RISING SALINITY IN THE GREAT LAKES REGION: ECOLOGICAL AND REGULATORY PERSPECTIVES

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Department of Environmental Sciences and Lake Erie Center

THE UNIVERSITY OF TOLEDO

PNAS

Increased salinization of fresh water in the northeastern United States

Sujay S. Kaushal*†‡, Peter M. Groffman*, Gene E. Likens*‡, Kenneth T. Belt§, William P. Stack¶, Victoria R. Kelly*, Lawrence E. Band‖, and Gary T. Fisher**

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Contributed by Gene E. Likens, August 4, 2005

WATER

Saving freshwater from salts

Ion-specific standards are needed to protect biodiversity

By M. Cañedo-Argüelles,[1,2] C. P. Hawkins,[3] B. J. Kefford,[4] R. B. Schäfer,[5] B. J. Dyack,[4] S. Brucet,[6,1] D. Buchwalter,[7] J. Dunlop,[8] O. Frör,[5] J. Lazorchak,[9] E. Coring,[10] H. R. Fernandez,[11] W. Goodfellow,[12] A. L. González Achem,[11] S. Hatfield-Dodds,[13] B. K. Karimov,[14] P. Mensah,[15] J. R. Olson,[16] C. Piscart,[17] N. Prat,[2] S. Ponsá,[1] C.-J. Schulz,[18] A. J. Timpano[19]

esa

ECOSPHERE

A global perspective on wetland salinization: ecological consequences of a growing threat to freshwater wetlands

ELLEN R. HERBERT,[1,†] PAUL BOON,[2] AMY J. BURGIN,[3] SCOTT C. NEUBAUER,[4] RIMA B. FRANKLIN,[4] MARCELO ARDÓN,[5] KRISTINE N. HOPFENSPERGER,[6] LEON P. M. LAMERS,[7] AND PETER GELL[8]

Salinisation of rivers: An urgent ecological issue

Miguel Cañedo-Argüelles [a,*], Ben J. Kefford [b], Christophe Piscart [c], Narcís Prat [a], Ralf B. Schäfer [d], Claus-Jürgen Schulz [e]

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[b] *Centre for Environmental Sustainability, School of the Environment, University of Technology Sydney (UTS), Sydney, PO Box 123, Broadway, NSW 2007, Australia*
[c] *Université de Lyon, UMR5023 Ecologie des Hydrosystèmes Naturels et Anthropisés, Université Lyon 1, ENTPE, CNRS, 6 rue Raphaël Dubois, 69622 Villeurbanne, France*
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SALINIZATION: WE HAVE A SALT PROBLEM

Chicago Tribune

Road salt drives salinization of lakes

Researchers express alarm about human health, ecosystems

MOTHERBOARD

Road Salt is Turning North America's Freshwater Lakes into Saltwater

If current trends continue, many freshwater lakes in the US and Canada will be too salty for human use or aquatic life.

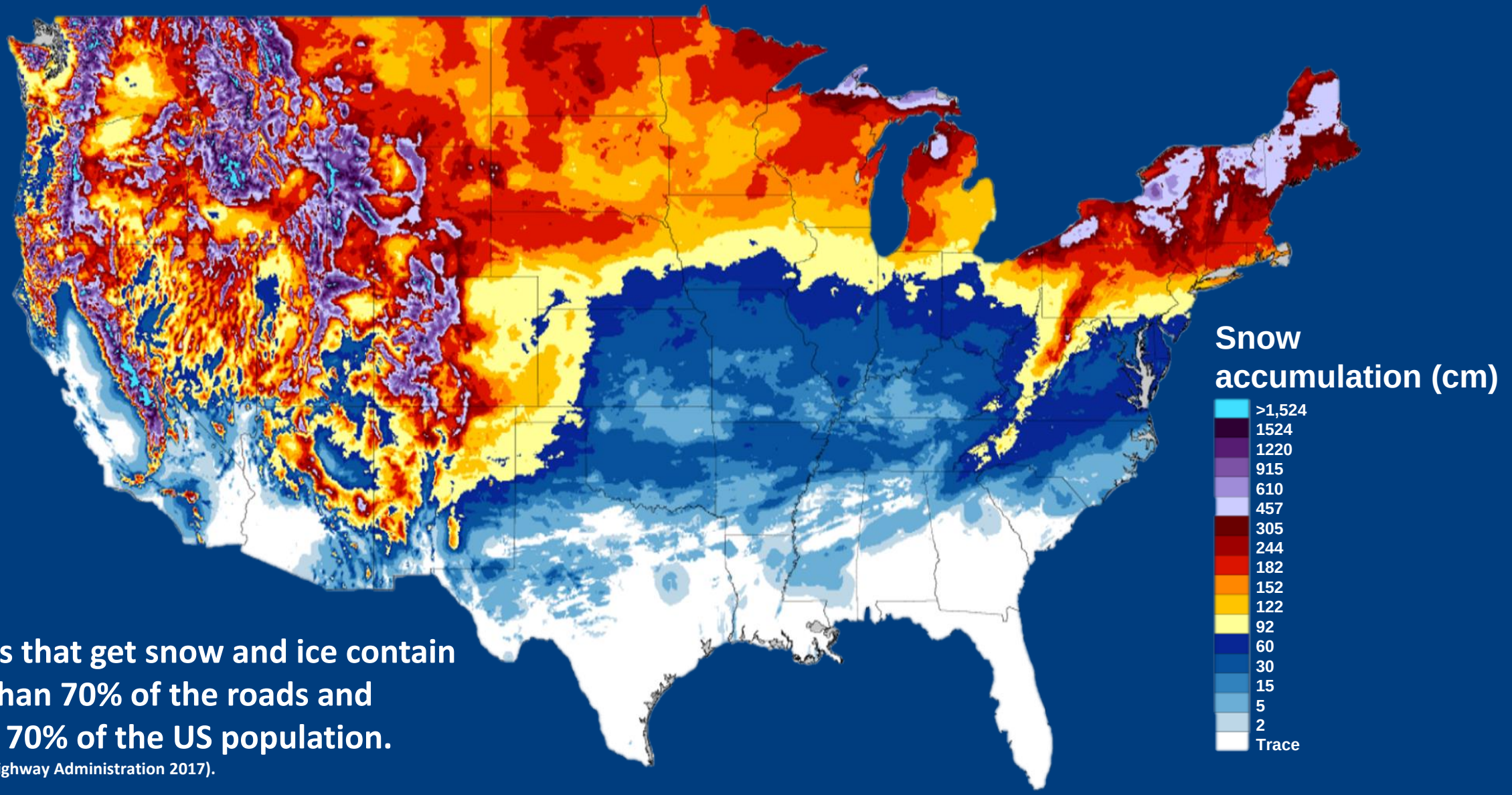
NATIONAL GEOGRAPHIC

North America's Waterways are Getting Saltier. That's a Big Problem.

ROAD SALTS ARE VERY NECESSARY FOR HUMAN SAFETY

Road salts reduce accident rates on average by 87% and 78% on two-lane and multi-lane highways, respectively

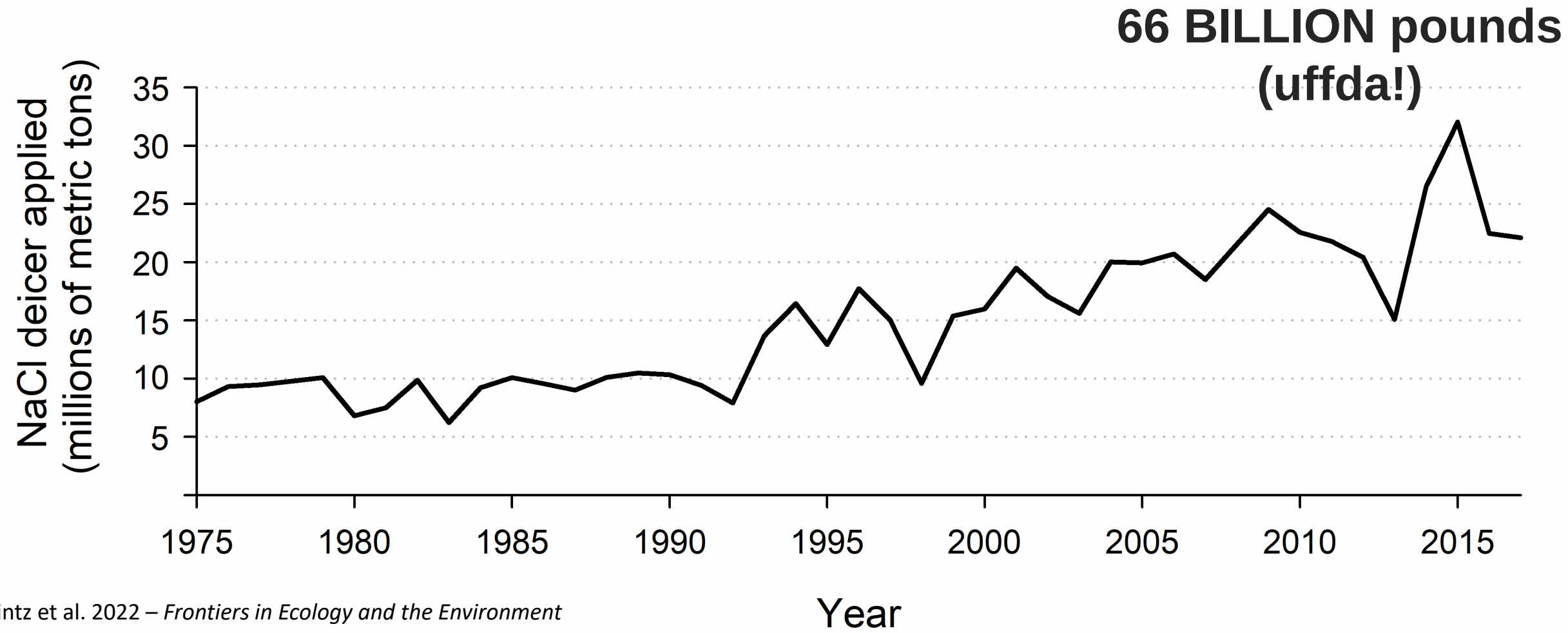
The need for road salts in the US



Regions that get snow and ice contain more than 70% of the roads and almost 70% of the US population.

(US Federal Highway Administration 2017).

How much road salt is applied?



Hintz et al. 2022 – *Frontiers in Ecology and the Environment*

How much road salt is applied?

Annual application rates of deicing salts in many states and other countries range from 12–75 metric tons/km of two-lane highway

That's 2.9 – 18.2 lbs/m^2

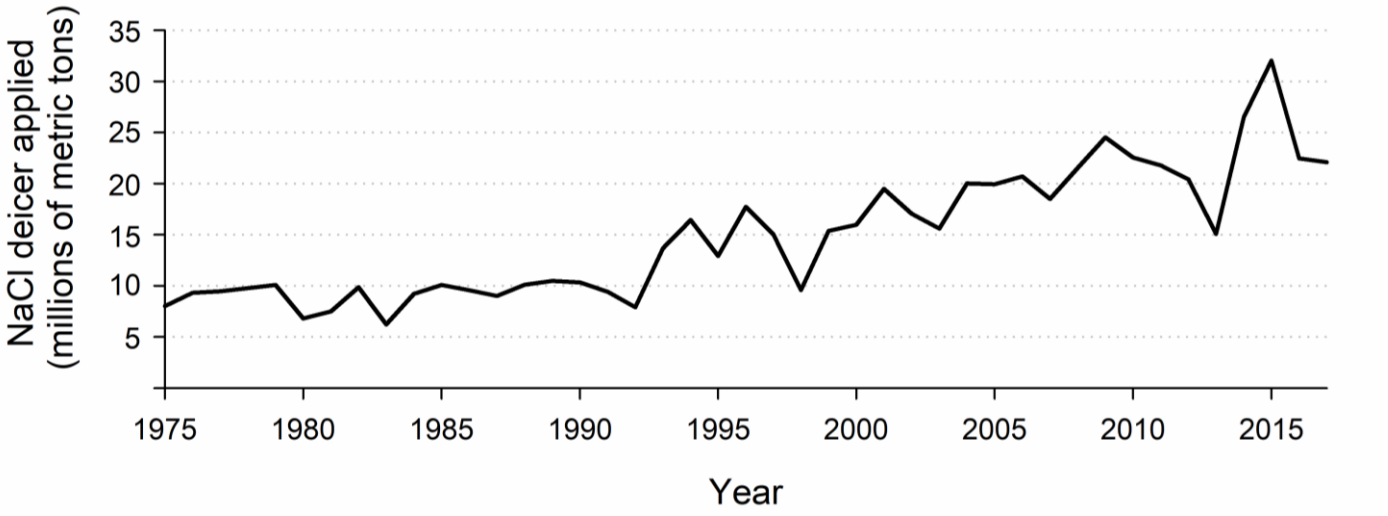
(Environment Canada and Health Canada; Langen et al. 2006).

How much salt is applied?

The white on the sidewalk and parking lot is not snow… it's salt

Photo: B. Hintz

Why so much salt?



Contents lists available at SciVerse ScienceDirect

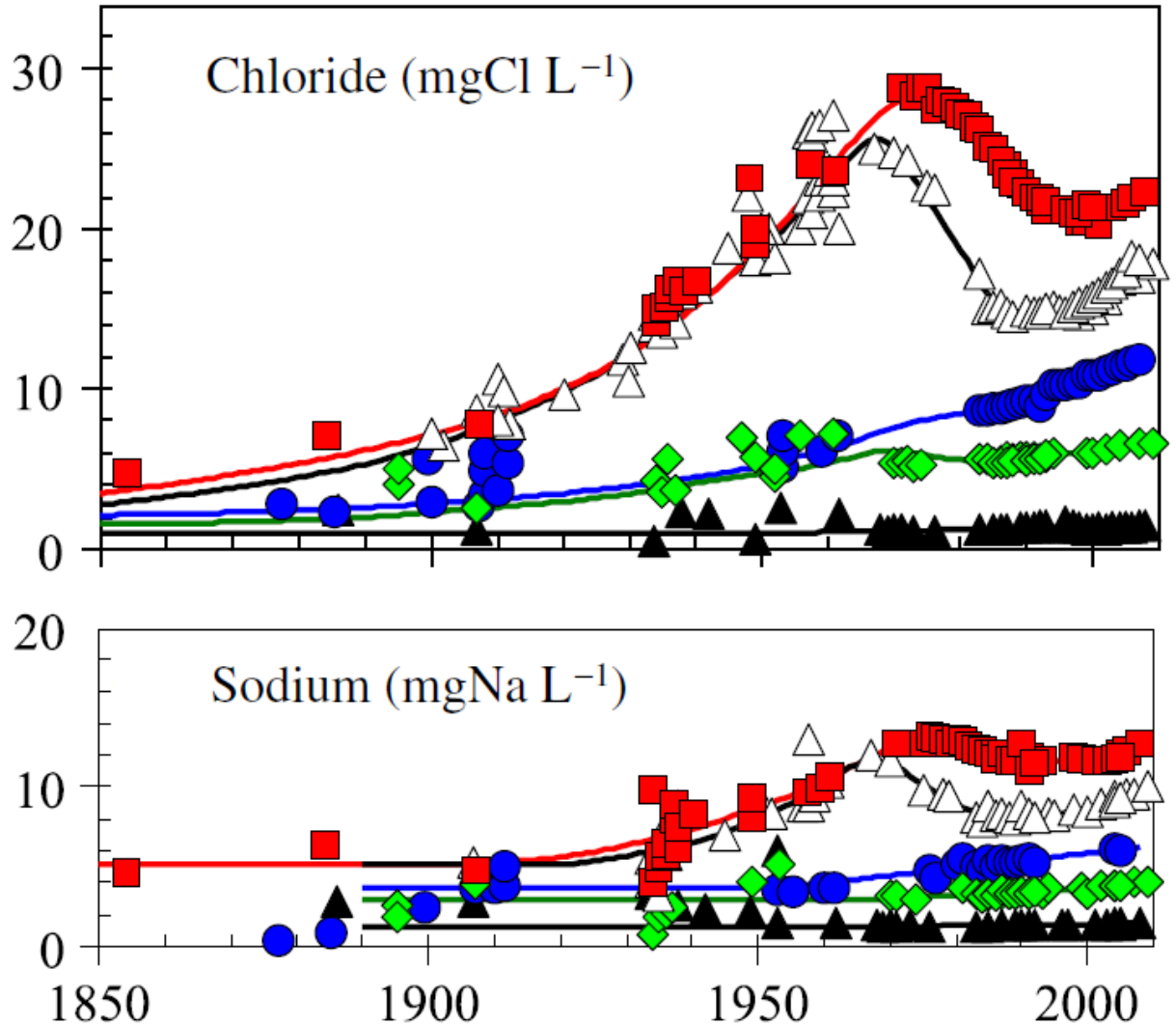
Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Long-term trends of Great Lakes major ion chemistry

Steven C. Chapra [a], Alice Dove [b,*], Glenn J. Warren [c]

[a] Civil and Environmental Engineering Department, Tufts University, Medford, MA 02155, USA
[b] Water Quality Monitoring and Surveillance, Environment Canada, Burlington, ON, Canada L7R 4A6
[c] U.S. EPA Great Lakes National Program Office, 77 W. Jackson Blvd., Chicago, IL 60604, USA



SPECIAL ISSUE-LETTER

Tributary chloride loading into Lake Michigan

Hilary A. Dugan[1]*, *Linnea A. Rock*[1], *Anthony D. Kendall*[2], *Robert J. Mooney*[1]
[1]Center for Limnology, University of Wisconsin-Madison, Madison, Wisconsin; [2]Department of Earth and Environmental Sciences, Michigan State University, East Lansing, Michigan

- 1.08 Tg/yr = 2,380,992,431 pounds per year of chloride
- Year after year
- Other stressors
  - Invasive species
  - Climate change
  - Other contaminants

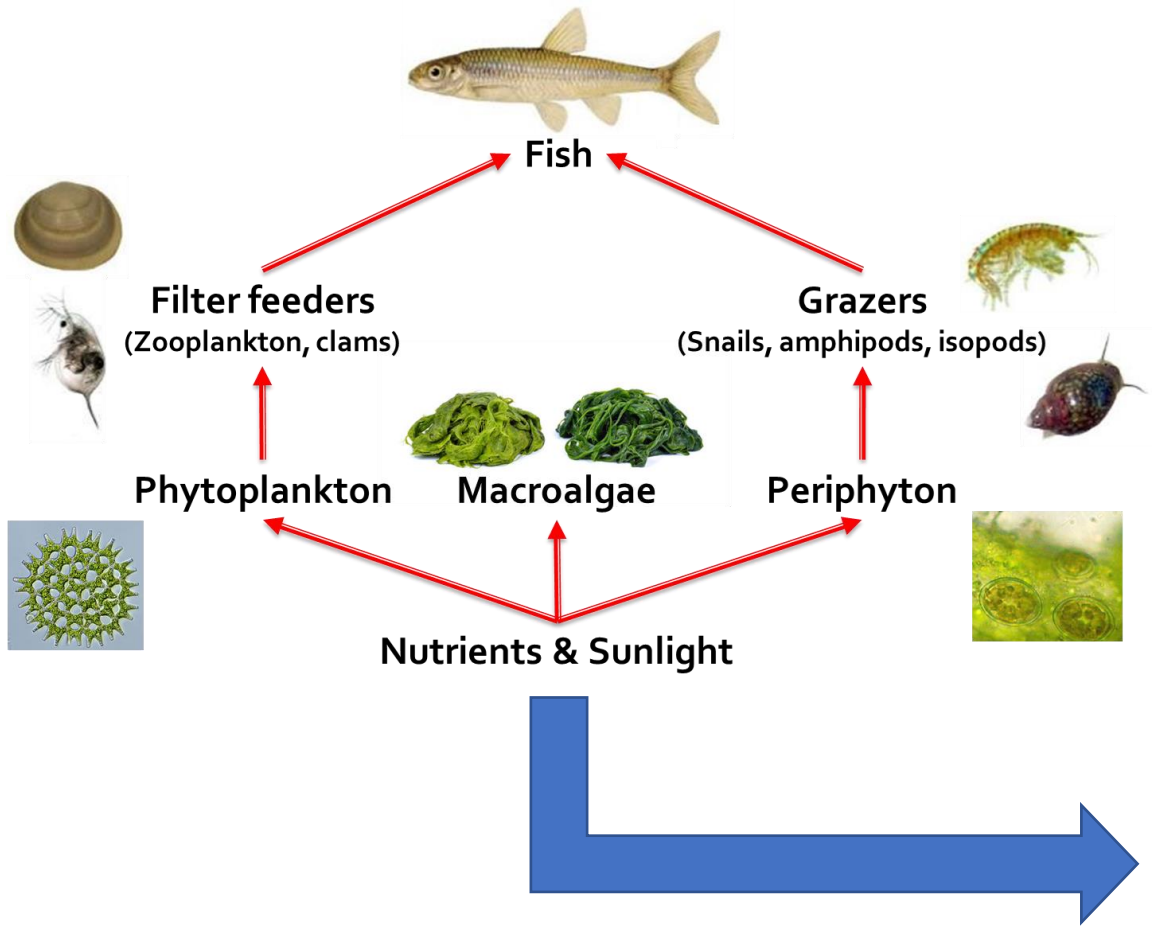
https://idsb.tmgrup.com.tr/ly/uploads/images/2020/10/08/63604.jpg

What are some of the ecological impacts of road salts?

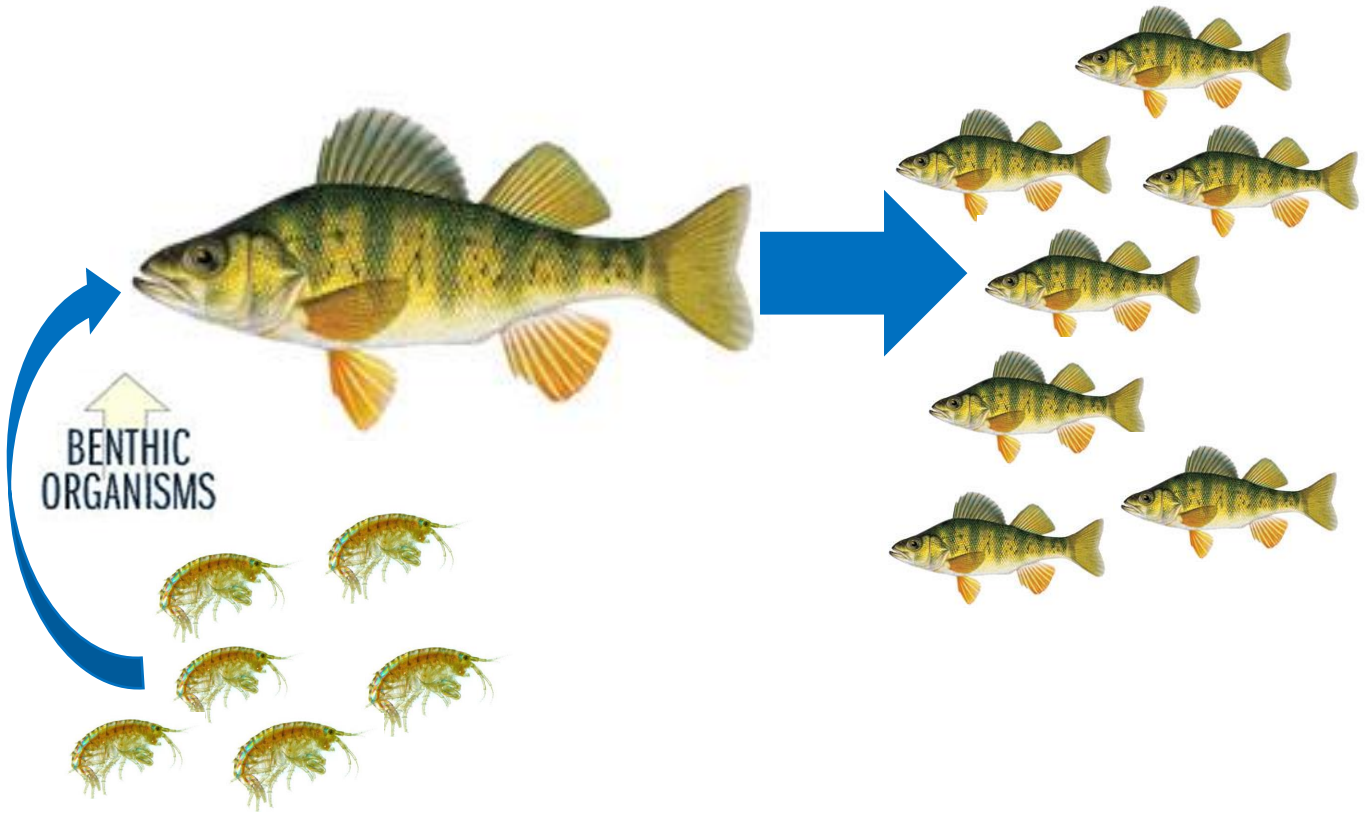
How do we answer questions about salt pollution?

Large-scale experimental studies

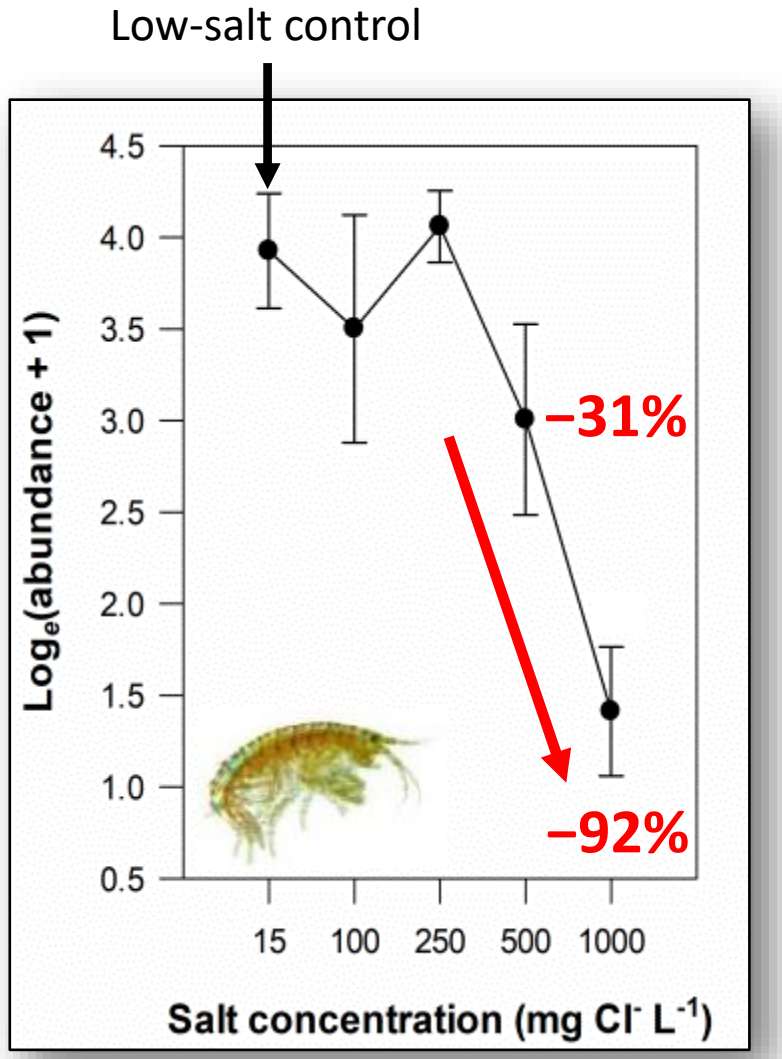
Experimental food web



A loss of food resources for freshwater fishes in highly contaminated systems

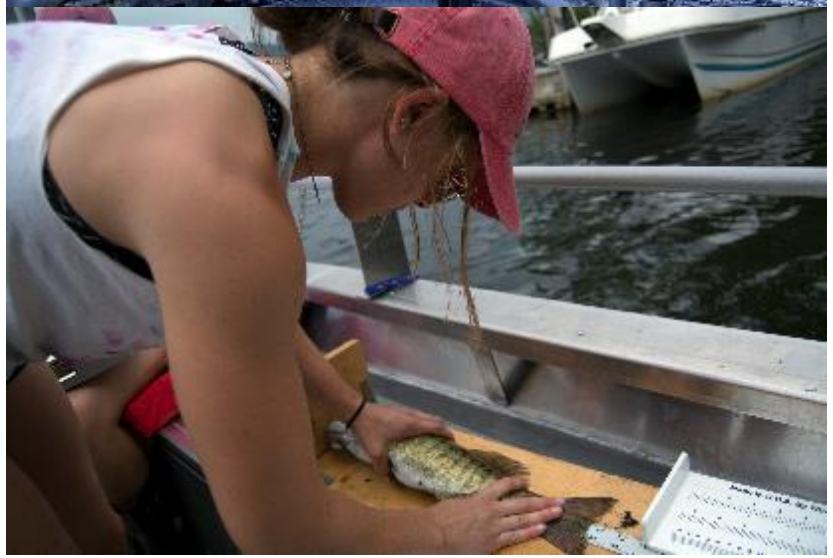


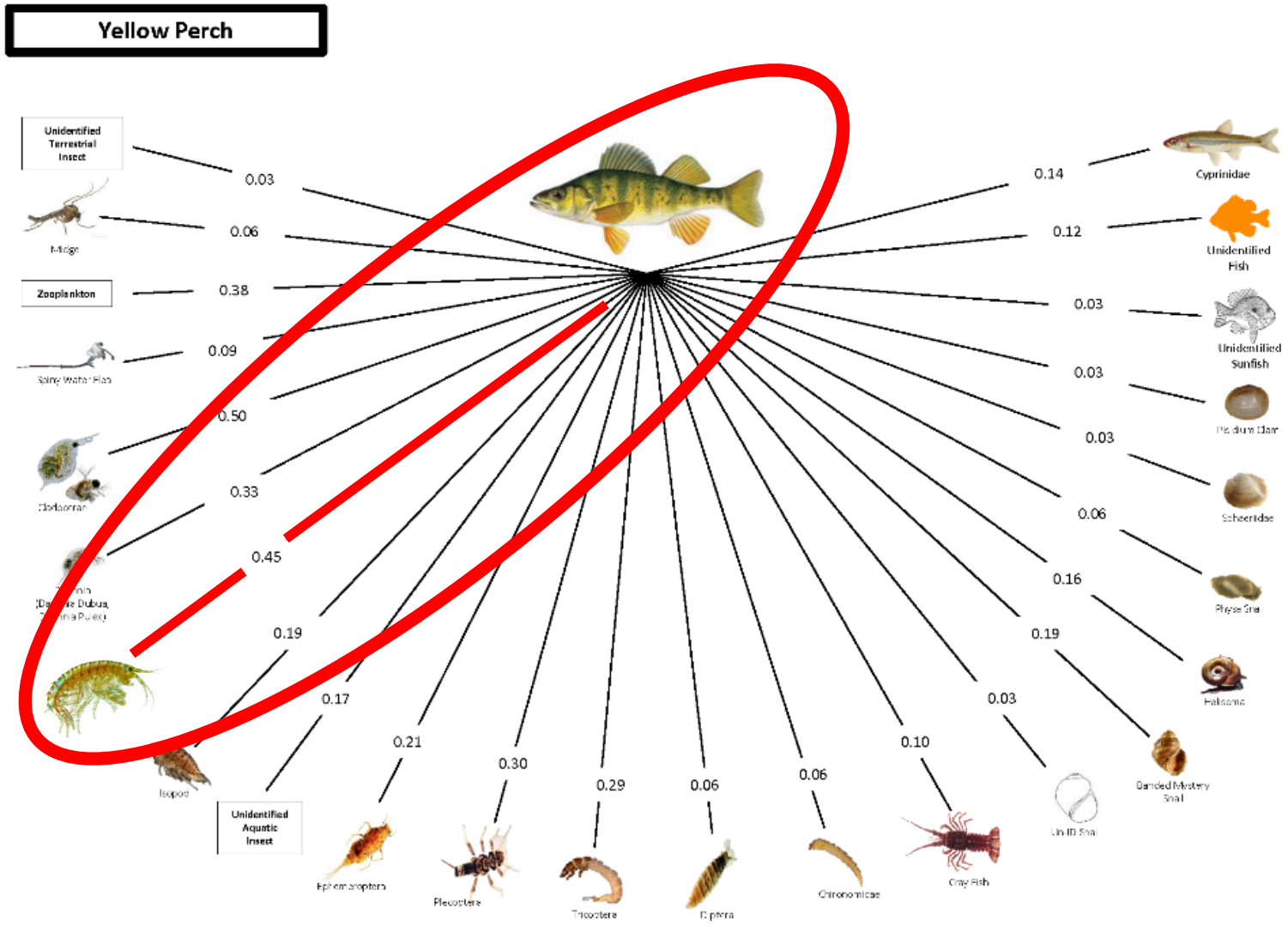
= Amphipod (fish food, among many other things)



Hintz et al. 2017, *Ecological Applications*

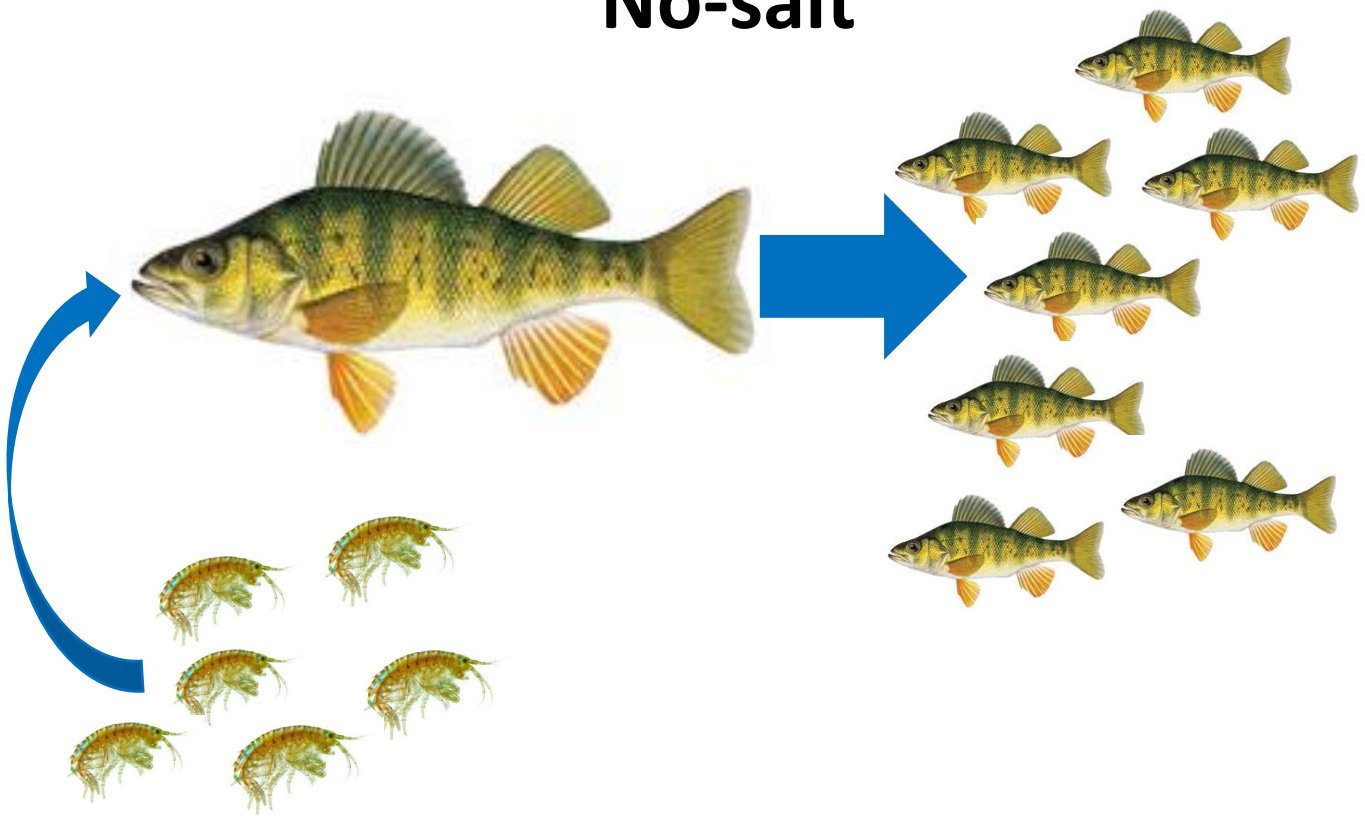
In our field studies, amphipods a highly preferred food item for yellow perch





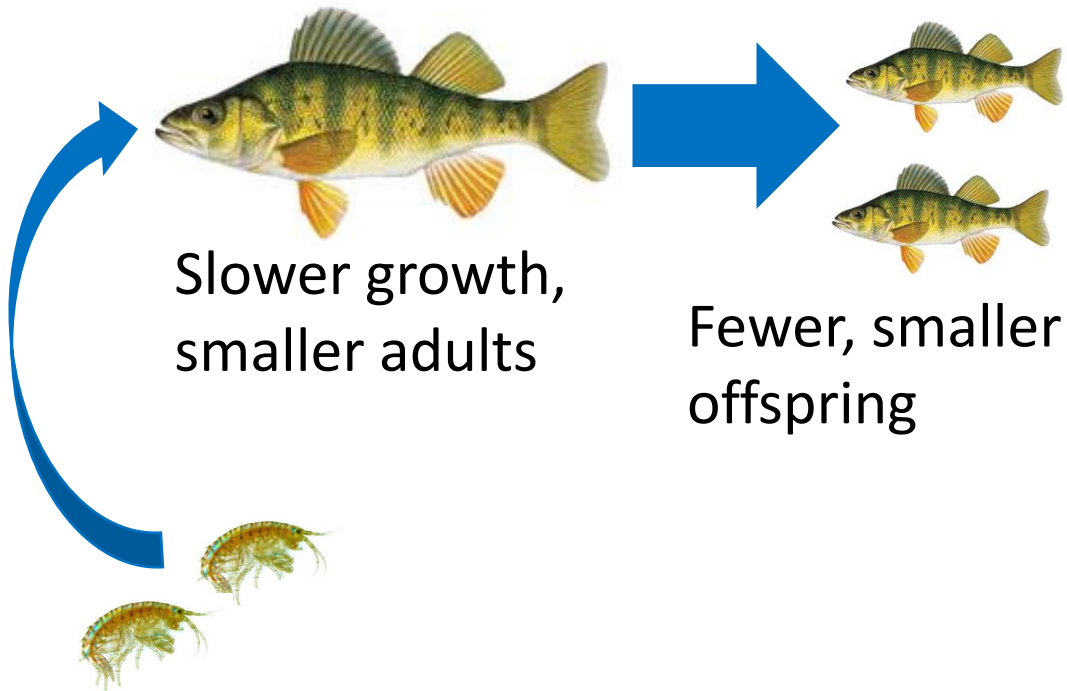
Concerns with loosing certain species within an ecosystem

No-salt



= Amphipod (fish food)

High salt?



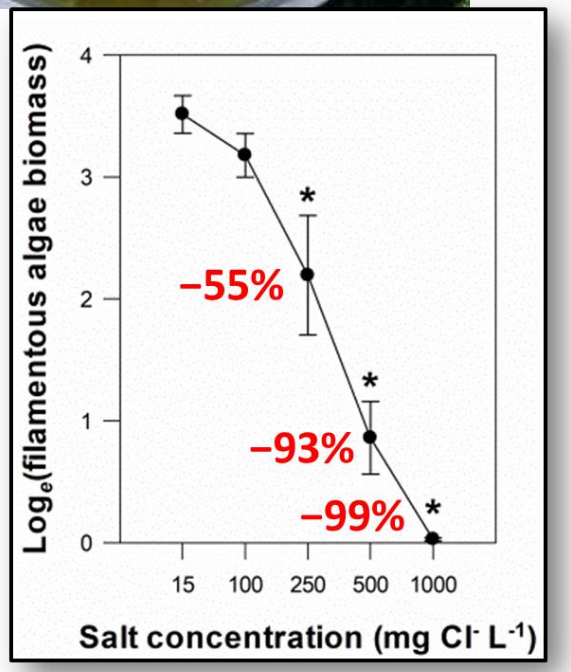
Slower growth, smaller adults

Fewer, smaller offspring

Reduced availability of quality food resources?

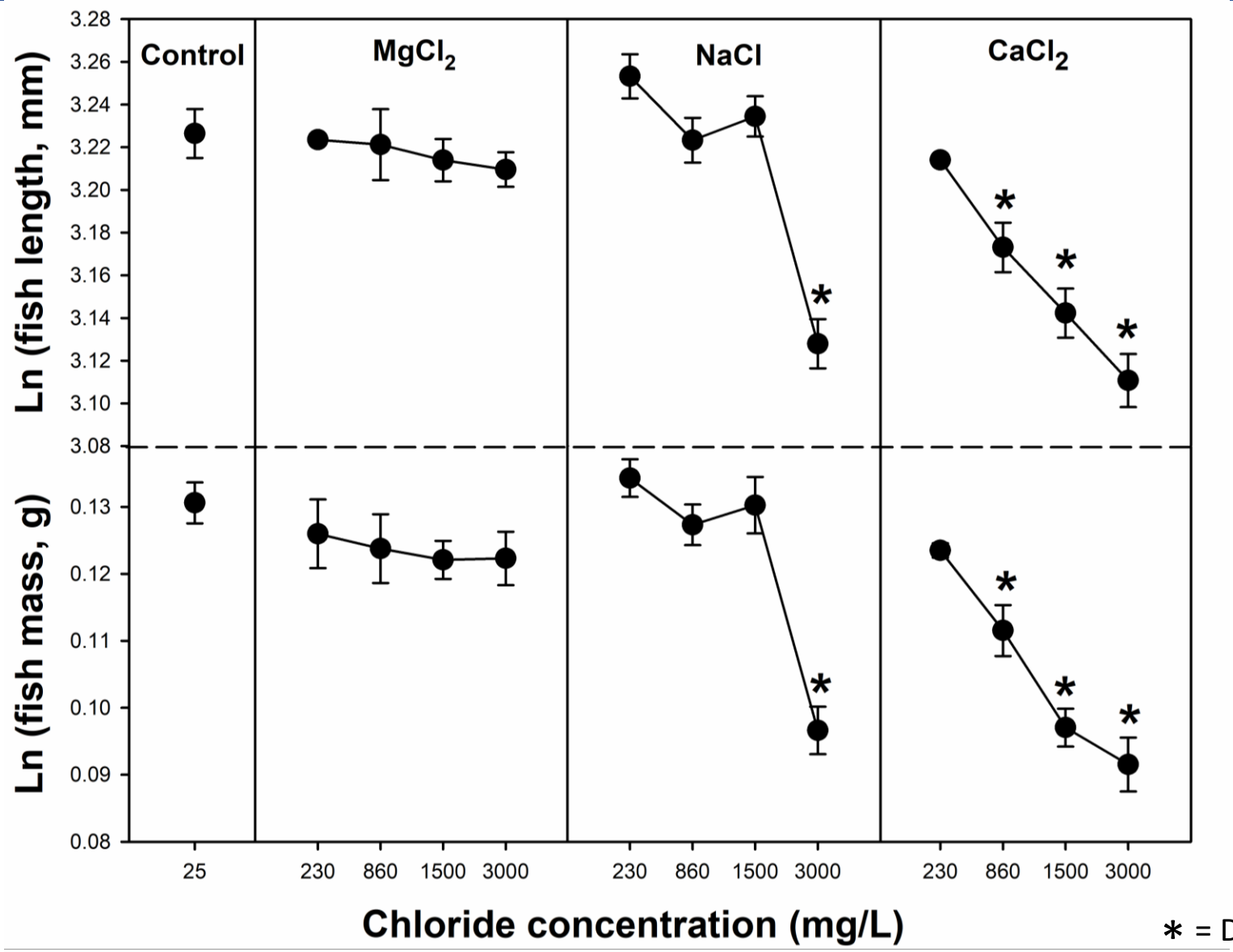
A loss of fish and invertebrate habitat…

Macroalgae



Hintz et al. 2017, *Ecological Applications*

Rainbow trout growth: salt type matters

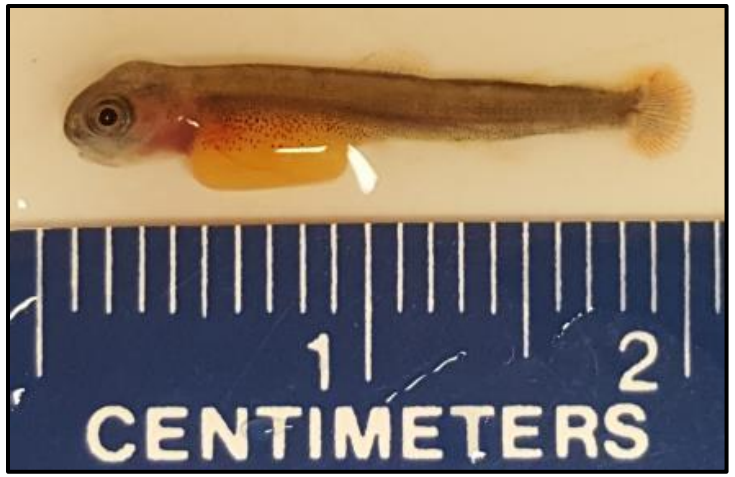


Hintz and Relyea 2017, *Environmental Pollution*

Road salt reduces trout growth

What will/could/has happened over the long-term to our fisheries?

After 25 days



Hintz and Relyea 2017, *Environmental Pollution*

WATER QUALITY GUIDELINES: FEDERAL

Chloride (Cl^-) thresholds applicable to protecting freshwater environments from salinization

CANADA

Chronic: 120 mg Cl^-/L

UNITED STATES

Chronic: 230 mg Cl^-/L

GERMANY

50 – 200 mg Cl^-/L, “slightly polluted”

200 – 400 mg Cl^-/L, “moderately polluted”

STATE OF MICHIGAN

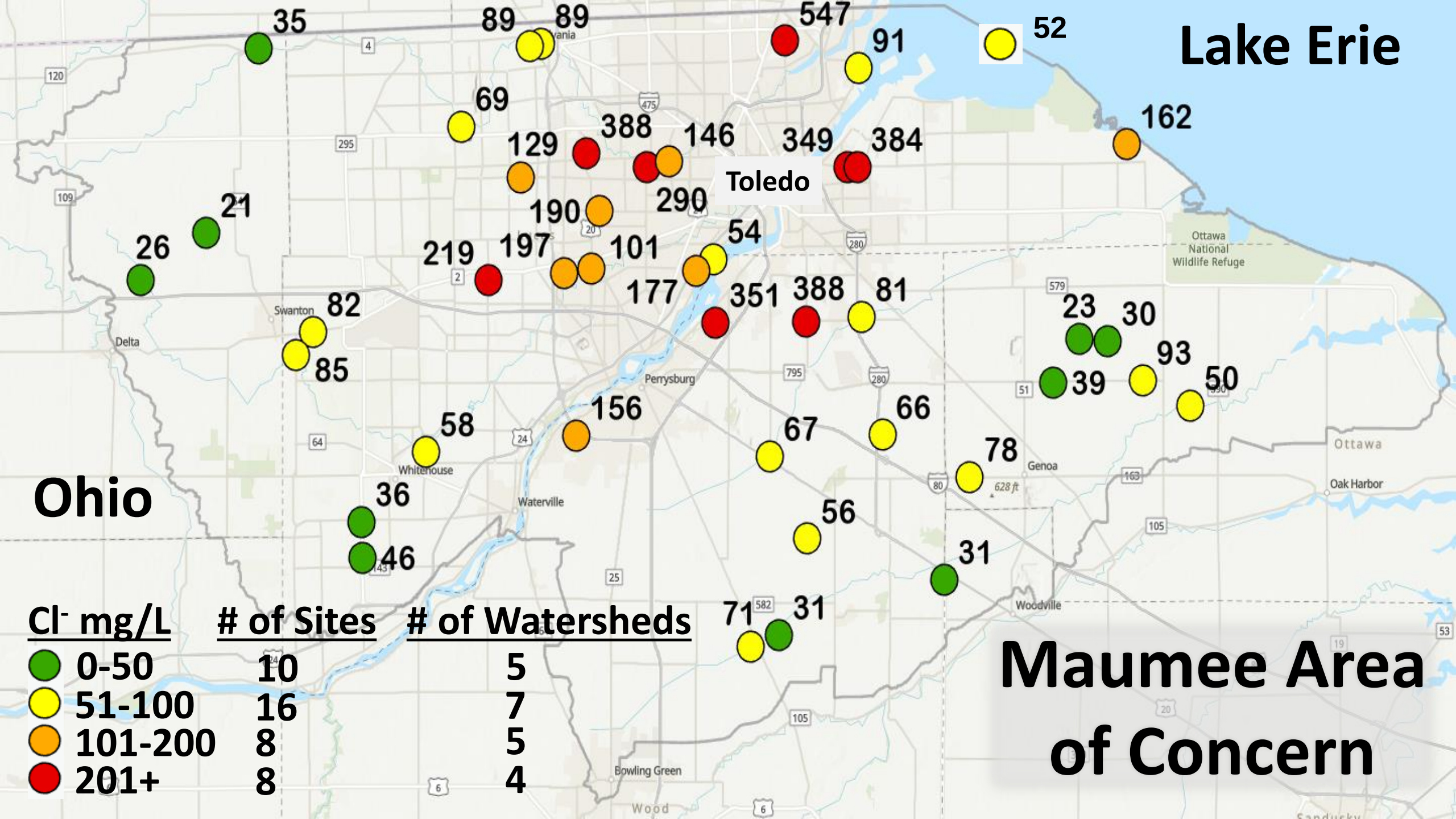
No water should exceed 500 mg/L of dissolved solids

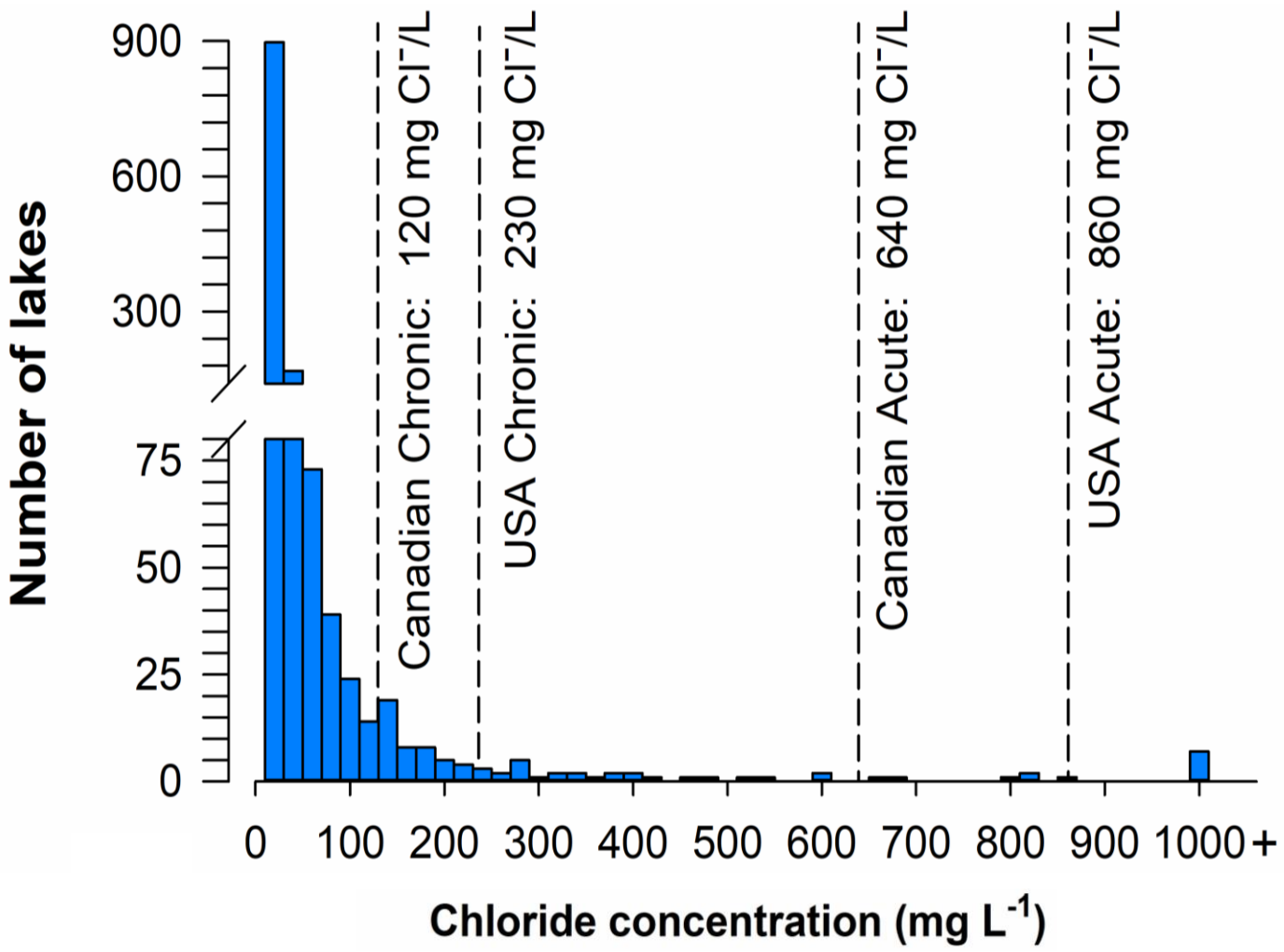
Public water supply not to exceed 125 mg Cl^-/L

Great lakes and connecting waters not to exceed 50 mg Cl^-/L

WATER QUALITY GUIDELINES: STATES

Chloride (Cl^-) thresholds applicable to protecting freshwater environments from salinization


Lake Erie
Ohio
Toledo
Maumee Area of Concern
35
89
89
547
91
52
69
388
146
129
349
384
162
290
190
21
26
219
197
101
54
177
351
388
81
82
85
23
30
93
39
50
58
156
67
66
78
36
46
56
31
71
31
Swanton
Delta
Perrysburg
Whitehouse
Waterville
Genoa
Oak Harbor
Woodville
Ottawa
Ottawa National Wildlife Refuge
Bowling Green
Wood
628 ft
Cl- mg/L
# of Sites
# of Watersheds
0-50 10 5
51-100 16 7
101-200 8 5
201+ 8 4

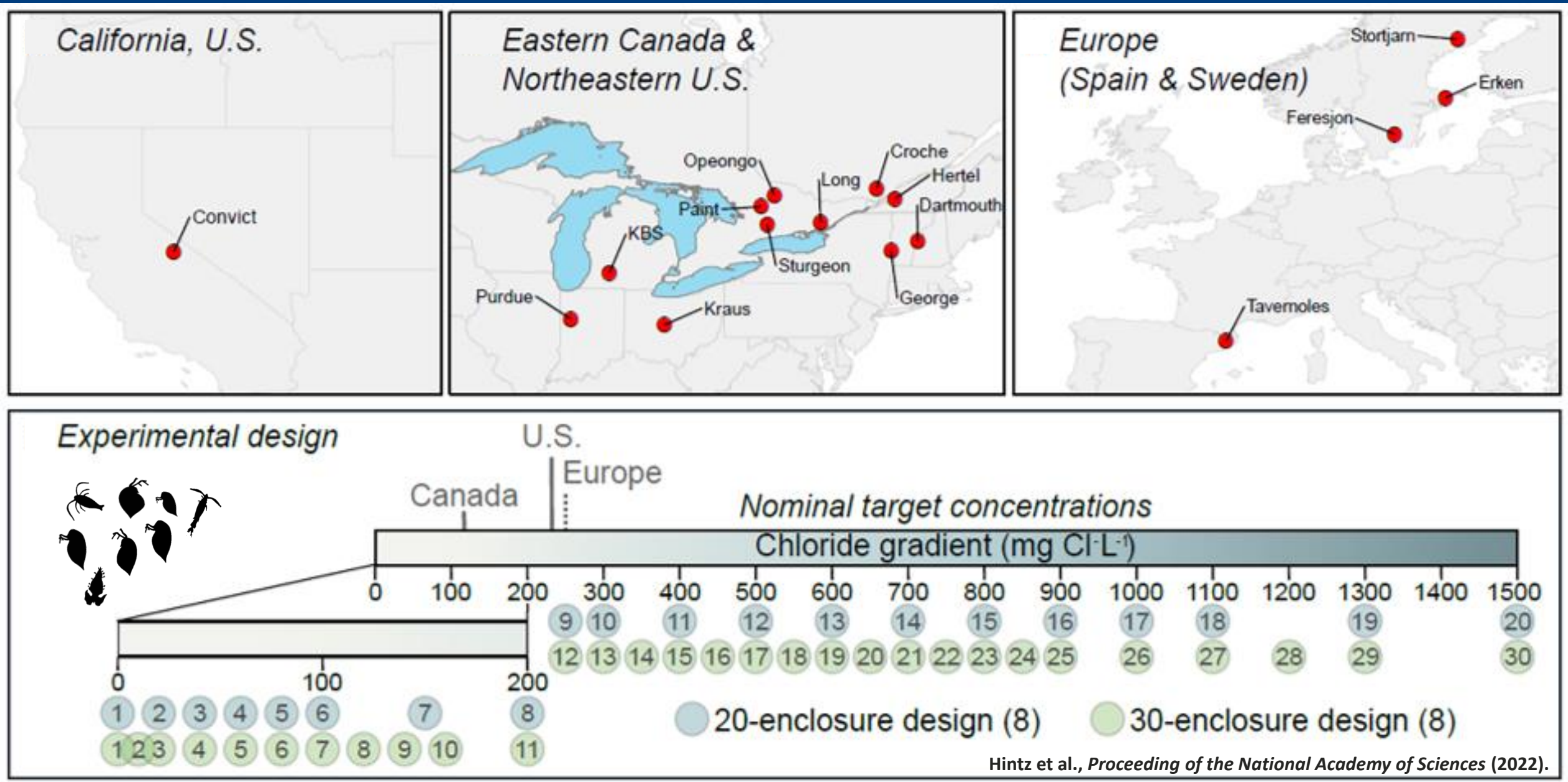


DO CHLORIDE THRESHOLDS PROTECT FRESHWATER ORGANISMS?

Need a broad-scale test

US Environmental Protection Agency's National Aquatic Resource Surveys (NARS) and scientific literature.

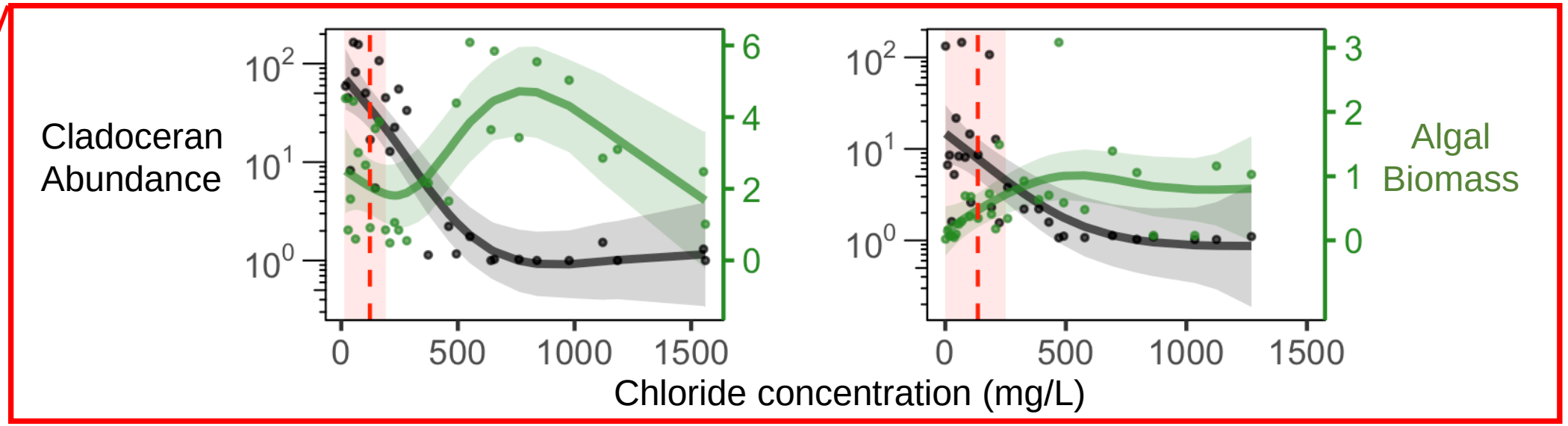
The impacts of NaCl on the zooplankton-algal energy pathway

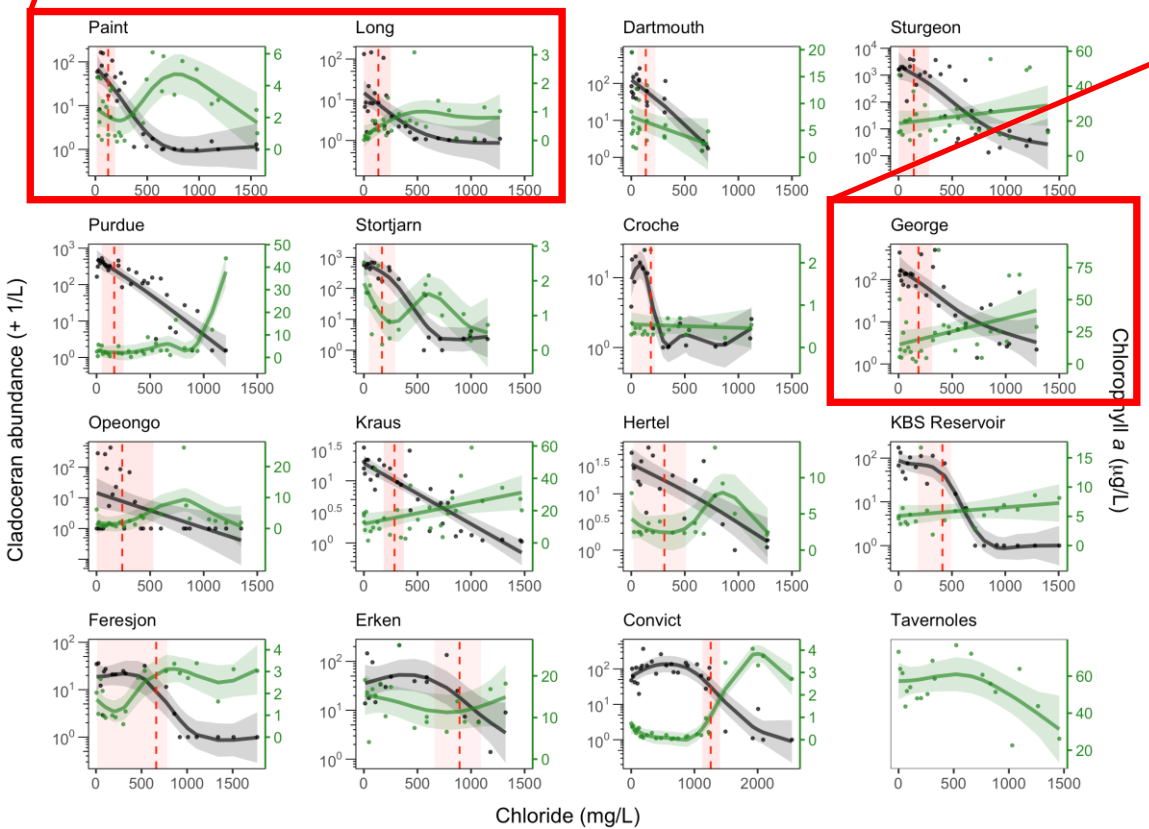


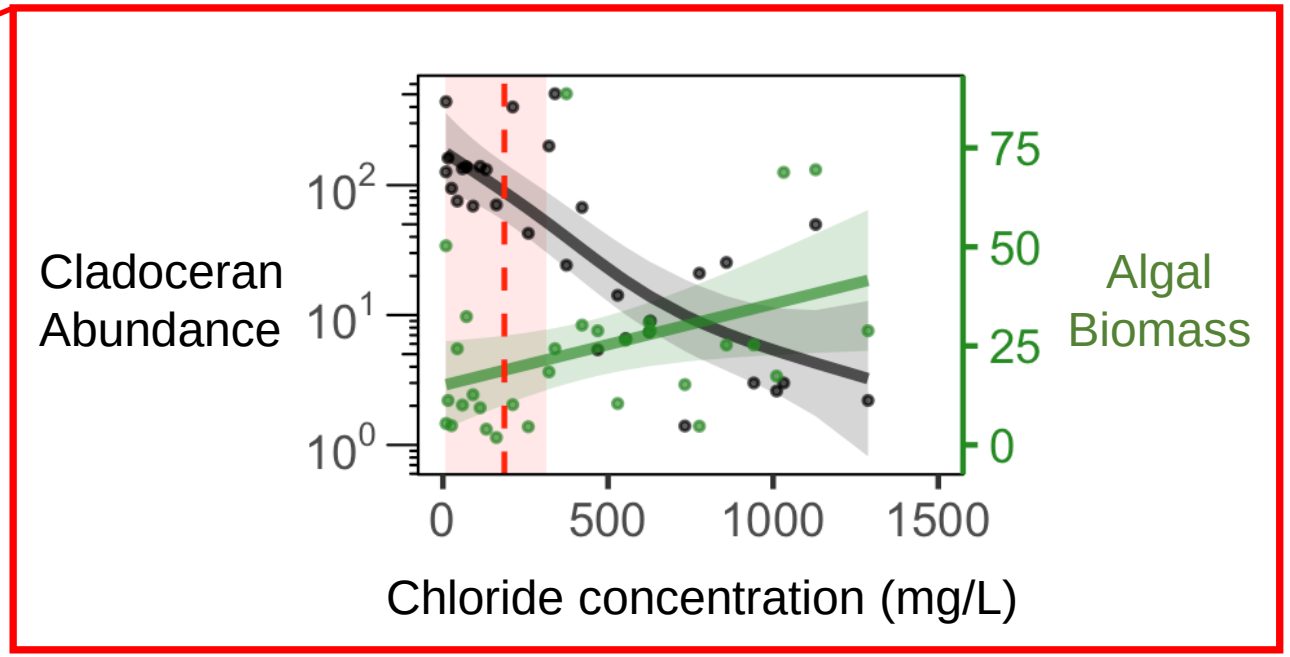
Hintz et al., *Proceeding of the National Academy of Sciences* (2022).

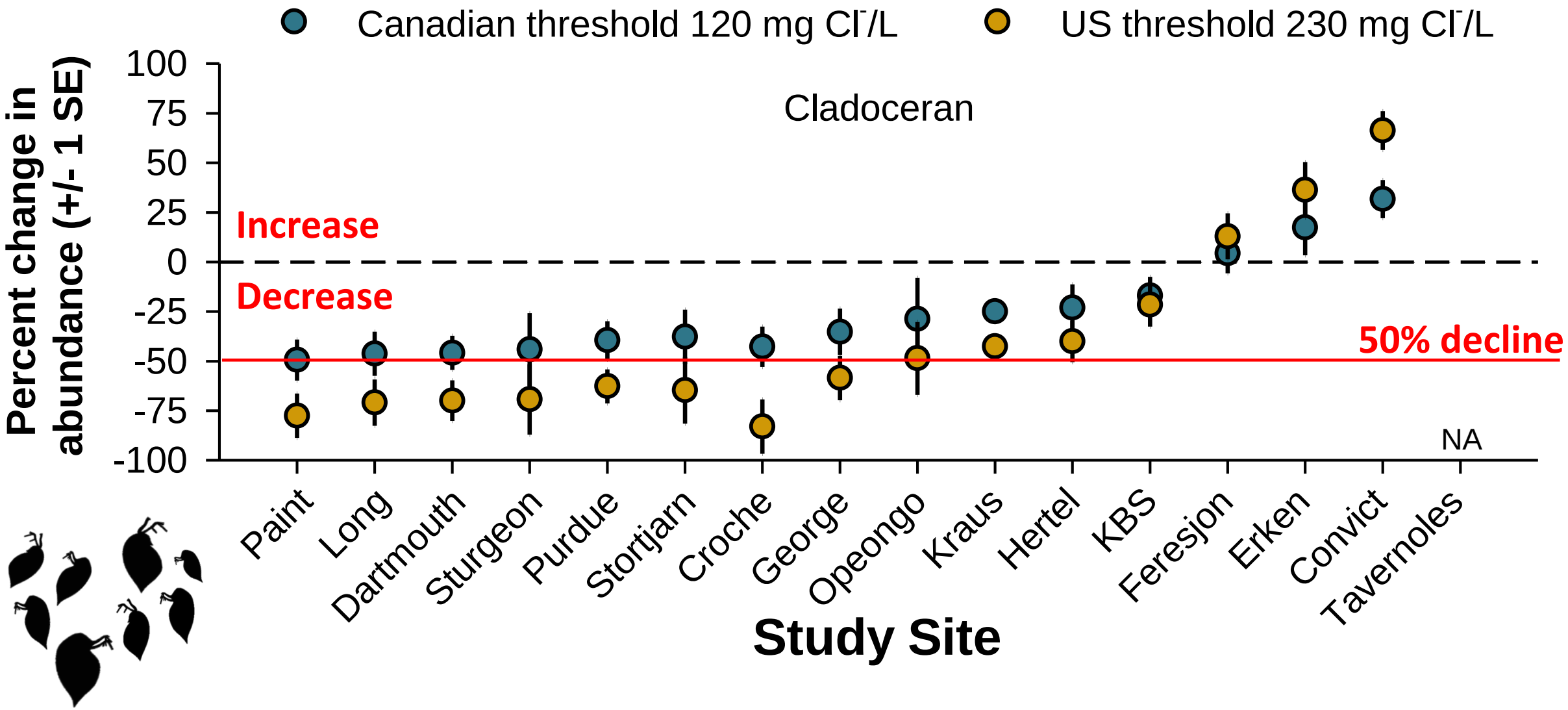
Global Salt Experiment

https://mesocosm.org/mesocosm/lake-mesocosms/


Cladoceran Abundance
Algal Biomass
Chloride concentration (mg/L)


Paint
Long
Dartmouth
Sturgeon
Purdue
Stortjarn
Croche
George
Opeongo
Kraus
Hertel
KBS Reservoir
Feresjon
Erken
Convict
Tavernoles
Cladoceran abundance (+ 1/L)
Chlorophyll a (µg/L)
Chloride (mg/L)


Cladoceran Abundance
Algal Biomass
Chloride concentration (mg/L)



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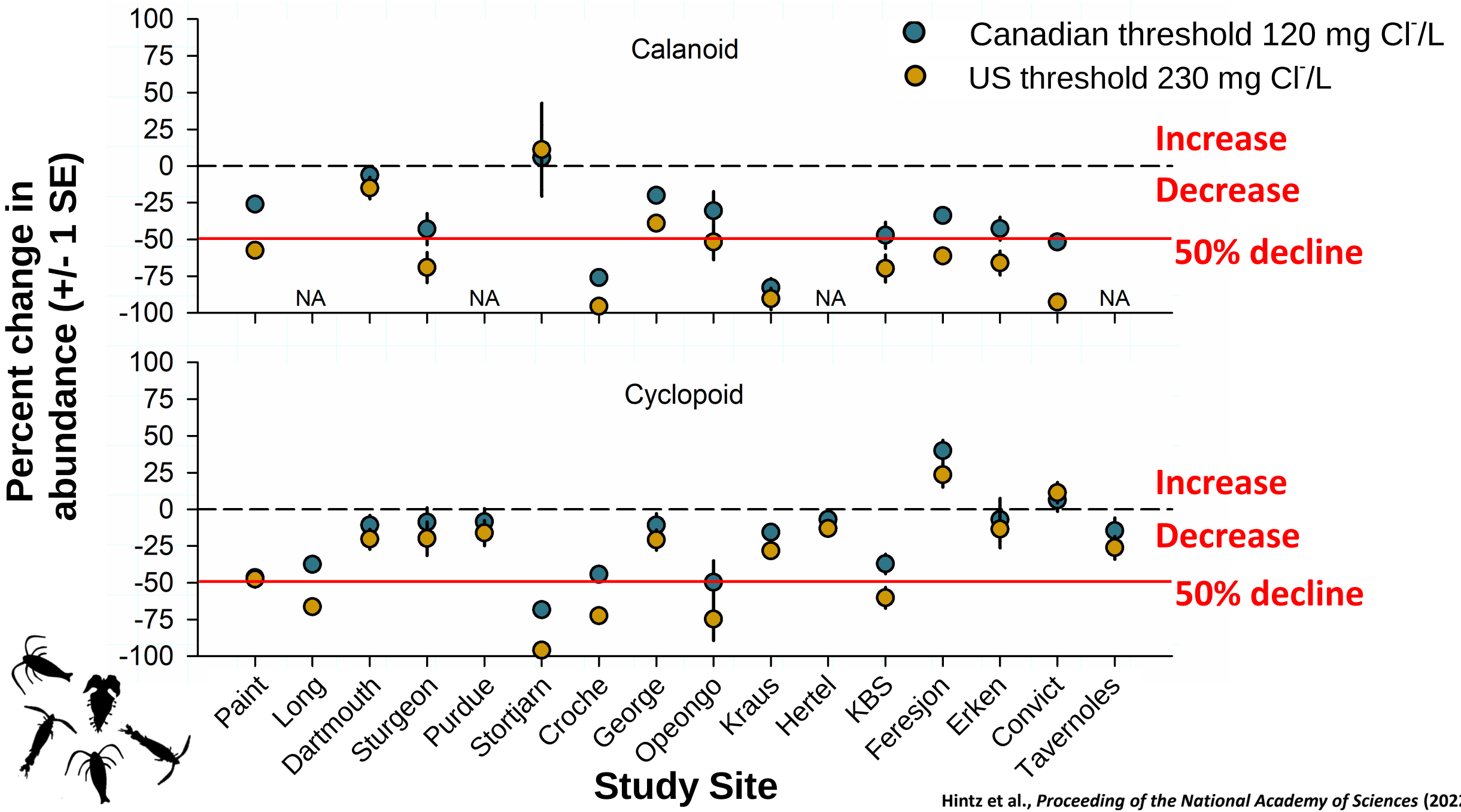
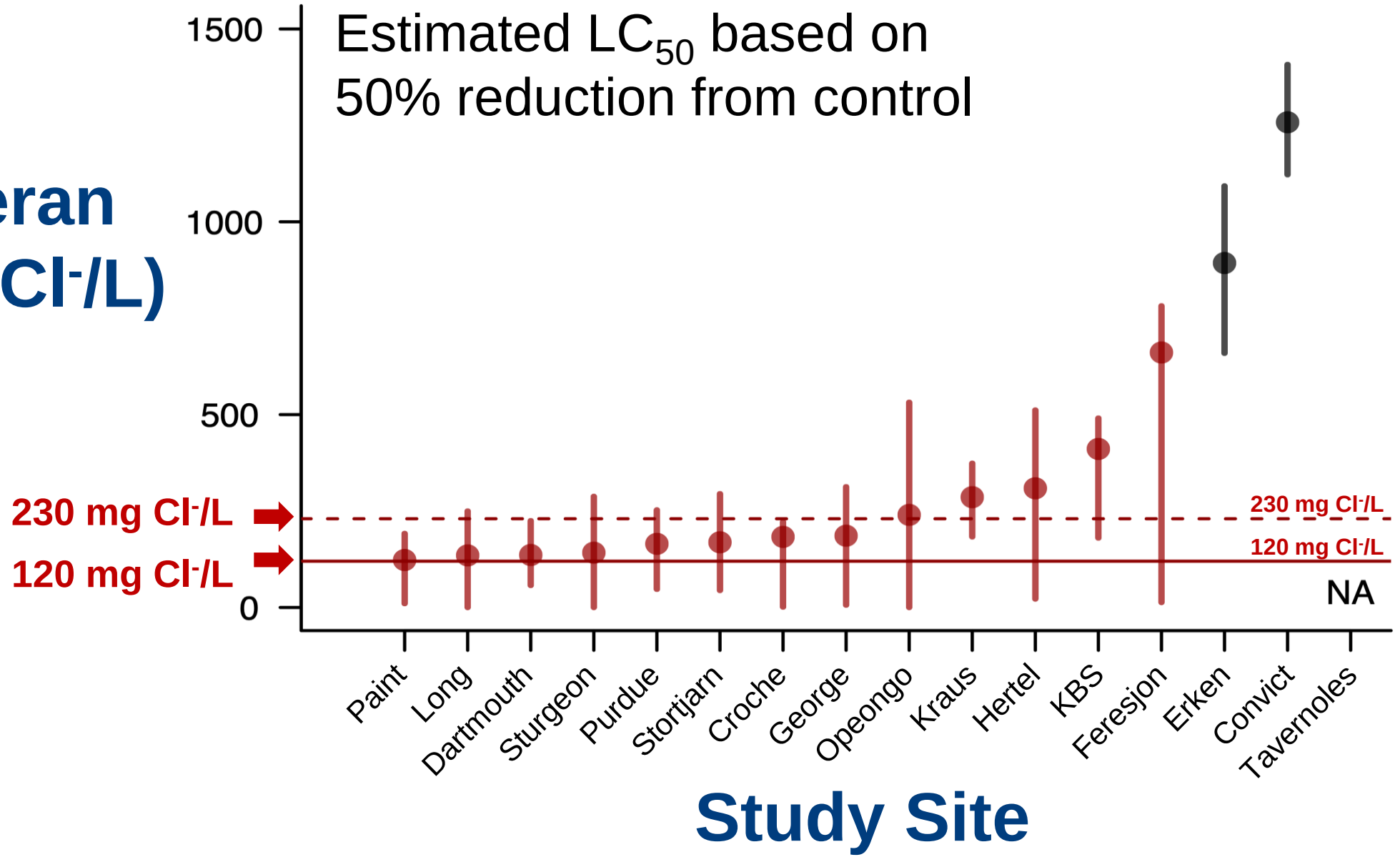


Hintz et al., *Proceeding of the National Academy of Sciences* (2022).

Cladoceran LC_{50} (mg Cl^-/L)



Hintz et al., *Proceeding of the National Academy of Sciences* (2022).

More algae due to the loss of zooplankton grazers

Hintz et al., *Proceedings of the National Academy of Sciences* (2022).

CANADA

Chronic: 120 mg Cl^-/L

UNITED STATES

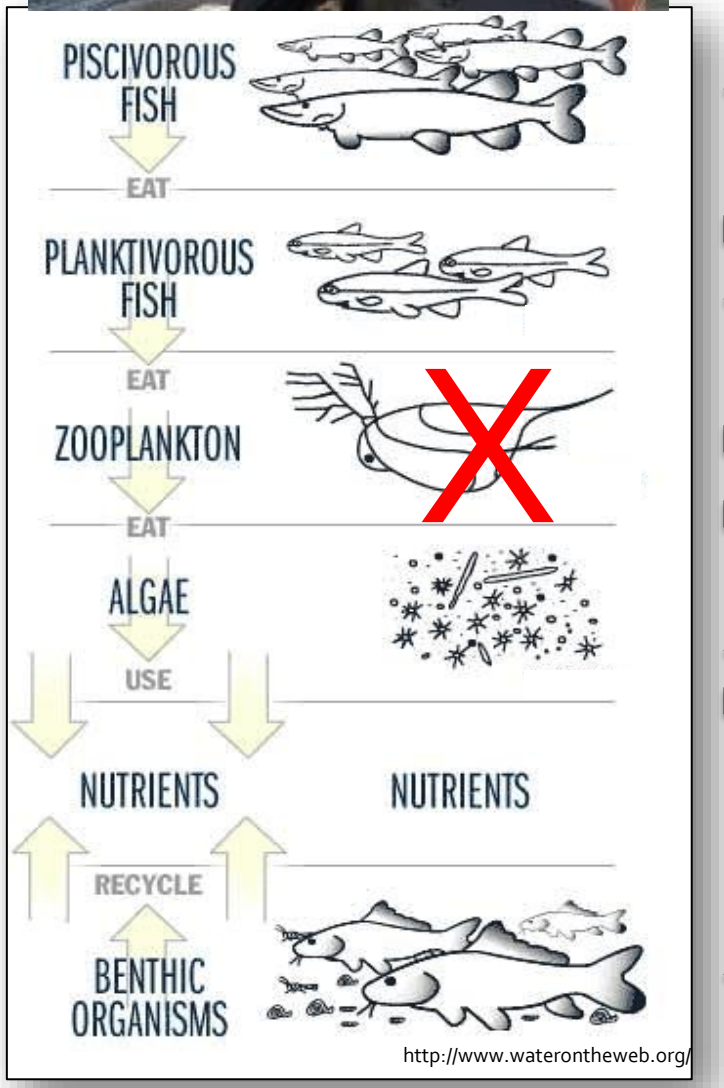
Chronic: 230 mg Cl^-/L

GERMANY

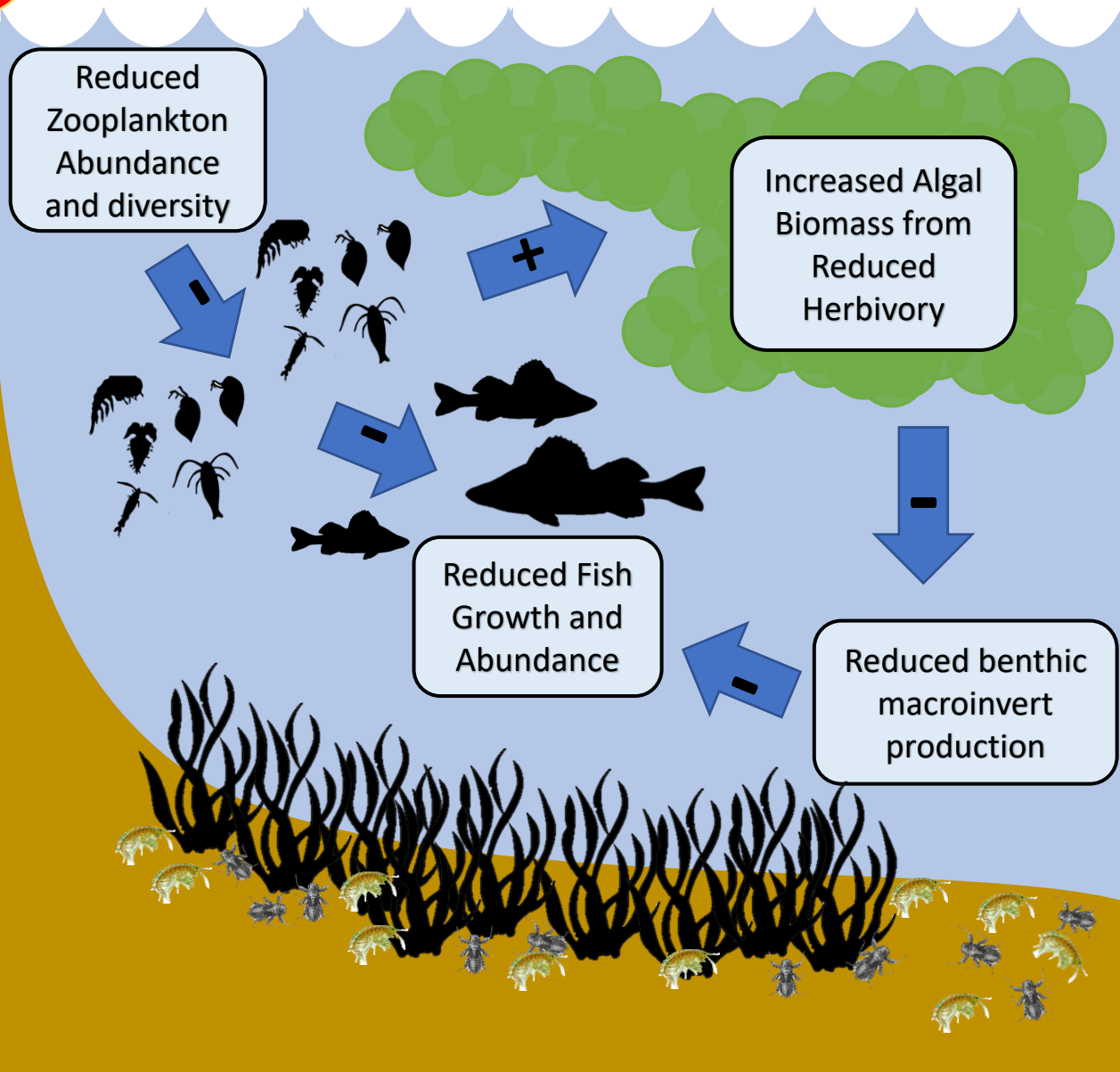
50 – 200 mg Cl^-/L, “slightly polluted”

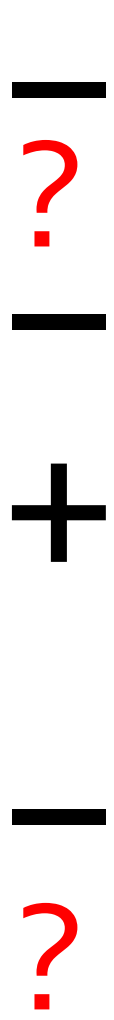
200 – 400 mg Cl^-/L, “moderately polluted”

CHLORIDE THRESHOLDS DO NOT PROTECT ECOLOGICAL COMMUNITIES IN MANY LAKES



Impacts on lake food webs





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Long-term trends of Great Lakes major ion chemistry

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[a] Civil and Environmental Engineering Department, Tufts University, Medford, MA 02155, USA
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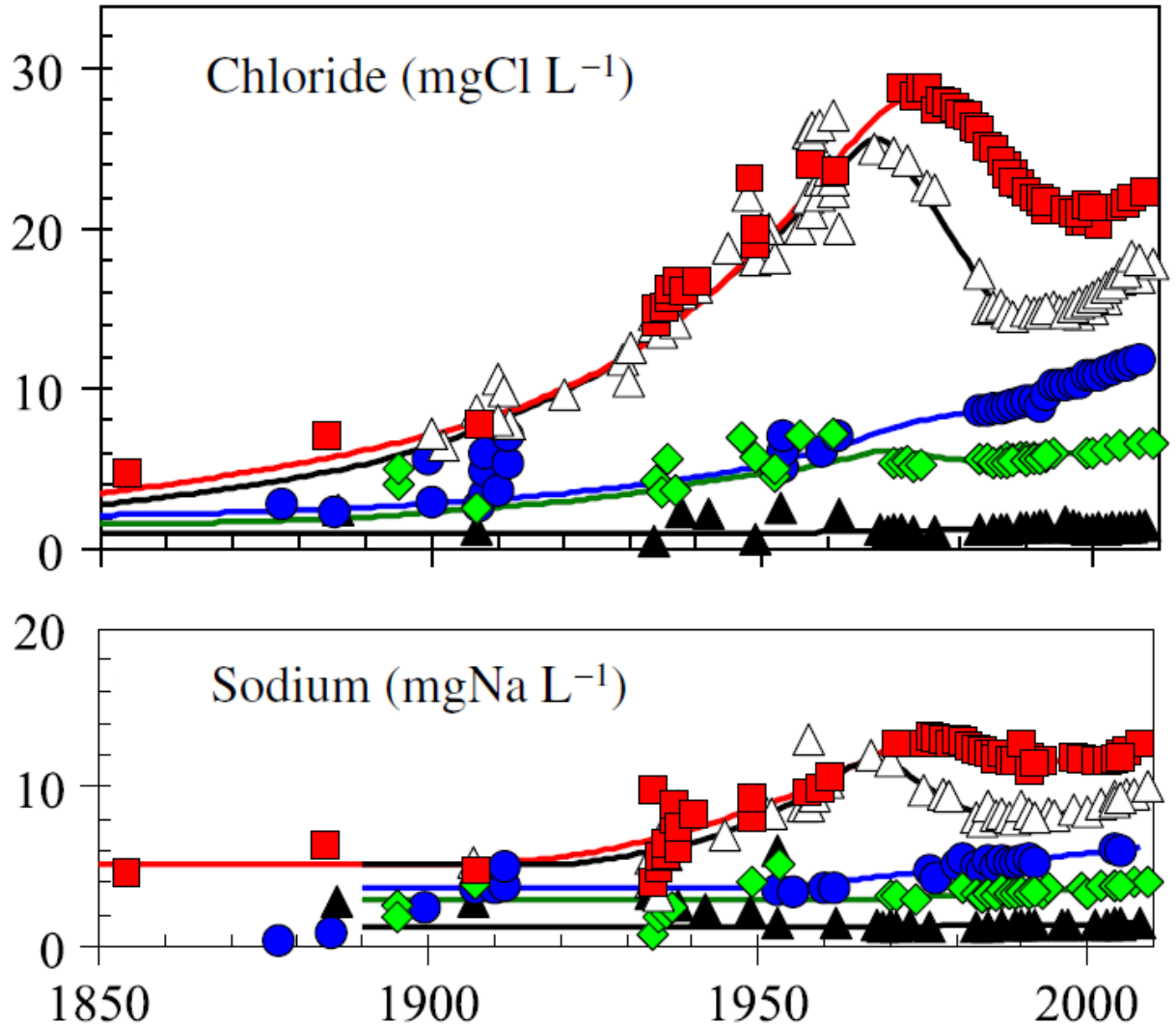
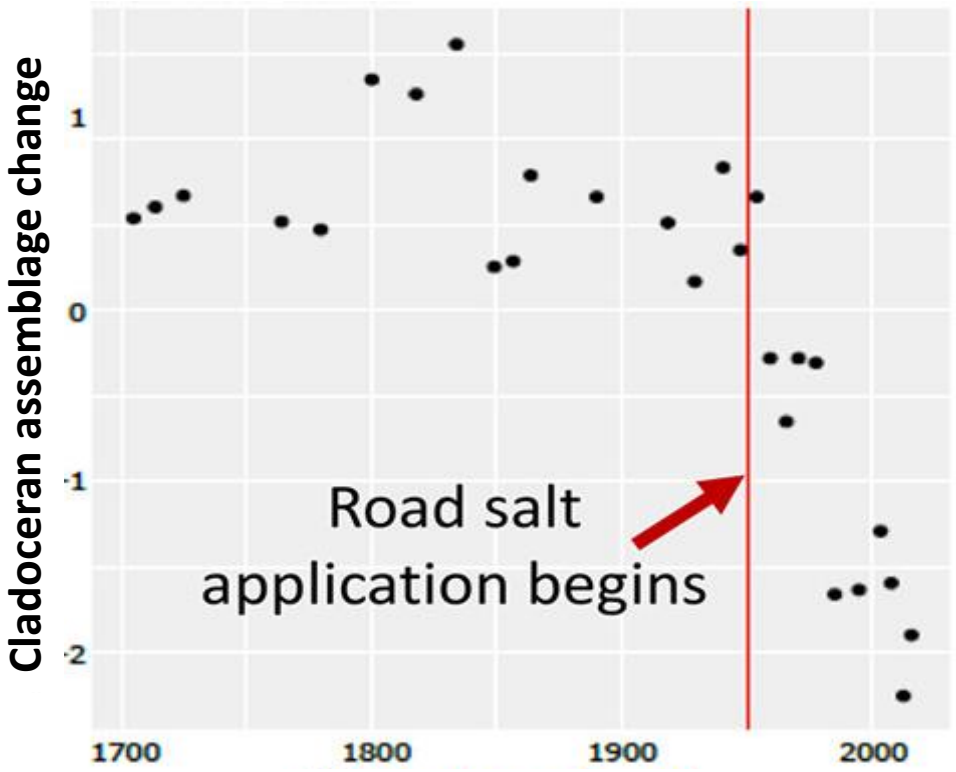
[c] U.S. EPA Great Lakes National Program Office, 77 W. Jackson Blvd., Chicago, IL 60604, USA

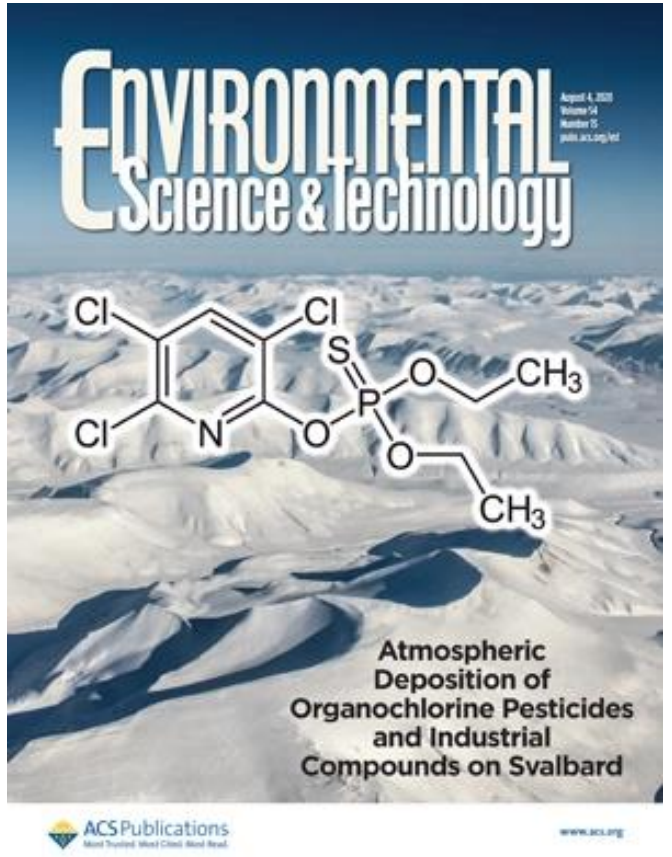


Road Salt Impacts Freshwater Zooplankton at Concentrations below Current Water Quality Guidelines

Shelley E. Arnott*, Martha P. Celis-Salgado, Robin E. Valleau, Anna M. DeSellas, Andrew M. Paterson, Norman D. Yan, John P. Smol, and James A. Rusak

Cite this: *Environ. Sci. Technol.* 2020, 54, 15, 9398–9407
Publication Date: June 28, 2020
https://doi.org/10.1021/acs.est.0c02396





The susceptibility of key aquatic herbivores in Canadian Shield lakes, at low Cl^- concentrations ranging from 5 to 40 mg/L, provides strong evidence that current water quality guidelines do not protect sensitive aquatic taxa.

Beyond the ecology…

ECONOMIC COSTS TO OUR ROADS, INFRASTRUCTURE, CARS

- ✓ $1,320 to $3,000 per ton of road salt applied
- ✓ > 15 million tons applied each year
- ✓ Estimates: $19.8 - $45 billion
- ✓ $1 road salt, $10 in damage

Vitaliano 1992. *Journal of Policy Analysis and Management*
Schuler, Canedo-Arguelles, Hintz, et al. 2019. *Philosophical Transactions of the Royal Society*

ECONOMIC COSTS TO OUR DRINKING WATER

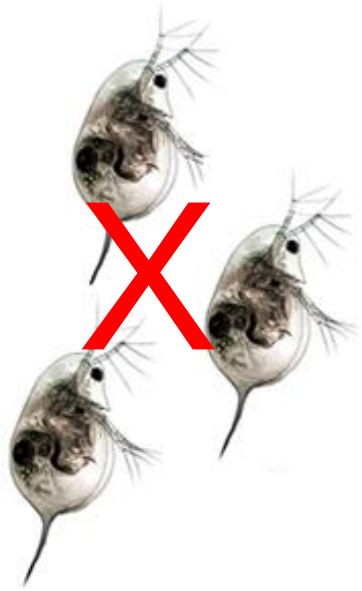
In southern New York, 25 – 50% of wells used for drinking water surpass US EPA guideline of 250 mg Cl/L

Costs to fix:

$4.7 million (20 homes)

$13.2 million (500 homes)

Schuler, Canedo-Arguelles, Hintz, et al. *Philosophical Transactions of the Royal Society*
Kelly et al. 2018. *Journal of Environmental Quality*
French 2016. *Politico*



Value of water clarity

1 m of water clarity worth US$140 million

Walsh et al. 2016 – *Proceedings of the National Academy of Sciences*

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Solutions to the problem?

Road salts reduce accident rates on average by 87% and 78% on two-lane and multi-lane highways, respectively

Hintz, Fay, and Relyea. 2022. *Frontiers in Ecology and the Environment*

A collaboration to address salt pollution in northwest Ohio

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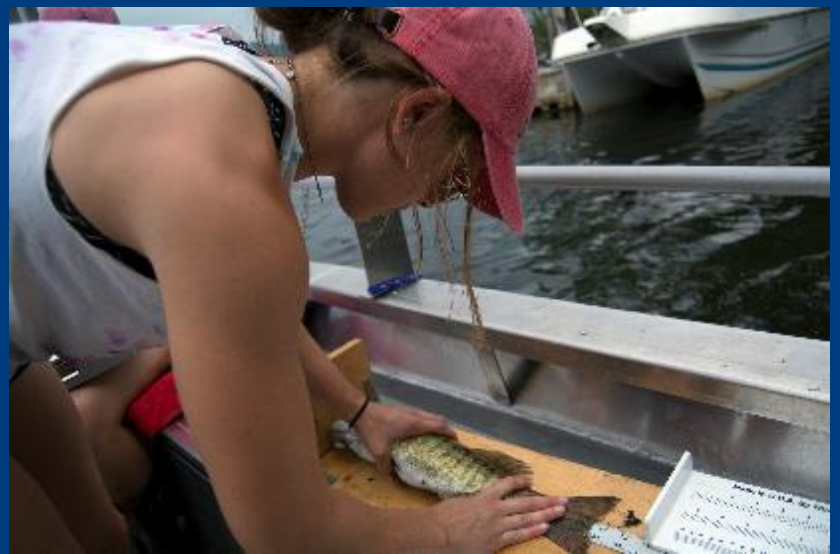
Many thanks to undergrads and technicians!



With some great collaborators and co-authors:

Shelley E. Arnott, Celia C. Symons, Danielle A. Greco, Alexandra McClymont, Jennifer A. Brentrup, Miguel Cañedo-Argüelles, Alison M. Derry, Amy L. Downing, Derek K. Gray, Stephanie J. Melles, Rick A. Relyea, James A. Rusak, Catherine L. Searle, Louis Astorg, Henry K. Baker, Beatrix E. Beisner, Kathryn L. Cottingham, Zeynep Ersoy, Carmen Espinosa, Jaclyn Franceschini, Angelina T. Giorgio, Norman Göbeler, Emily Hassal, Marie-Pier Hébert, Mercedes Huynh, Samuel Hylander, Kacie L. Jonasen, Andrea E. Kirkwood, Silke Langenheder, Ola Langvall, Hjalmar Laudon, Lovisa Lind, Maria Lundgren, Lorenzo Proia, Matthew S. Schuler, Jonathan B. Shurin, Christopher F. Steiner, Maren Striebel, Simon Thibodeau, Pablo Urrutia-Cordero, Lidia Vendrell-Puigmitja, Gesa A. Weyhenmeyer

KEY TAKEAWAYS

- ✓ Road salts are changing the ecology and functioning of freshwater ecosystems
- ✓ Current “guidelines” may not protect a many freshwater organisms
- ✓ We must develop and implement policies and strategies to better protect our fresh waters from salt pollution

QUESTIONS?

Contact: William.Hintz@utoledo.edu

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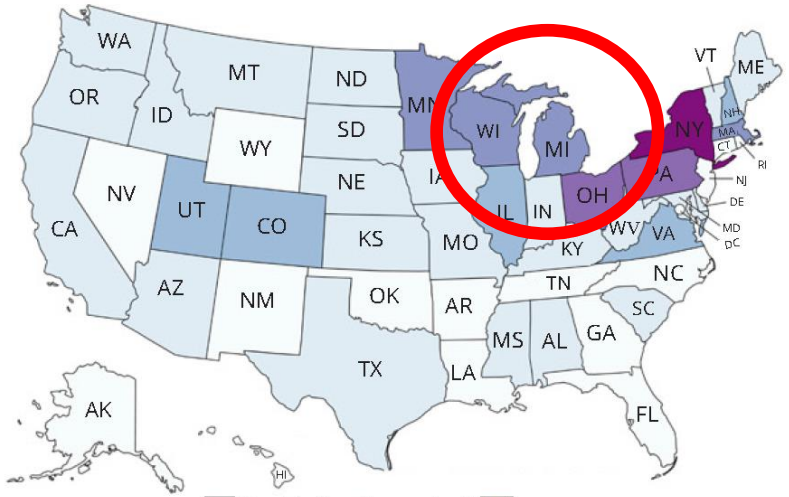
Use of Salt Solids (Metric Tons)



- No Data Reported
- 1 - 175,000
- 175,001 - 350,000
- 350,001 - 500,000
- 500,001 - 750,000
- 750,001 - 1,000,000

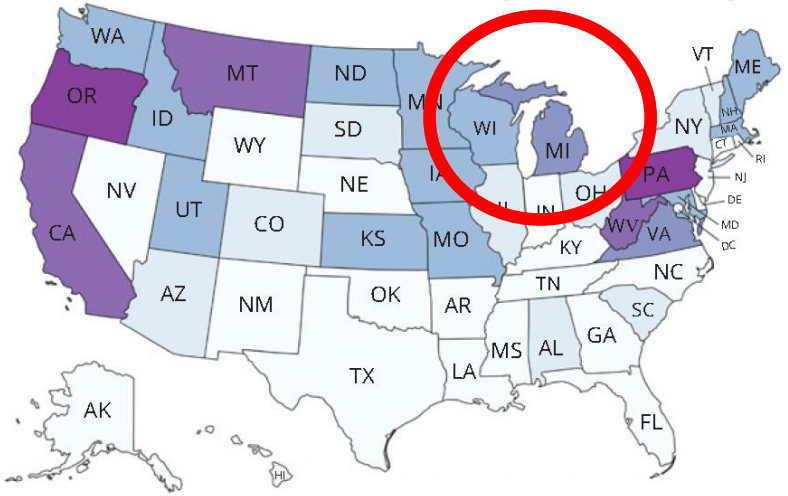
Use of Salt Brines (Liters)

- No Data Reported
- 1 - 5,000,000
- 5,000,001 - 15,000,000
- 15,000,001 - 30,000,000
- 30,000,001 - 45,000,000
- 45,000,001+

Use of Enhanced Brines (Liters)

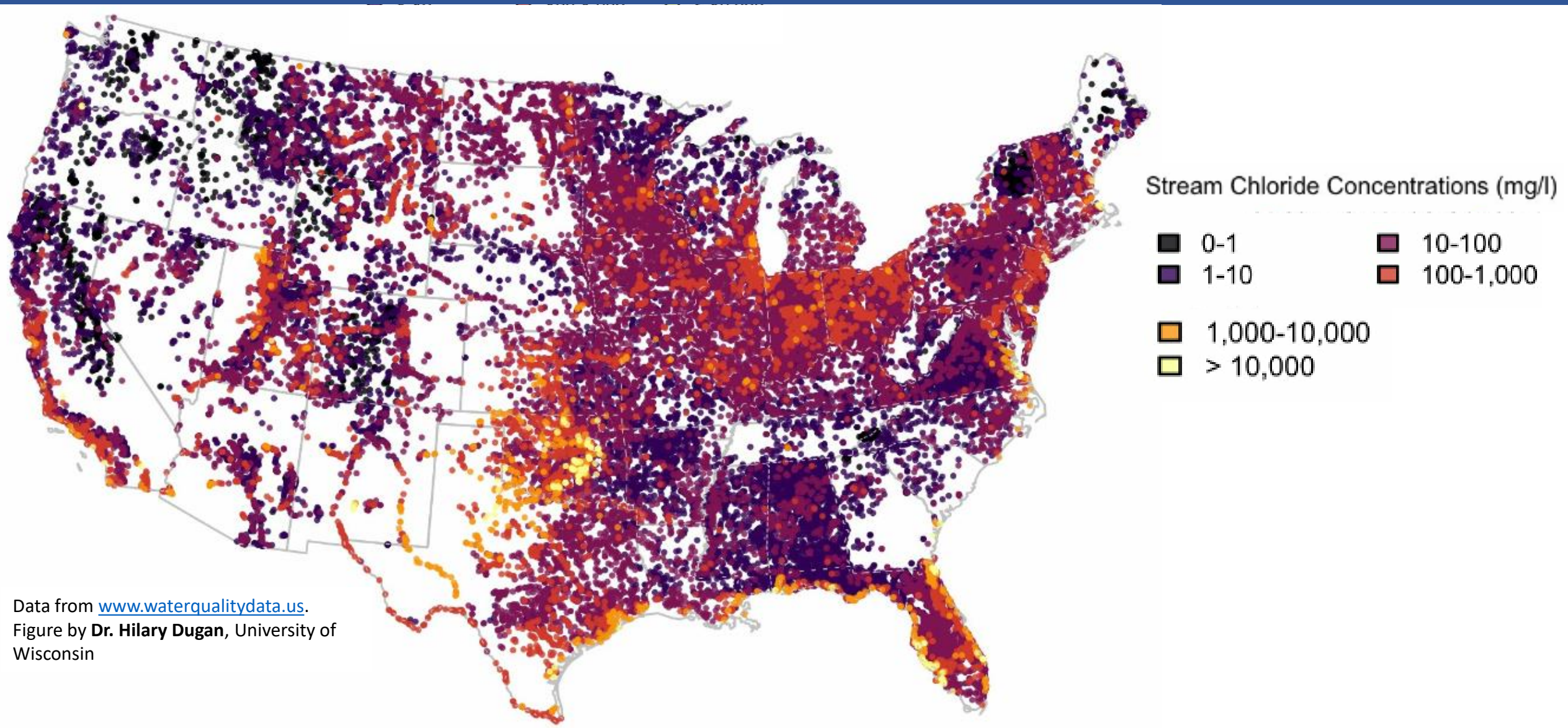
- No Data Reported
- 1 - 1,000,000
- 1,000,001 - 5,000,000
- 5,000,001+

Use of Abrasives (Metric Tons)

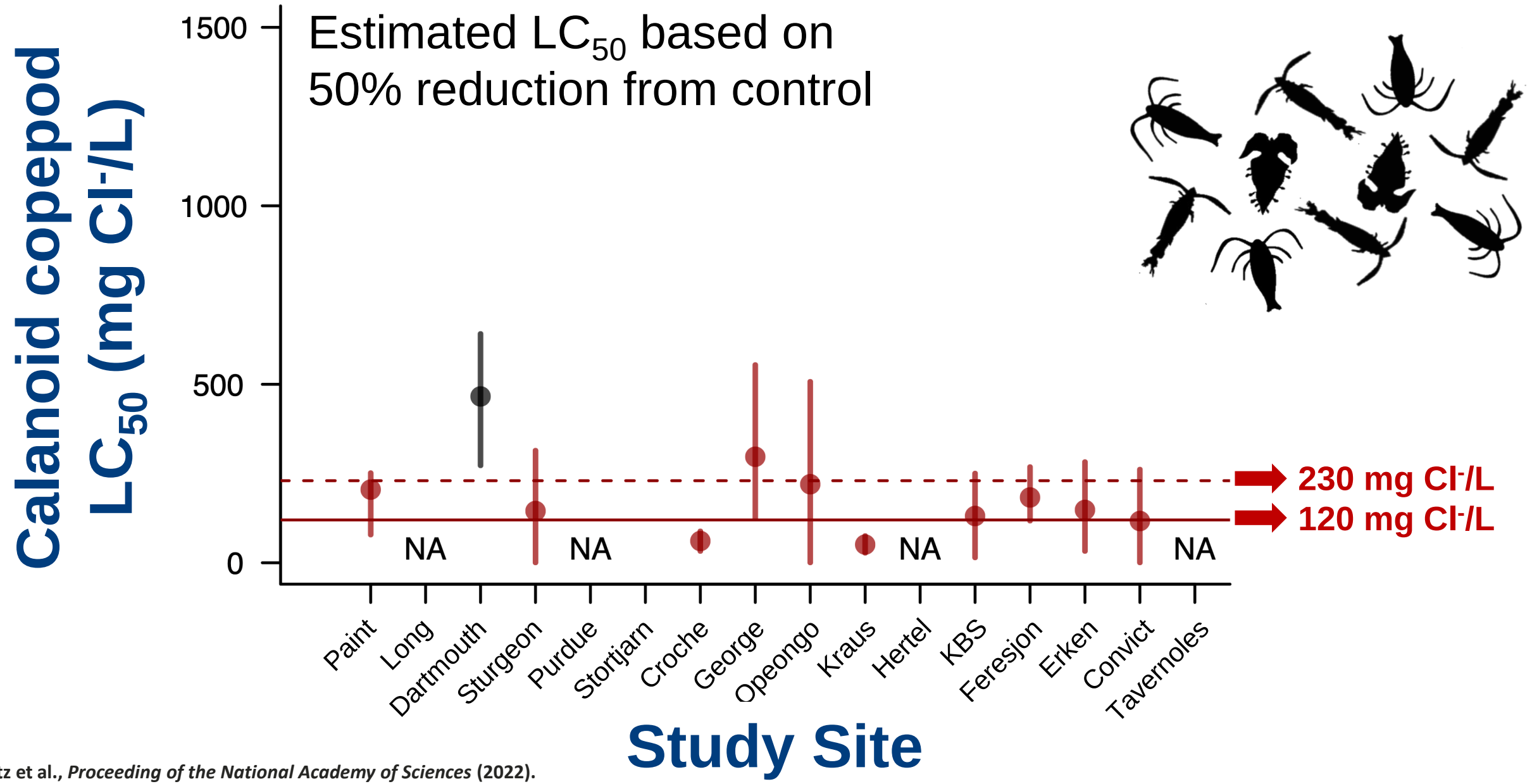


- No Data Reported
- 1 - 10,000
- 10,001 - 50,000
- 50,001 - 100,000
- 100,001 - 250,000
- 250,001 - 500,000

What about streams?

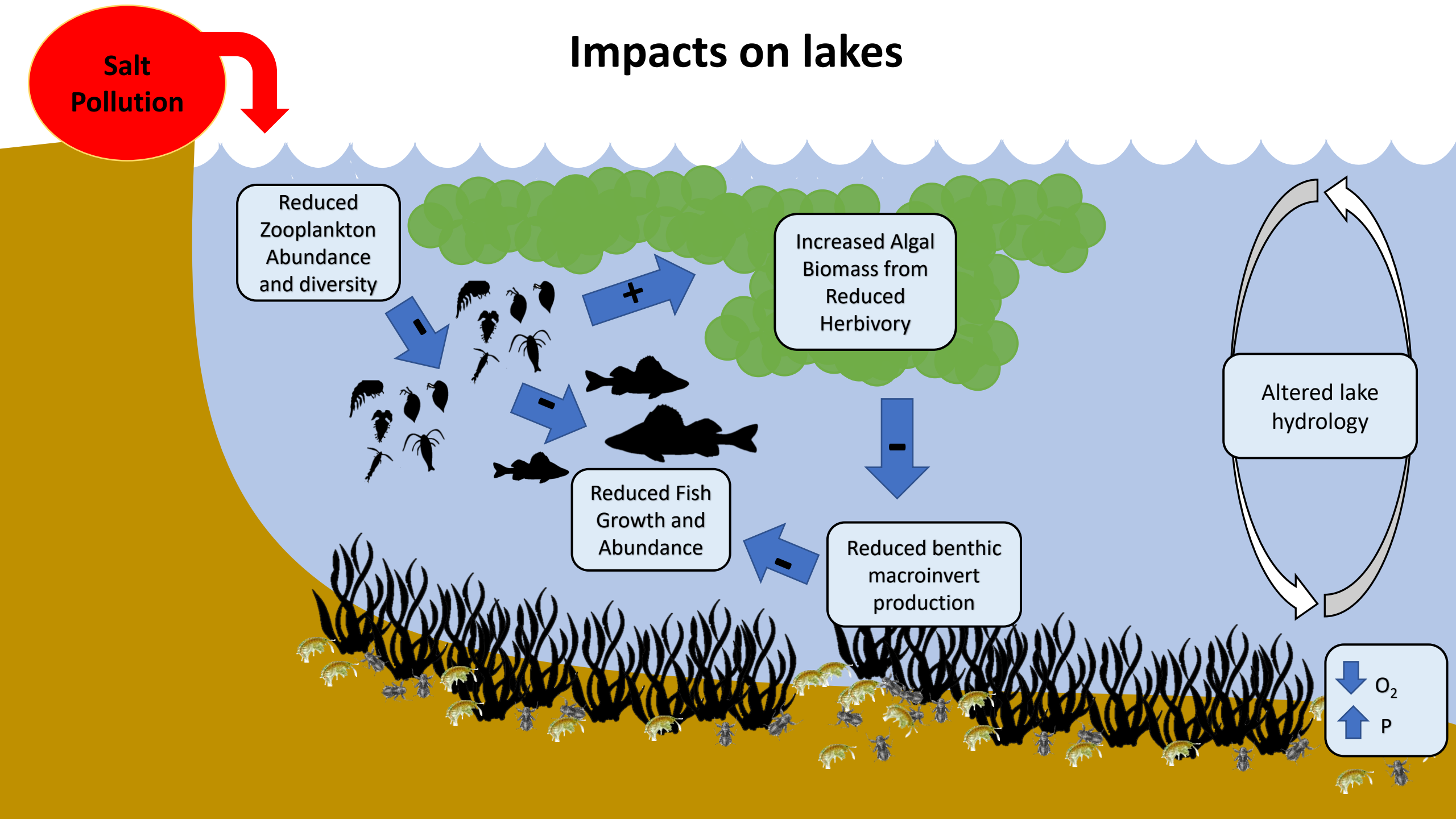


Data from www.waterqualitydata.us.
Figure by **Dr. Hilary Dugan**, University of Wisconsin



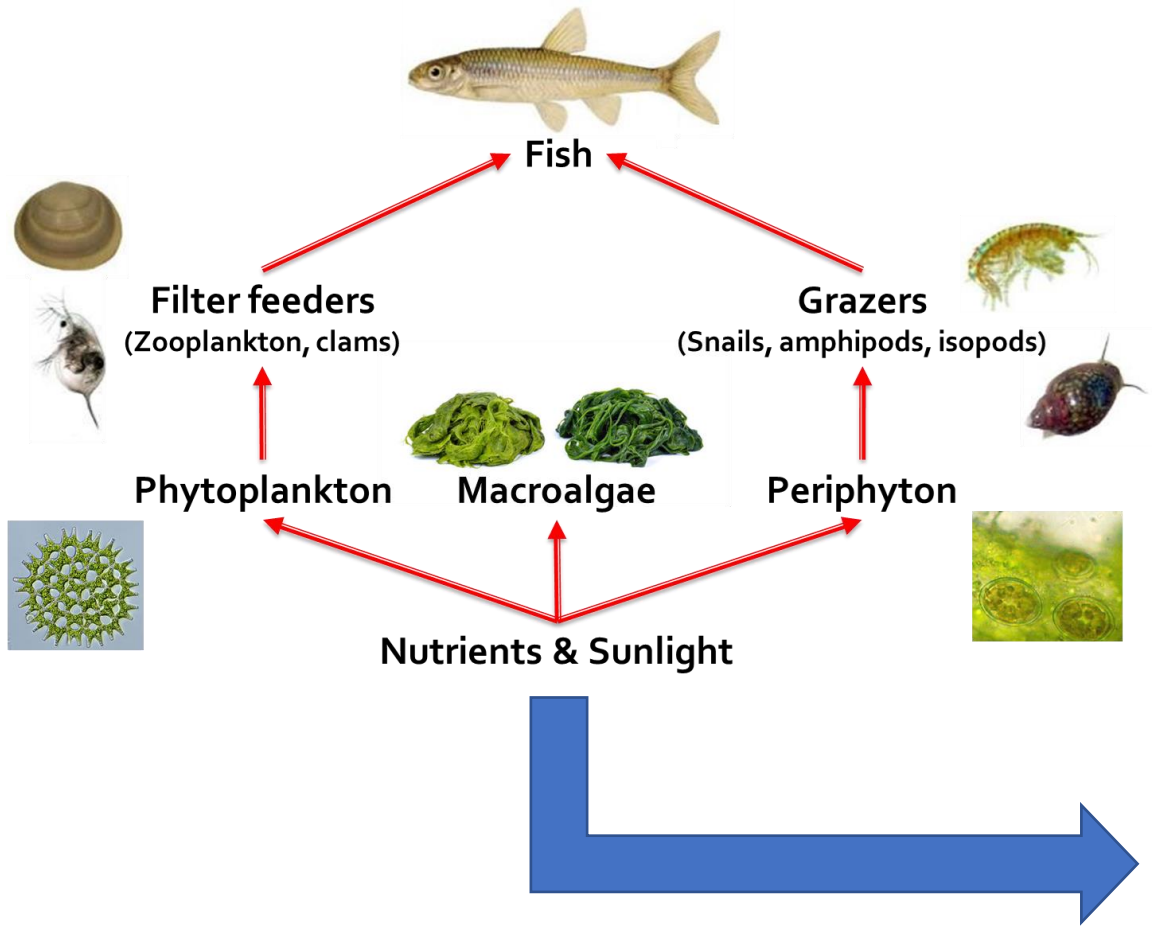
Hintz et al., *Proceeding of the National Academy of Sciences* (2022).

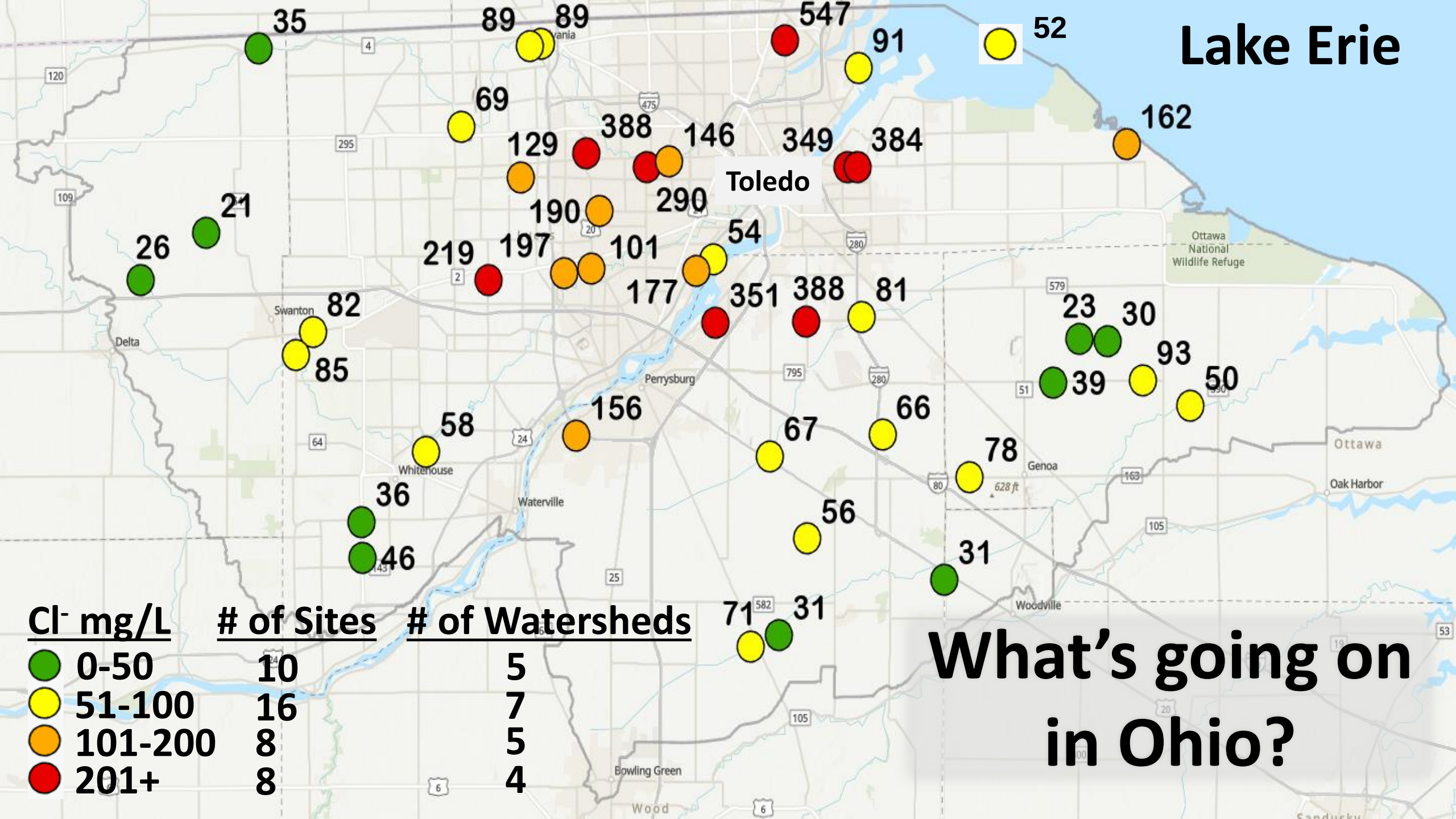
Impacts on lakes

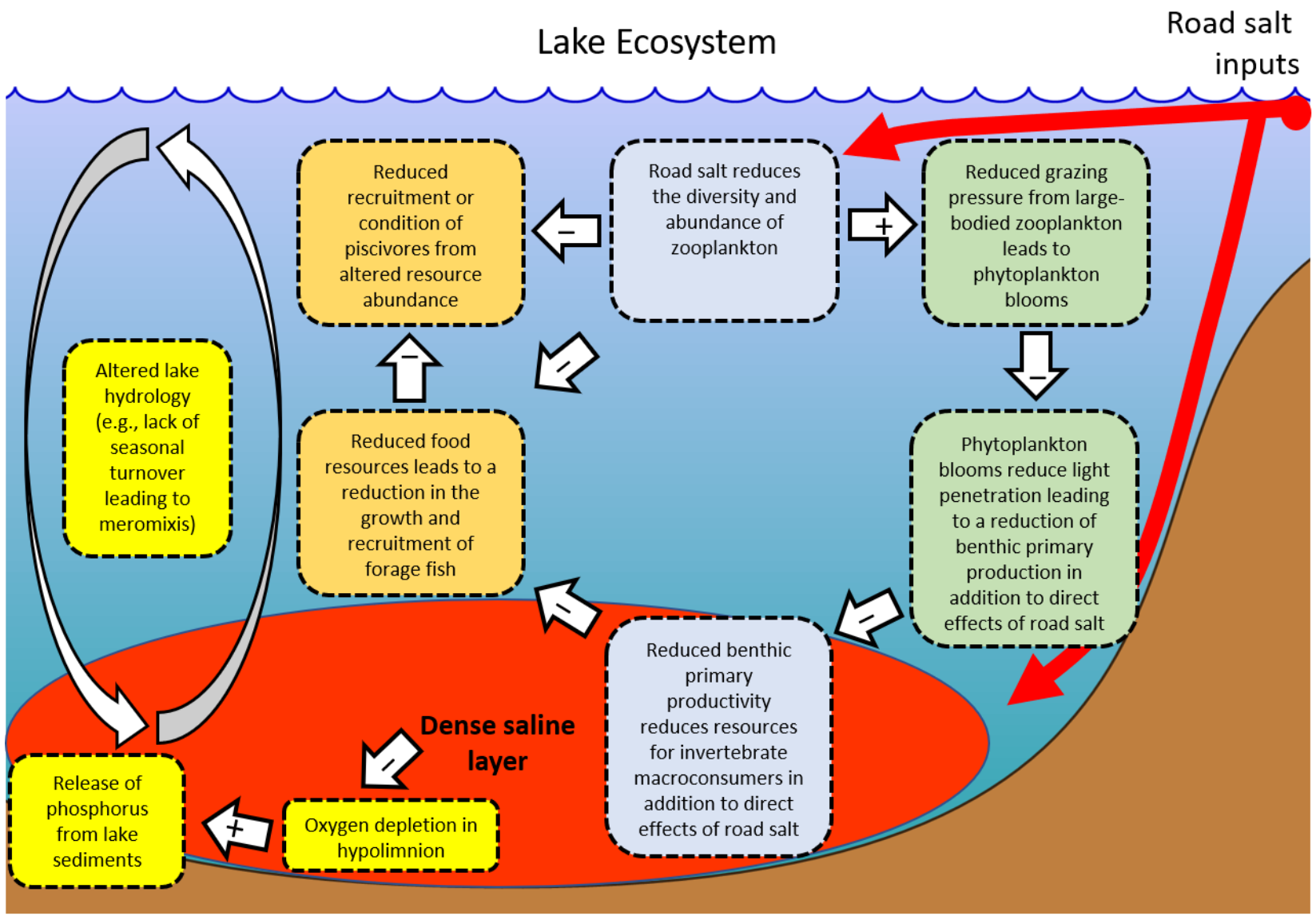


Let’s look at impacts of road salts on other species

Experimental food web




Lake Erie
Toledo
35
89
89
547
91
52
69
162
129
388
146
349
384
290
190
54
219
197
101
177
351
388
81
26
21
82
85
23
30
93
39
50
58
156
67
66
78
36
56
46
31
71
31
Swanton
Delta
Perrysburg
Whitehouse
Waterville
Genoa
Ottawa
Oak Harbor
Woodville
Bowling Green
Wood
Ottawa National Wildlife Refuge
628 ft
Cl- mg/L
# of Sites
# of Watersheds
0-50
10
5
51-100
16
7
101-200
8
5
201+
8
4
What's going on in Ohio?


Lake Ecosystem
Road salt inputs
Road salt reduces the diversity and abundance of zooplankton
Reduced recruitment or condition of piscivores from altered resource abundance
Reduced grazing pressure from large-bodied zooplankton leads to phytoplankton blooms
Altered lake hydrology (e.g., lack of seasonal turnover leading to meromixis)
Reduced food resources leads to a reduction in the growth and recruitment of forage fish
Phytoplankton blooms reduce light penetration leading to a reduction of benthic primary production in addition to direct effects of road salt
Reduced benthic primary productivity reduces resources for invertebrate macroconsumers in addition to direct effects of road salt
Dense saline layer
Release of phosphorus from lake sediments
Oxygen depletion in hypolimnion

Rank	State	Metric tons
1.	New York	758,677
2.	Pennsylvania	746,160
3.	**Ohio**	**692,760**
4.	Tennessee	482,685
5.	Massachusetts	445,540

OHIO RANKS # 3 IN ROAD SALT USE

2017 Clear Roads Survey