nutrient reduction goals and efforts to reduce nutrient run-off to Chesapeake Bay. Additionally, when roadside plant survival is adversely influenced by salt, increased erosion may occur, with more sediment in streams and ultimately Chesapeake Bay.

Both short and long hydroperiod stormwater ponds have the potential to serve as long-term, year round sources of chloride and other toxins from road runoff to adjacent surface and ground waters. Since stormwater ponds are a point of recharge to ground and stream water, they may serve as road salt hotspots. As a result, pond ground water, floodplain groundwater, and stream water can be elevated in conductivity and chlorides throughout the year, not just during salt application and snow melt periods (Casey et al. 2012).

Road salt can interact with other environmental factors causing increased toxicity to freshwater plants and animals (Gallagher et al. 2011; Cañedo-Argüelles et al. 2013). In relatively low concentrations, salt may ameliorate the influence of certain toxins in certain species. For example, 500 mg/L salinity reduced copper toxicity of up to 325 µg Cu/L to green frog (*Lithobates clamitans*) eggs and larvae (Brown et al. 2012).

In select Baltimore streams, the concentration of chlorides in freshwater is correlated with impervious land cover in the watershed (Kaushal et al. 2005). Given the sensitivity of certain freshwater animals to salt-related toxicity, the higher salt concentrations with higher proportions of impervious land cover may contribute to the altered biological condition of streams observed with increasing levels of impervious land cover (e.g., Klein 1979; Schueler 1994; Stranko et al. 2008; Wenger et al. 2009). Salt-related toxicity in urban streams may also limit the degree of success achieved by stream restoration projects that focus primarily on physical changes, and may help explain the limited success so far for improving the biological condition of urban streams via restoration (Tullos et al. 2009; Violin et al. 2011; Stranko et al. 2012).

Sensitivity of freshwater animals to salt

Salinity is a major factor limiting the natural distribution of plants and animals (Williams 1987). Aquatic plants and animals differ substantially in their preferences and tolerances for salinity, resulting largely from their ability to balance salt concentrations in their tissues with that in the surrounding environment (osmoregulation). While most ocean dwelling animals require high levels of salinity to survive, the majority of freshwater species prefer water with very low concentrations of salt (e.g., less than 100 mg/L).

We reviewed the salt and chloride toxicity literature of four freshwater animal groups (benthic macroinvertebrates, fish, amphibians, and mussels). We also included relationships between chloride and these animal groups drawn from MBSS data to show results that pertain most directly to DNR management goals and objectives. MBSS derived chloride data come from one time grab samples during spring base flow. While this likely provides a representation of chloride concentration, it does not characterize the highest levels streams likely experience during winter de-icing periods and during summer when the least dilution occurs. The MBSS chloride and biological data are displayed as scatterplots without statistical analyses. These scatterplots are informative and show patterns in the distribution of animals along a gradient of chloride concentration.

Stream benthic macroinvertebrates

According to results from field and laboratory studies, stream benthic macroinvertebrates, as a group, appear to be less sensitive to elevated concentrations of salt/chloride compared to some other freshwater animals. But there is a great deal of disparity among benthic macroinvertebrates in terms of their salinity tolerances (Blasius and Merritt 2002). Toxicity also depends on length of exposure. Long-term exposure is more harmful than acute exposure. Mayflies, stoneflies, and caddissflies are the most salt-sensitive stream insects (Hartman et al. 2005; Pond et al. 2008; Pond 2010). Certain dragonflies, crustaceans, beetles, and true flies tolerate the highest salt concentrations (Cañedo-Argüelles et al. 2013). Due to the variability in salinity tolerance across taxa, the highest insect richness in streams can occur at slightly elevated salinity levels (Kefford et al. 2011). In a literature review by Blasius and Merritt (2002), the most sensitive stream insects were affected by sodium chloride concentrations of approximately 800 mg/L (240 mg/L chloride) and many were not affected until concentrations exceeded 2,000 mg/L (800 mg/L chloride).

MBSS results largely support findings from the literature. However, benthic macroinvertebrates may be more sensitive in Maryland, or other factors may be coupled with chloride here. Benthic macroinvertebrate index of biotic integrity (BIBI) scores appear to decline as chloride concentrations increase (Figure 6). No streams with BIBI scores higher than 4.0 (the threshold for the highest quality streams) had chloride concentrations above 190 mg/L. Only one stream with a chloride concentration above 500 mg/L had a BIBI score higher than 3.0. The 3.0 BIBI score is relevant here because watersheds with scores averaging less than 3.0 are included on Maryland's List of Impaired Waters by the Maryland Department of the Environment (www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/index.aspx). Thus chlorides from road salt could be (at least partially) responsible for the listing of certain "impaired" streams in Maryland.

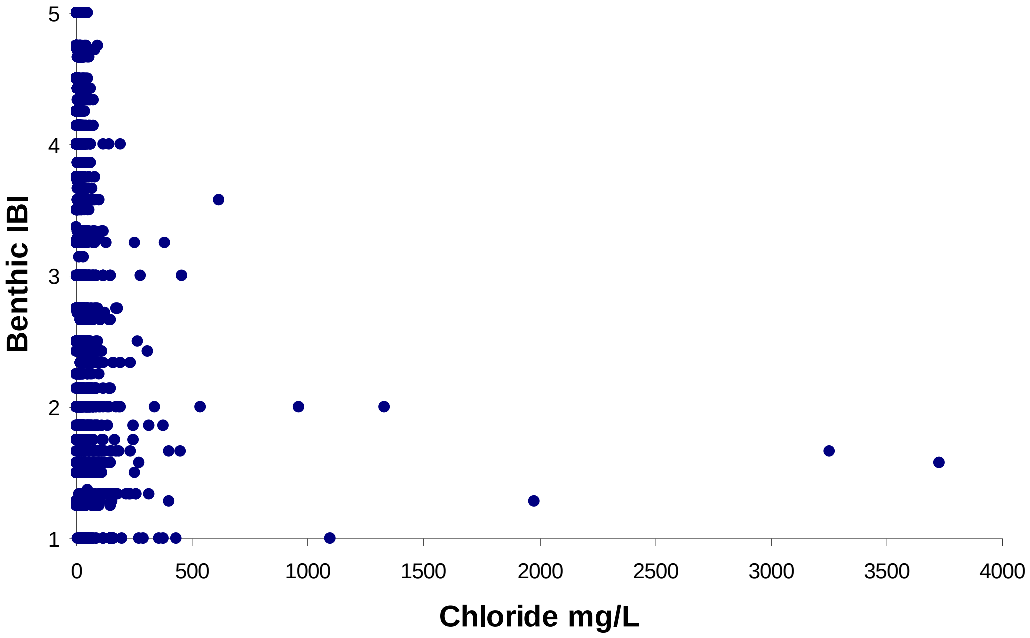

Figure 6. Benthic macroinvertebrate index of biotic integrity (BIBI) scores and chloride concentrations from Maryland Biological Stream Survey sites sampled 2000 – 2011.

The group of benthic macroinvertebrates in Maryland streams that tends to be most sensitive to pollution and watershed disturbance is the mayflies. The richness (number of genera) within this insect order declined with increasing chloride concentration at MBSS sites (Figure 7). Almost no mayflies were found in streams with chloride concentrations greater than 500 mg/L.

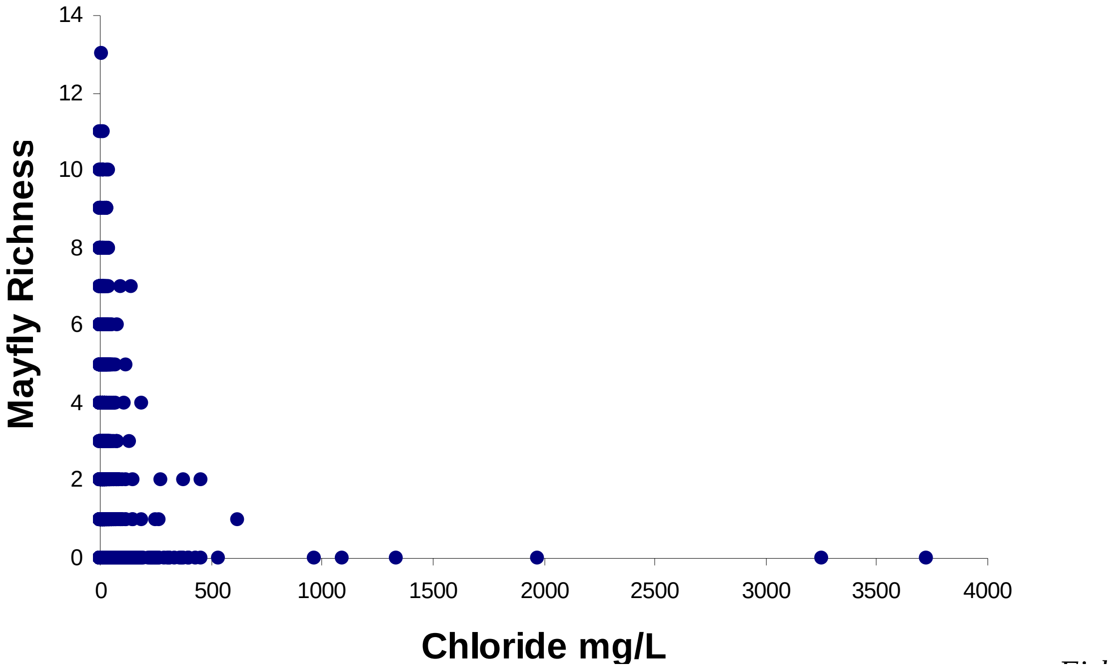

Figure 7. Mayfly genus richness and chloride concentrations from Maryland Biological Stream Survey sites sampled 2000 – 2011.

Freshwater fish

Exposure to high levels of salinity for freshwater fish effects osmoregulation and breathing. Freshwater fishes have been shown to reduce food intake and conversion, as well as exhibit slower growth, when exposed to high levels of chlorides (Boef and Payan 2001). Salt is particularly deleterious to early life stages (sperm and eggs) of some fishes (Whiterod and Walker 2006). Studies have shown a wide range of salt tolerance among species of freshwater fishes (Cañedo-Argüelles et al. 2013). A recent paper (Morgan et al. 2012) used MBSS data to investigate the relationship between chloride and conductivity concentrations and fish in Maryland. They concluded that streams that are exposed to repeated, heavy road salting had increased stream conductivity and also displayed altered fish assemblages. Assemblages in streams where conductivities were highest consisted of only pollution tolerant and habitat generalist species. The authors further surmised that species declines and loss have likely resulted from high chloride and conductivity levels in some Maryland freshwater streams.

Brook trout tend to be particularly sensitive to stream alterations and pollution compared to most other fish species in Maryland streams. Although the potential effects of temperature and sediment-related impacts that also accompany urbanization cannot be easily separated from the chloride signal, brook trout are only present in streams with chloride levels less than 280 mg/L (Figure 8). The highest densities of brook trout are found in streams with low chloride concentrations (less than 100 mg/L).

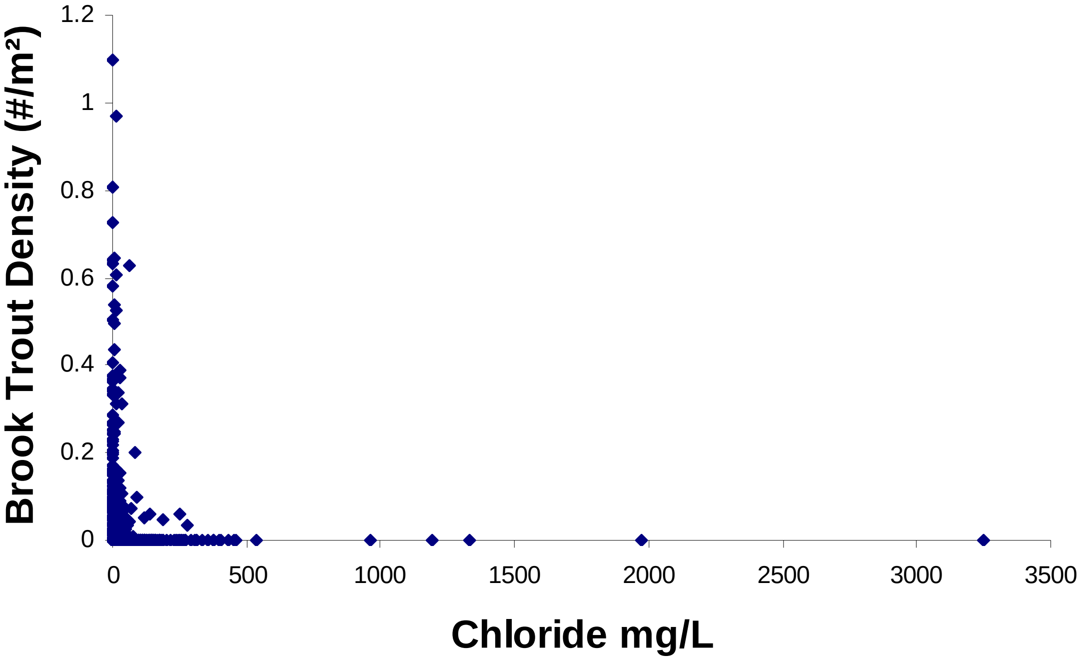

Figure 8. Brook trout density and chloride concentrations from Maryland Biological Stream Survey sites sampled 2000 – 2011.

Additionally, Uphoff et al. (2010, 2011) associated declines in anadromous fish spawning to increases in conductivity. They applied the 171 µmho/cm (1 µmho – 1µS/cm) criteria proposed by Morgan et al. (2007) to data from Piscataway and Mattawoman Creeks, and found Piscataway Creek exceeded this criterion over 90% of the time. The frequency of measurements greater than 171 µmho/cm varied in Mattawoman, with the greatest number of violations observed in 2009 after a significant snowfall event. Uphoff et al. (2012) reported spawning habitat losses in both watersheds, with spawning in Piscataway Creek observed at only one site out of five historically documented as spawning habitats and five out of seven in Mattawoman Creek.

Amphibians

As a group, amphibians tend to be more sensitive to salt compared with most other animals. This is probably because amphibians are poor osmoregulators (Dunlop et al. 2005). Pond breeding amphibians (especially those that could use stormwater ponds) may be at the highest risk from salt toxicity (Karraker et al. 2008) because salt can accumulate over time in these habitats. Pond-breeding species that place eggs on or near the bottom are at particular risk from road salt exposure, as their embryos will experience the highest salt concentrations and rates of mortality (Dobbs et al. 2012). Declines in survival of spotted salamanders have been documented at 145 mg/L chloride. Amphibian responses to salt in ponds may not always result in direct mortality but can have sublethal effects. High salt concentrations in ponds were correlated with malformations in green frogs (*Lithobates clamitans*) (Karraker 2007).

We are not aware of any studies that specifically examined salt effects on stream salamanders. Based on MBSS data, the number of salamander species found in Maryland streams is lower with increasing chloride concentrations (Figure 9). No salamanders were found in streams with chloride concentrations above 440 mg/L, and no more than two species were found in any streams with chloride concentrations higher than 190 mg/L. While these results could represent urban-related influences other than chloride toxicity, the loss of species with increased chlorides is consistent with results from other studies of other amphibians, as described briefly above.

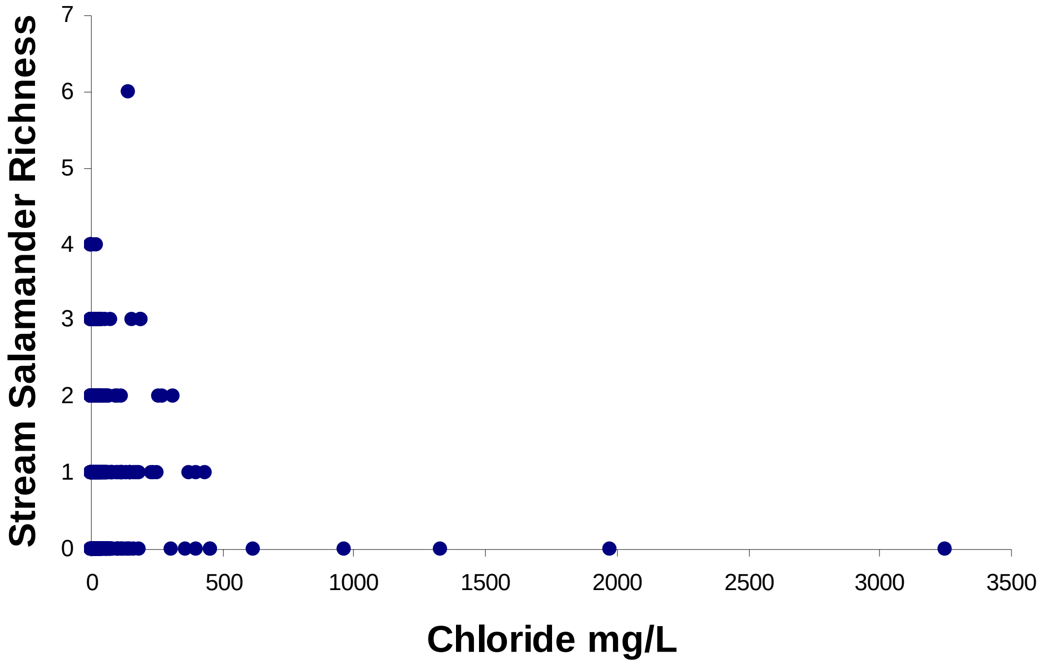

Figure 9. Stream salamander species richness and chloride concentrations from Maryland Biological Stream Survey sites sampled 2000 – 2011.

Freshwater mussels

Some freshwater mussels may be particularly sensitive to salt. Laboratory experiments have shown that certain species can be adversely affected at levels as low as 24 mg/L chloride (Bringolf et al. 2007). However, some species may be able to tolerate salt levels exceeding 1,500 mg/L (e.g., Bringolf et al. 2007; Valenti et al. 2007). To our knowledge, no studies have examined sodium chloride toxicity of mussels from Maryland and only one study included a Maryland species (Gillis 2011). According to MBSS data, although mussels were collected from 179 of 801 Maryland stream sites sampled from 2000 – 2011, no freshwater mussels were collected with chloride concentrations greater than 85 mg/L (Figure 10).

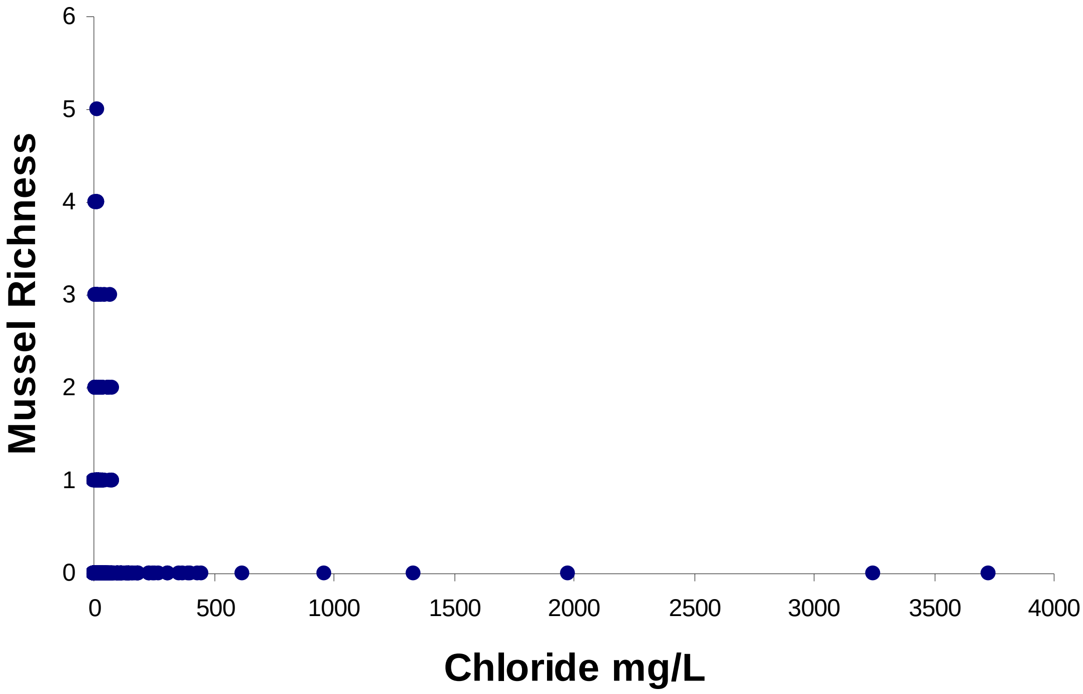

Figure 10. Freshwater mussel species richness and chloride concentrations from Maryland Biological Stream Survey sites sampled 2000 – 2011.

Regulations/policies/management plans

USEPA, the Canadian Council of Ministers of the Environment, and many states within the U.S. set water quality limits or guidelines for chloride. According to USEPA water quality criteria, the "criterion maximum concentration" (short-term exposure) limit for freshwater should be less than 860 mg/L. The "criterion continuous concentration" (long-term exposure) should be less than 230 mg/L (USEPA 1988)(http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm). The Canadian Council of Ministers of the Environment recommends lower limits (640mg/L and 120 mg/L respectively) for short-term and long term exposure and recommends that more stringent limits be imposed where particularly rare or sensitive species are known to exist.

Tim Fox (Maryland Department of the Environment, MDE) provided a table of chloride water quality criteria for U.S. states (Appendix B). Each state has a different approach to setting chloride concentration standards. In Iowa, for example, the standard for drinking water is 250 mg/L, but there is no numeric chloride standard for the protection of aquatic life. Instead, Iowa has adopted an equation-based approach to setting site specific chloride standards. Based on research indicating how the toxicity of chloride varies due to the hardness of the water and the concentrations of other anions, the Iowa Department of Natural Resources developed a set of equations in which the chloride criterion value is dependent upon both hardness and sulfate concentrations (Iowa Department of Natural Resources 2009). Calcium hardness and not total hardness seems to be the primary factor in ameliorating chloride toxicity based on Maryland data. Also, the sulfate expression in the Iowa equation was probably the result of the fact that decreasing sulfate reduces the overall toxicity of the ionic matrix, but does not specifically ameliorate the toxicity of chloride itself (Personal Communication, Tim Fox, MDE).

In contrast, Texas applies a watershed approach, using use-attainability analyses to determine appropriate water quality standards for specified stream reaches. The chloride criteria for stream segments are given in Chapter 307, Appendix A of the Texas Administrative Code (2010) as maximum annual averages for individual stream segments. These vary widely, from as little as 50 mg/L to 37,000 mg/L.

Wyoming applies the federal chloride standards for aquatic life to specially classified waters (e.g., waters for drinking, water that supports game fisheries, or that are considered "outstanding enough to prevent any further degradation"). However, Wyoming also applies site specific standards to waters, with unique attributes making the general criteria unsuitable. Site specific standards for instantaneous maximum chloride standards range from 531 mg/L to 1600 mg/L (http://deq.state.wy.us/wqd/wqdrules/Chapter_01.pdf).

States have also collaborated to determine water quality standards for large river basins that cross state lines. The Delaware River Basin Commission, which includes participants from Delaware, New Jersey, Pennsylvania, and New York, has classified certain waters as special protection waters due to either outstanding quality or resource significance. In waters designated as such, no statistically significant decrease in water quality is allowed.

Therefore, the concentration limits on chloride and other chemicals are based on median values as defined by the DRBC Water Quality Regulations Administrative Manual. The median values for chlorides referenced in this document range from as little as 8.9 mg/L to as high as 48 mg/L. The DRBC has also set water quality regulations for specific zones along the Delaware River. Of these zones, only the first two occurring in the tidal portion of the Delaware River, Zones 2 and 3, have numeric standards for chloride concentration. In Zone 2, the maximum 15-day average for chloride concentration is 50 mg/L. In Zone 3 at river mile 98, the maximum 15-day average for chloride concentration is 180 mg/L.

Currently, there are no water quality criteria for chloride or sodium chloride in Maryland. But, the MDE is working on developing state-specific criteria. MDE also requires certain counties to control the overuse of winter weather de-icing materials. Certain counties, municipalities, and Maryland's State Highway Administration (SHA) must also report the quantity of de-icing chemicals used as a requirement for receiving a National Pollution Discharge Elimination System (NPDES) permit (Maryland Department of the Environment 2004).

In January 2013, the Chesapeake Bay Commission (CBC) reviewed road salt policies in Maryland, Pennsylvania, and Virginia to see if additional policy action was necessary to protect resources (Chesapeake Bay Commission 2013). The consensus was that "indiscriminate application of road salt does not typically occur". Additionally, due to the increasing cost of road salts, it is in the best interest of State transportation agencies to balance public safety concerns with salt application. Although the CBC document acknowledged environmental and drinking water threats from road salt application, no significant policy actions were deemed necessary. The CBC document concluded that the best way to address the environmental impacts associated with snow and ice removal is to more effectively control stormwater runoff and minimize the creation of impervious surfaces.

In response to two bills (House Bill 0903, Senate Bill 0775; Maryland State Legislature 2010a,b) passed by the Maryland State Legislature in 2010, the State Highway Administration (SHA), in conjunction with MDE, were required to establish a statewide Salt Management Plan. This plan includes several best management practices for use by the state and local jurisdictions to minimize the adverse environmental impacts of road salt runoff. The SHA plan (MD State Highway Administration 2012) states that the best practices described in the plan "should be seen as a starting point management plan to minimize the impact of salt on the environment in Maryland." The SHA plan also states that "best practices for salt management should be a living document that is updated on a regular basis." Recent information from SHA indicates that they are continuing to test and evaluate new winter materials, equipment and strategies in an ongoing effort to improve the level of service provided to motorists during winter storms while at the same time minimizing the impact of its operations on the environment.

Reducing the environmental effects

Many Best Management Practices are available for potentially reducing the environmental effects of road salt that include, but are not limited to, methods for improving application efficiency and using alternative de-icing chemicals. The

Minnesota Pollution Control Agency also offers ways to "reduce salt use while maintaining high safety standards" on their web site (www.pca.state.mn.us). Examples include using sand to improve traction and removing excess salt.

There is strong and consistent scientific evidence for environmental problems associated with road salt applications. Balancing public safety with environmental protection could become a significant challenge as accumulating concentrations of salt in our freshwater continues to threaten the environment and drinking water supplies. It is possible that by managing and, in some areas limiting, road salt use now, we may be able to halt the steady increase in surface and ground water concentrations (Jin et al. 2011).

Summary and conclusions

As supported by many scientific studies, road salt is contributing to long-term salinization of streams of the northeastern U.S (including Maryland). Salinization appears to alter the ecological condition of freshwater stream ecosystems in many places including Maryland. A preliminary examination of data collected by the Maryland Biological Stream Survey indicated that benthic macroinvertebrates, fish, salamander, and freshwater mussel richness respond negatively to elevated chloride concentrations. Consistent with other studies, amphibians and freshwater mussels seem to be the most sensitive stream-dwelling animals. The Canadian Council of Ministries of the Environment and several U.S. states have set water quality limits or guidelines for chloride. MDE is working toward chloride water quality criteria for Maryland waters, but none exist at this time. The Maryland State Highway Administration (SHA), in conjunction with MDE established a statewide Salt Management Plan in October 2011. This plan includes several best management practices that SHA is required to use and State and local jurisdictions are encouraged to use to minimize the adverse environmental impacts of road salt runoff. Some other practices also exist and could be considered. There are strong relationships between impervious surface and chloride concentrations. If road salt continues to be applied to Maryland roadways at its current rate, salt concentrations in freshwater streams and drinking water reservoirs will continue to increase. But, by more aggressively managing and in some cases limiting, road salt use now, we may be able to halt, or at least slow, this increase.

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Appendix A
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Ecological Effects of Road Salt

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Appendix B. Table of state chloride criteria from Tim Fox, Maryland Department of the Environment.

	Chloride Criteria		
	Criteria Maximum Concentration	Criteria Continuous Concentration	Link to document explaining the criteria if available.
Alabama	NA	NA	http://adem.alabama.gov/alEnviroRegLaws/files/Division6Vol1.pdf
Alaska	860	230	http://dec.alaska.gov/water/wqsar/wqs/pdfs/Alaska%20Water%20Quality%20Criteria%20Manual%20for%20Toxic%20and%20Other%20Deleterious%20Organic%20and%20Inorganic%20Substances.pdf
Arizona	NA	NA	http://www.azdeq.gov/environ/water/standards/download/SWQ_Standards-1-09-unofficial.pdf
Arkansas	site specific	site specific	http://www.adeq.state.ar.us/water/branch_planning/wqs_review.htm
California	NA	NA	http://www.waterboards.ca.gov/mywaterquality/water_quality_standards/
Colorado	site specific (most are 250)		http://www.cdphe.state.co.us/regulations/wqccregs/
Connecticut	NA	NA	http://www.ct.gov/dep/lib/dep/water/water_quality_standards/wqs.pdf
Delaware	NA	NA	http://www.dnrec.state.de.us/DNREC2000/Divisions/Water/WaterQuality/WQStandard.pdf
Florida	250 or 10% deviation		http://www.dep.state.fl.us/legal/Rules/shared/62-302/62-302.pdf
Georgia	NA	NA	http://rules.sos.state.ga.us/docs/391/3/6/03.pdf
Hawaii	NA	NA	http://gen.doh.hawaii.gov/sites/har/AdmRules1/11-54.pdf
Idaho	NA	NA	http://adminrules.idaho.gov/rules/current/58/0102.pdf
Illinois	NA	NA	http://www.epa.state.il.us/water/water-quality-standards/water-quality-criteria-list.pdf
Indiana	860	230	http://www.in.gov/legislative/iac/T03270/A00020.PDF
Iowa	New Data	New Data	http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/ChemicalCriteria.aspx
Kansas	860	under investigation	http://www.kdheks.gov/water/download/kwqs_plus_supporting.pdf
Kentucky	1200	600	http://lrc.ky.gov/kar/401/010/031.htm
Louisiana	site specific		http://water.epa.gov/scitech/swguidance/standards/upload/2007_10_16_standards_wqslibrary_la_la_6_wqs.pdf
Maine	860	230	http://www.maine.gov/sos/cec/rules/06/chaps06.htm
Maryland	NA	NA	
Massachusetts	860	230	
Michigan	NA	NA	http://www.michigan.gov/documents/deq/wrd-swas-rule57_372470_7.pdf
Minnesota	860	230	https://www.revisor.mn.gov/rules/?id=7050.0220
Mississippi	site specific		http://www.deq.state.ms.us/mdeq.nsf/pdf/WMB_adopted_wqsstandoc_aug07/$File/WQS_std_adpt_aug07.pdf?OpenElement
Missouri	Iowa equations		http://www.sos.mo.gov/adrules/csr/current/10csr/10c20-7a.pdf
Montana	NA	NA	http://deq.mt.gov/wqinfo/Standards/default.mcpx
Nebraska	860	230	http://www.deq.state.ne.us/RuleAndR.nsf/23e5e39594c064ee852564ae004fa010/9f07eae313ae56d686256888005bc61e/$FILE/T117Ch4_4.1.12.pdf
Nevada	250 but also site specific for high water quality		http://www.leg.state.nv.us/nac/nac-445a.html#NAC445ASec118
New Hampshire	860	230	http://des.nh.gov/organization/commissioner/legal/rules/documents/env-wq1700.pdf
New Jersey	860	230	http://www.nj.gov/dep/rules/rules/njac7_9b.pdf
New Mexico	some site specific 250		http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0004.pdf
New York	250		http://www.dec.ny.gov/regs/4590.html
North Carolina	230 action level		http://portal.ncdenr.org/c/document_library/get_file?uuid=ad77b198-aa3d-4874-9723-54ce730b3a8d&groupId=38364
North Dakota	100 or 250 in some areas but also incorporate Na into standards!		http://www.legis.nd.gov/information/acdata/pdf/33-16-02.1.pdf
Ohio	NA		http://www.epa.ohio.gov/portals/35/rules/01-07.pdf
Oklahoma	site specific		http://www.owrb.ok.gov/util/rules/pdf_rul/RulesCurrent2011/Ch45-Current2011.pdf
Oregon	860	230	http://www.deq.state.or.us/wq/standards/toxics.htm#Cur
Pennsylvania	250pws		http://www.pacode.com/secure/data/025/chapter93/chap93toc.html
Rhode Island	860	230	http://www.dem.ri.gov/pubs/regs/regs/water/h2oq10.pdf
South Carolina	NA	NA	http://www.scdhec.gov/environment/water/regs/r61-68.pdf
South Dakota	NA	NA	http://legis.state.sd.us/rules/DisplayRule.aspx?Rule=74:51:01:0B
Tennessee	250		http://southeastaquatics.net/uploads/category/TDECWaterQualityStandards.pdf
Texas	site specific		http://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/307%60.pdf
Utah	NA	NA	http://www.rules.utah.gov/publicat/code.htm#Environmen
Vermont	NA		http://www.nrb.state.vt.us/wrp/publications/wqs.pdf
Virginia	860	230	http://www.deq.state.va.us/Portals/0/DEQ/Water/WaterQualityMonitoring/TOX/2012/Appendices/Appendix_A_DEQ_Water_Quality_Standards_Jan2011.pdf
Washington	860	230	http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-240
West Virginia	860	230	http://www.dep.wv.gov/WWE/getinvolved/sos/Documents/WQS/Standards.pdf
Wisconsin	757	395	http://dnr.wi.gov/org/water/wm/wqs/wqbel.htm
Wyoming	860	230	http://soswy.state.wy.us/Rules/RULES/6547.pdf