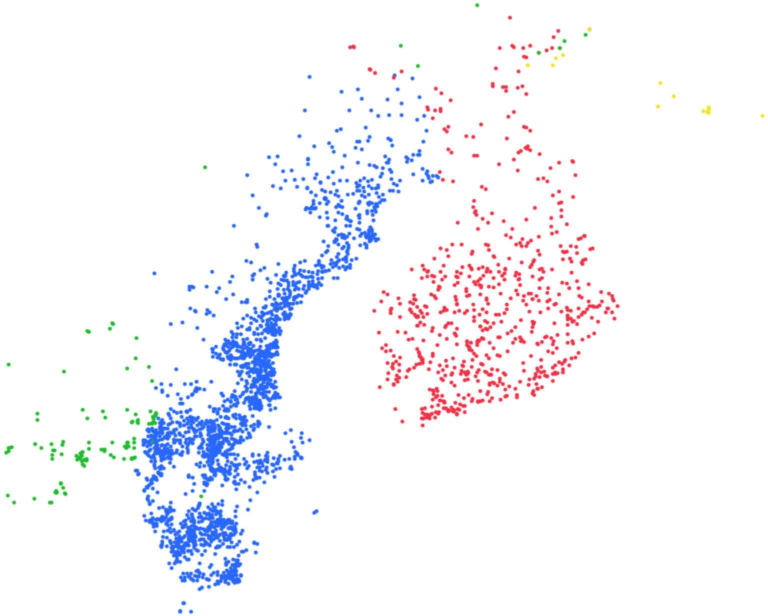
Spatial and temporal trends of mercury concentrations in Fennoscandian freshwater fish



Hans Fredrik Veiteberg Braaten, NIVA, Staffan Åkerblom, SLU, Heleen de Wit, NIVA

ICP Waters and ICP IM Joint Task Force Meeting,

Uppsala, Sweden, May 2017

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Tatiana Kashulina;
Petr Terentyev;
Guttorm Christensen;
Leah Jackson-Blake;
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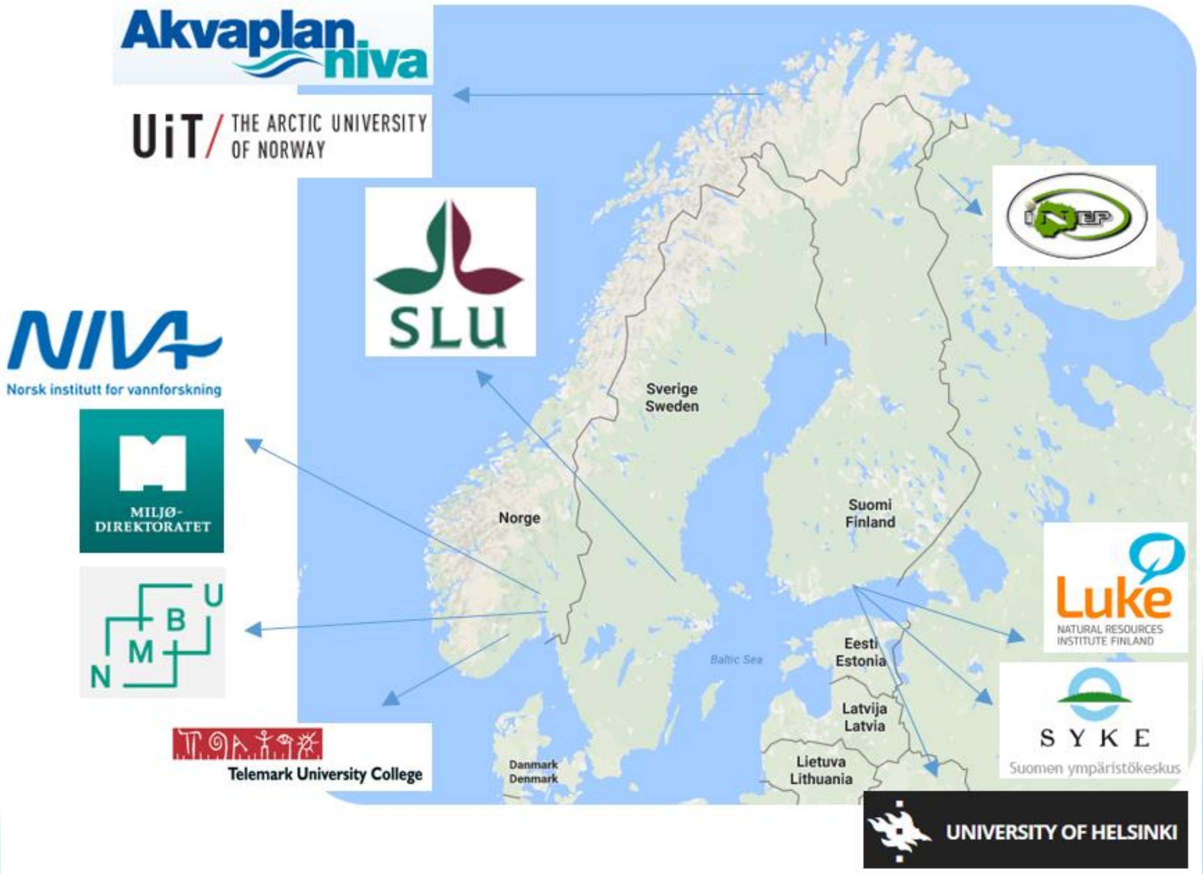
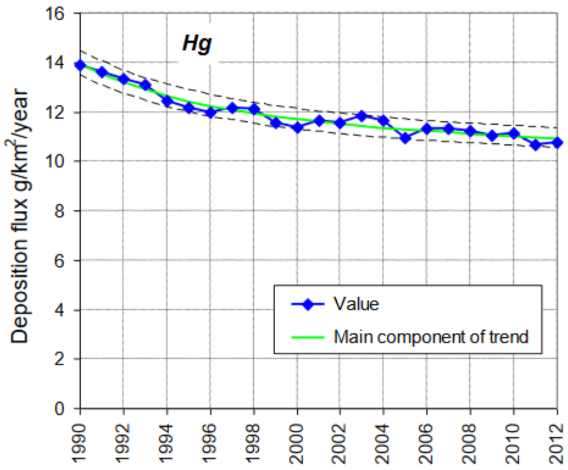


Study goal(s)

Collect "***all fish mercury data available from Fennoscandia***"

…in order to investigate the effects of long-range atmospheric transported mercury on freshwater ecosystems!



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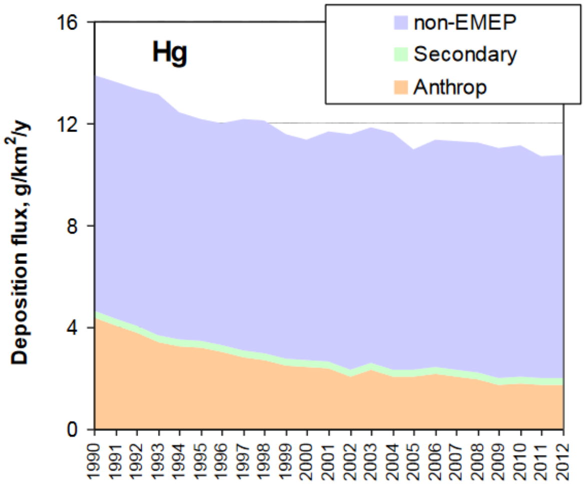

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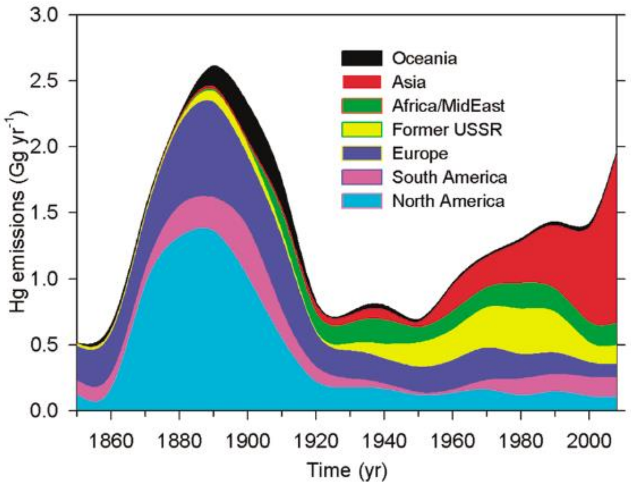
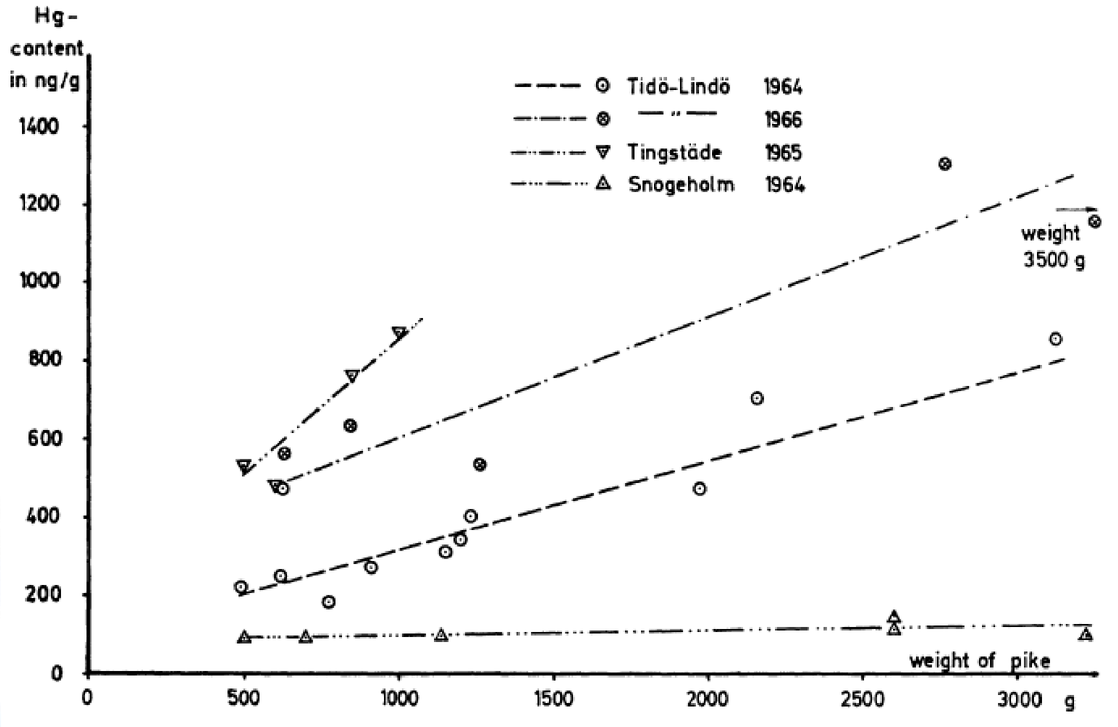


Streets et al. 2011, ES&T 45, 10485-10491

Mercury: an old challenge



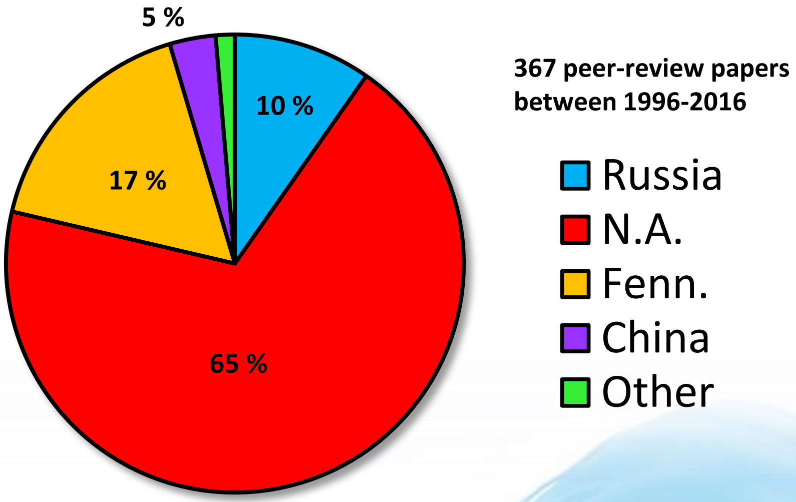
Pike (Esox lucius L.) and some other aquatic organisms in Sweden as indicators of mercury contamination in the environment

A. G. Johnels[1], T. Westermark[2], W. Berg[1], P. I. Persson[1] and B. Sjöstrand[3]

Oikos 18: 323–333. Copenhagen 1967

Mercury relevant (again) now

- Minamata Convention on Mercury
  (ratification and monitoring)
- Water Framework Directive
  (Hg prioritised substance)
- Arctic 2030
  (Ministry of Climate and Environment)
- Arctic Council
  (ACAP and AMAP)
- Present work
  (ICP Waters, ICP IM)
- Other circum-boreal work
  (Lescord et al.)



Lescord et al. In preparation. *A review of mercury research in freshwater ecosystems across the global boreal zone.*

Minamata Convention on Mercury

ELSEVIER
Science of The Total Environment
Volumes 569–570, 1 November 2016, Pages 888–903

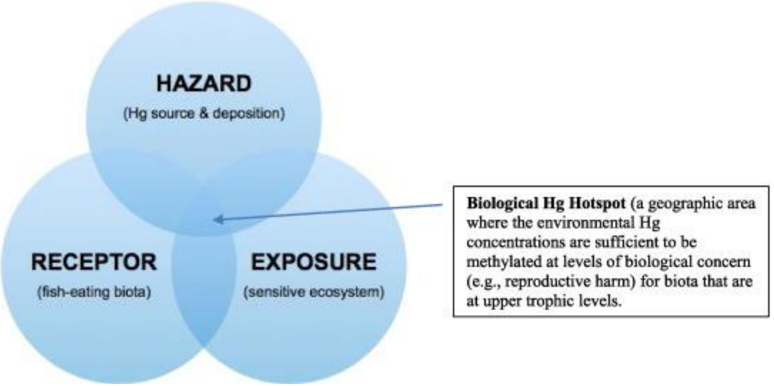
Evaluating the effectiveness of the Minamata Convention on Mercury: Principles and recommendations for next steps

David C. Evers[a], Susan Egan Keane[b], Niladri Basu[c], David Buck[a]

Environmental Science & Technology
Viewpoint
pubs.acs.org/est

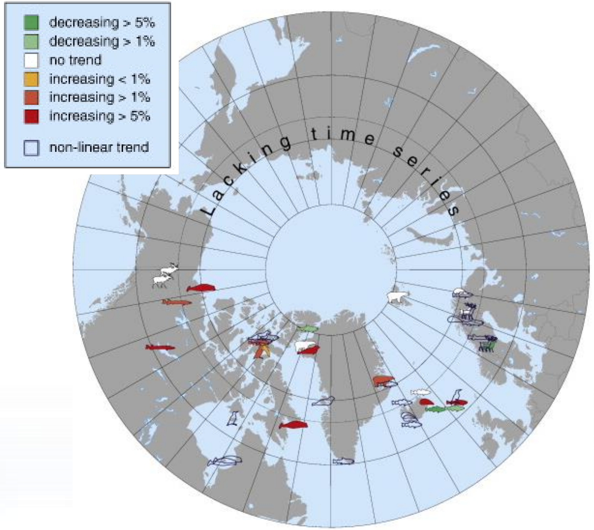
A Holistic Perspective Is Needed To Ensure Success of Minamata Convention on Mercury

Yan Lin,[†] Shuxiao Wang,[*,‡] Eirik Hovland Steindal,[§] Zuguang Wang,[∥] Hans Fredrik Veiteberg Braaten,[†] Qingru Wu,[‡] and Thorjørn Larssen[†]

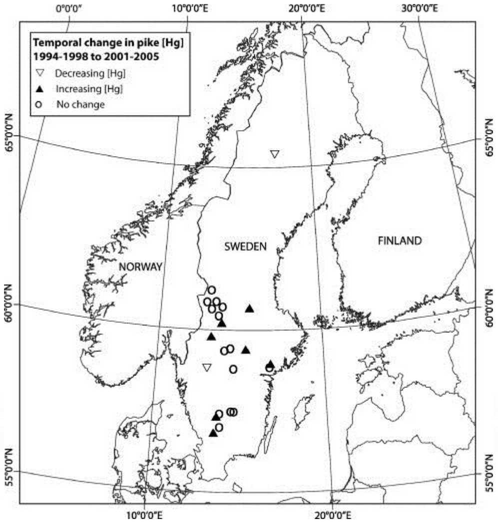


*«The use of **existing biotic Hg data** will define **spatial gradients**, baselines to develop relevant **temporal trends**, and an ability to **assess risk** to taxa and human communities»*

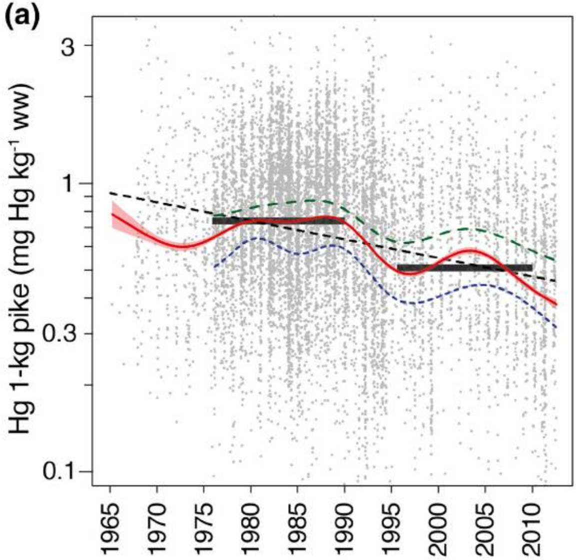
Time trends and historical development



Riget et al. 2011. *Temporal trends of Hg in Arctic biota, an update.* Science of the Total Environment, 409, 3520-3526.



Åkerblom et al. 2012. *Temporal change estimation of mercury concentrations in northern pike (Esox lucius L.) in Swedish lakes.* Chemosphere, 86(5): 439-45.



Åkerblom et al. 2014. *Half a century of changing mercury levels in Swedish freshwater fish.* Ambio, 43: 91-103.

Trend analyses

Citation	Study period	Fish species	Country/region	Number of populations (lakes)	Direction of trend
Munthe et al., 2007	1965-2004	Arctic charr, perch, pike, trout, whitefish	Finland, Norway and Sweden	2758	n.a.
Akerblom et al., 2014	1965-2012	Arctic charr, perch, pike, roach, trout + 10 others	Sweden	2881	↓
Paasivirta et al., 1981	1970-1980	Pike	Finland	1	↓
Åkerblom and Johansson, 2008	1972-2006	Perch, pike	Sweden	2223	↑↓
Paasivirta and Linko, 1980	1973-1978	n.a.	Finland	2	↔
Miller et al., 2013	1974-2005	Perch	Finland and Sweden	341	↑↓
Fjeld, 2010	1990-2010	Perch	South east Norway and Northern Norway	5	↑↔↓
Fjeld, 2009	1991-2008	Perch	South east Norway	10	↑↔
Rask et al., 2007	1993-2003	Perch, pike	Finland	1	↑↓
Akerblom et al., 2012	1994-2006	Pike	South to mid Sweden	152	↑↔↓
Braaten et al., 2014b	2010-2012	Perch	South east Norway	2	↑

?

Bioaccumulation of mercury

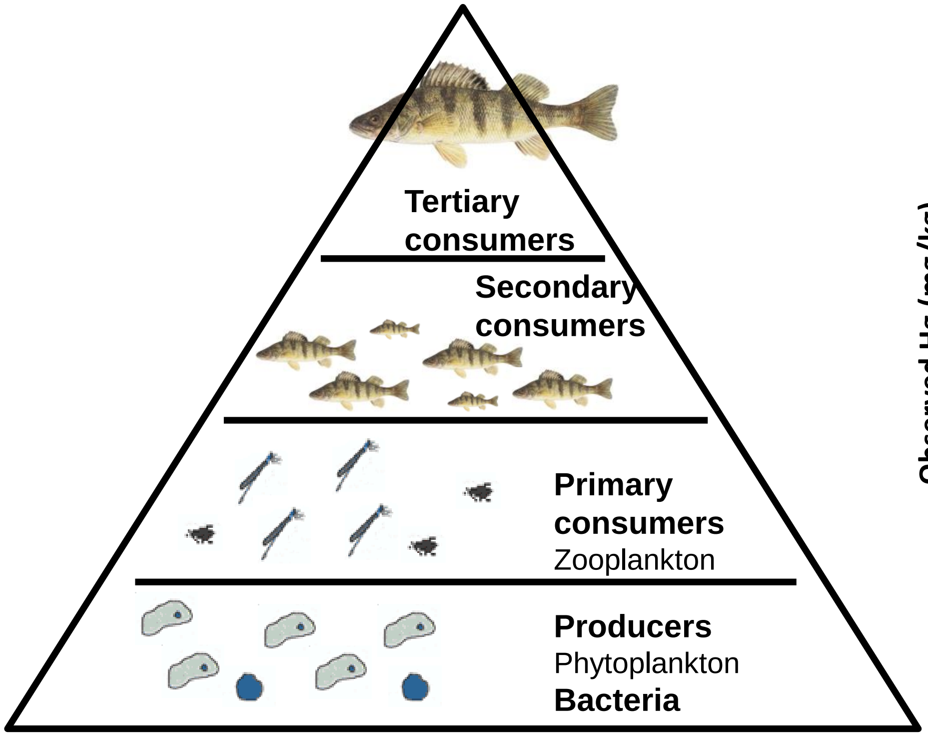
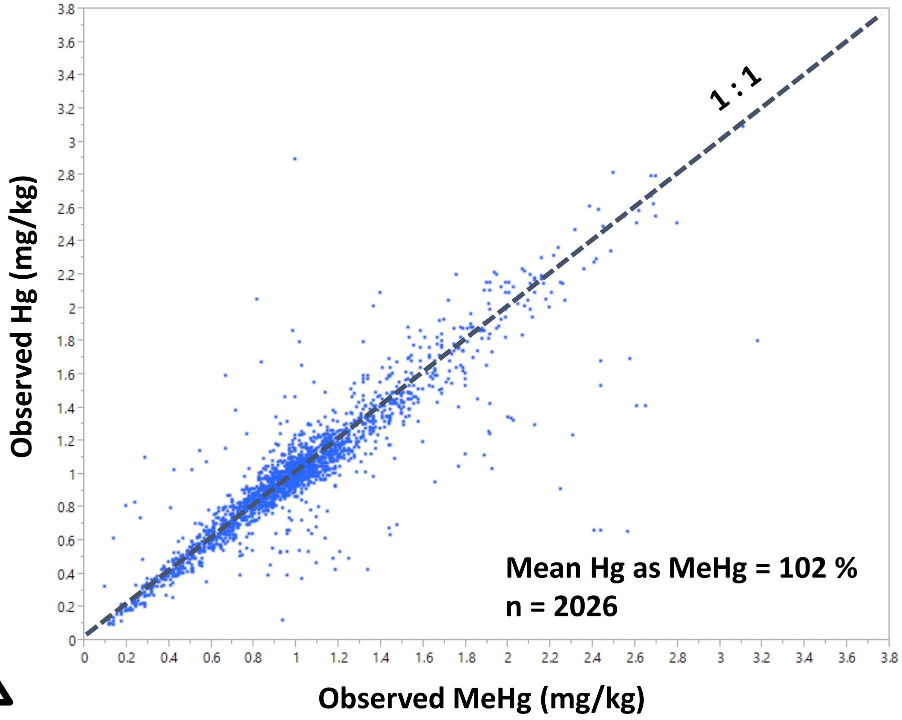


Figure modified from:
Clean the Lakes, National Wildlife Federation, 2000



Food consumption advice

- Norway has nationwide ***«advice against consumption of freshwater fish»*** due to Hg contamination

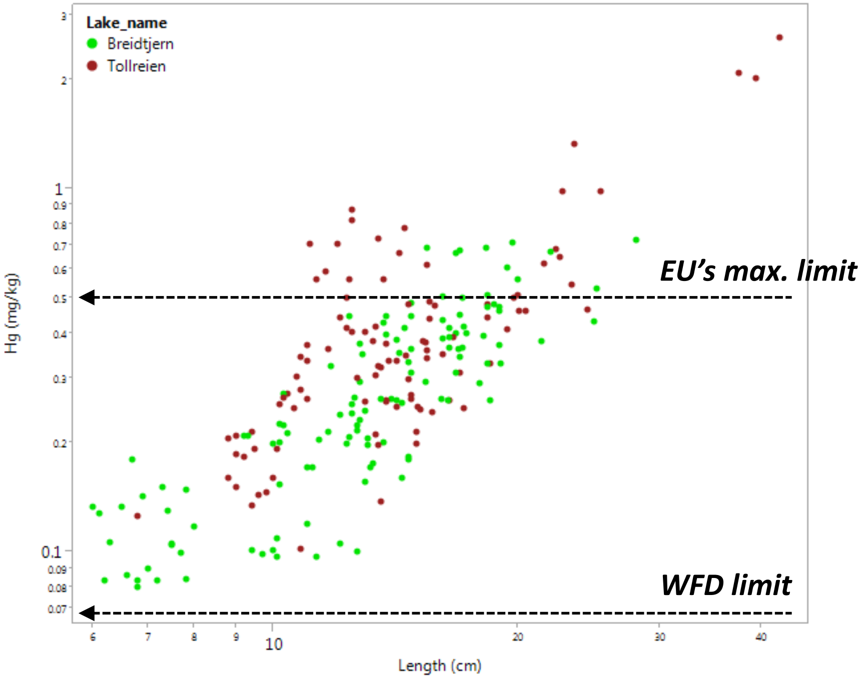
- **The advice:**
  - Pike and perch > 25 cm
  - Trout and charr > 1 kg

  (Not to be eaten more than once a month)

- **Target groups:**
  - Pregnant woman
  - Breastfeeding mothers
  - Small children

  (Should stay away from freshwater fish)

- Similar consumption advice exist in other countries with similar issues
  (Scandinavia, North America etc.)



Braaten et al. 2014, ET&C 33, 12, 2661-70.

Research questions

- Analyse spatial and temporal trends of mercury in fish
- Analyse on other themes than *country* (e.g. *deposition*, *water chemistry*, *climate*, *catchment characteristics*)

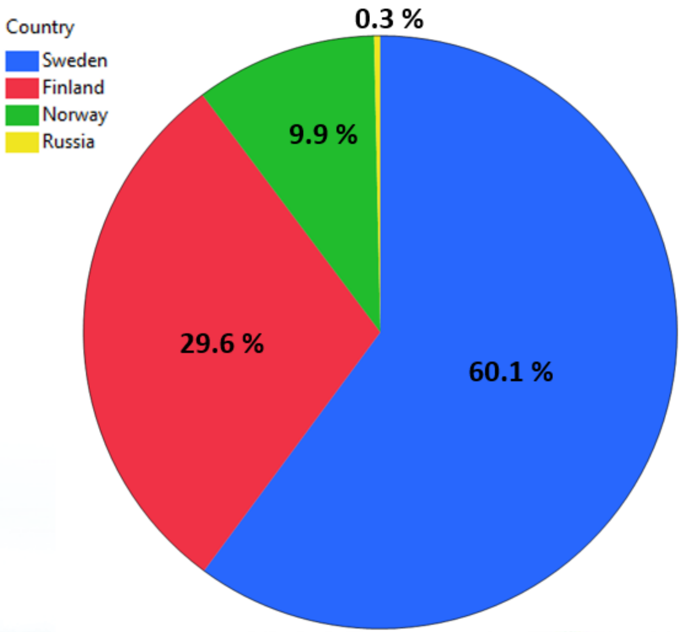
Spatial patterns

- Variation with country/region/latitude
- Point sources give higher Hg conc. than air pollution
- Variation closely linked to TOC and sediments

Temporal trends

- Catchment stored Hg limits the long-term decrease
- Variation significant between decades/latitude

The database



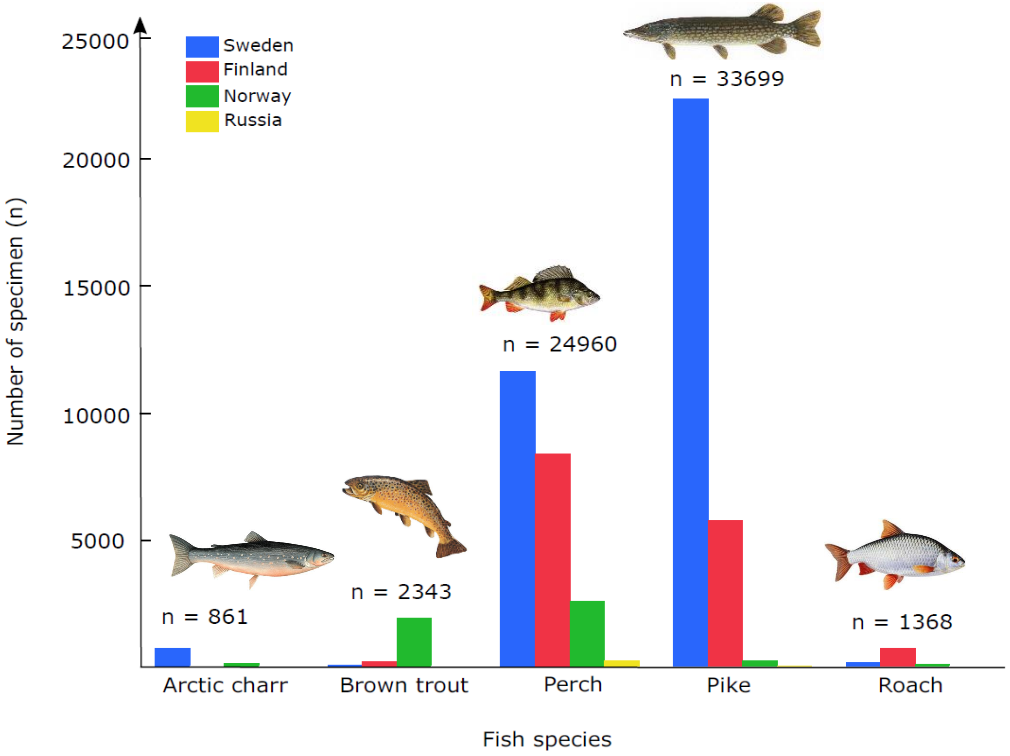
Originally n = 66 464 specimen were collected

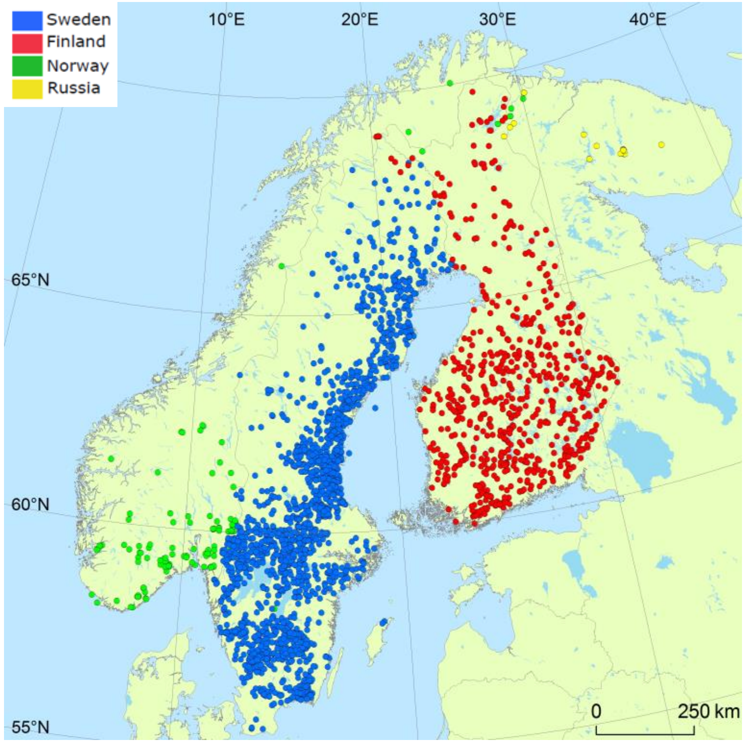
Criteria for selection:

- Concentrations of mercury
- Measurements of weight
- Realistic length vs. weight relationships
- Fish species (perch, pike, charr, trout and roach)
    - Distributed throughout Fennoscandia
    - «Mercury relevant»
- At least 5 measurements per lake/river

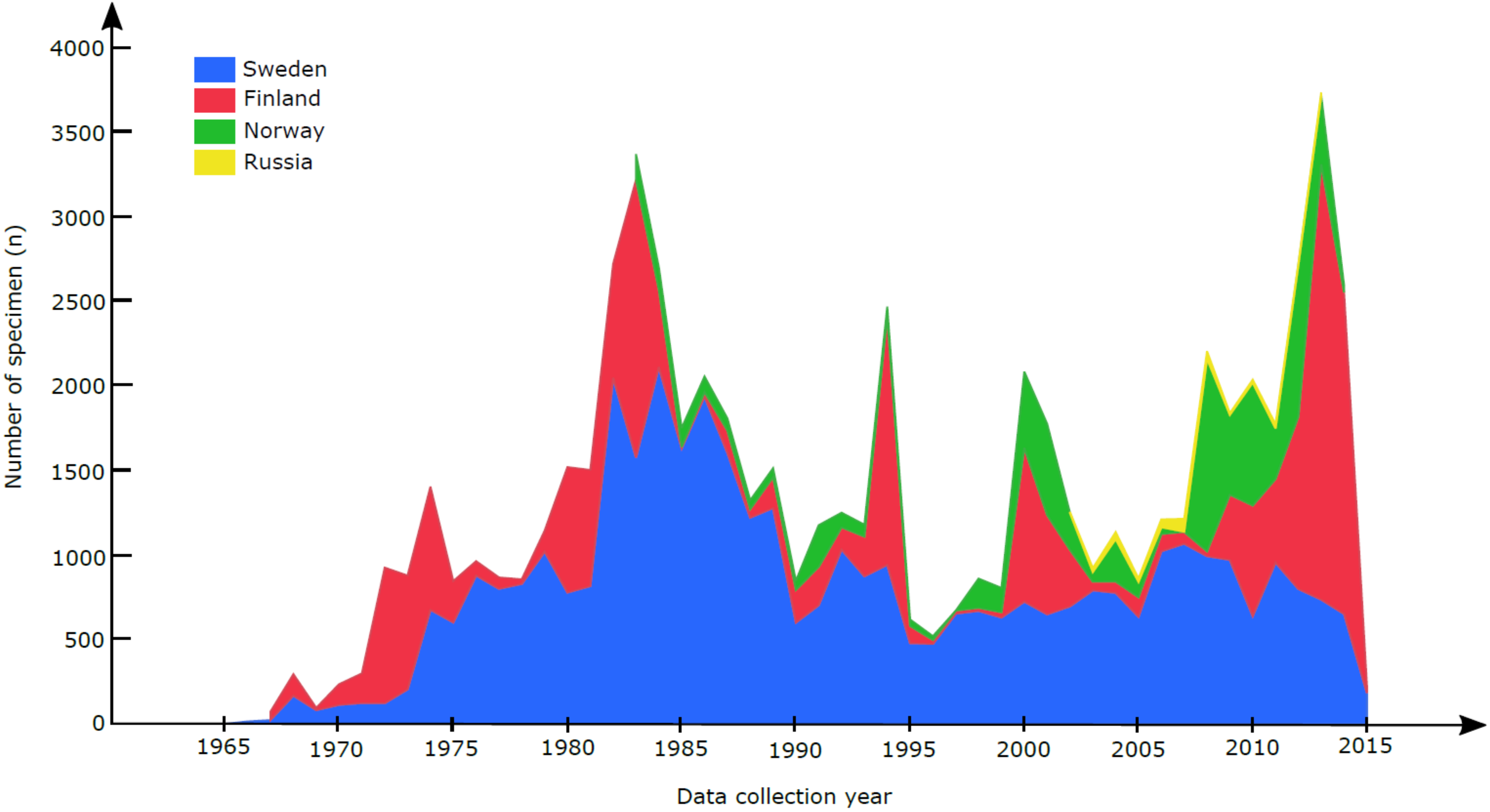
Final database consists of n = 54 560 specimen

The database

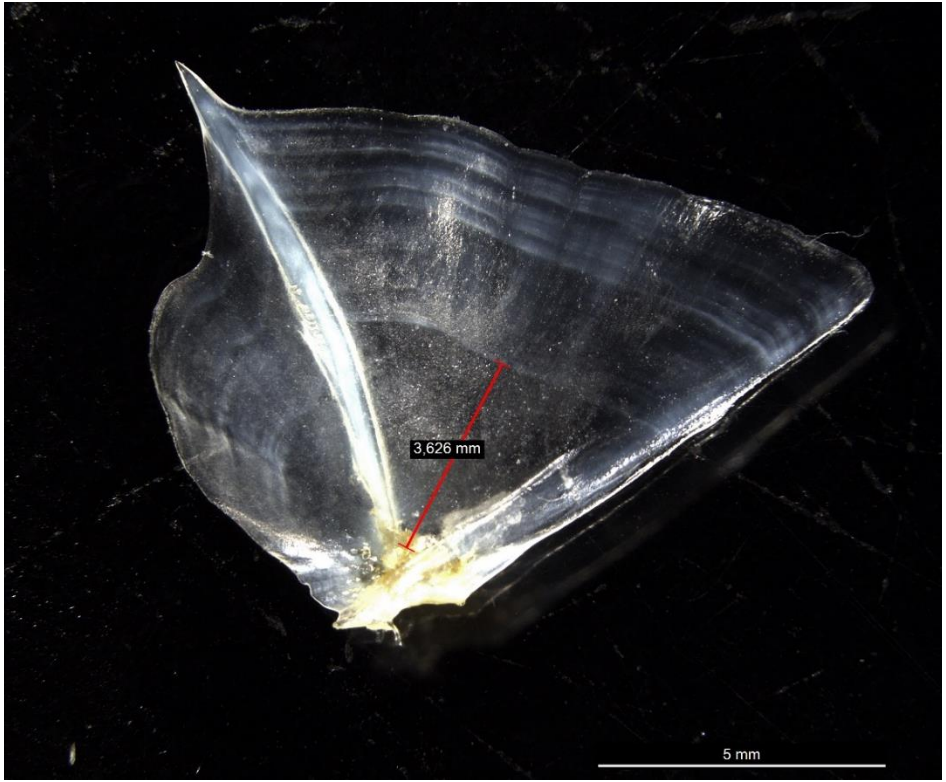


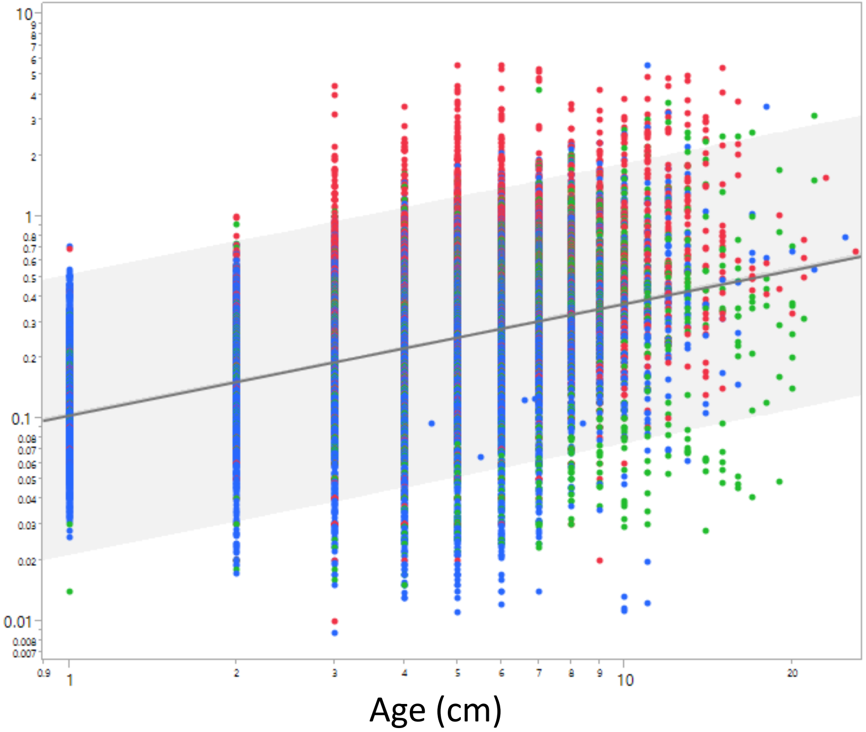


A total of 2775 lakes with data

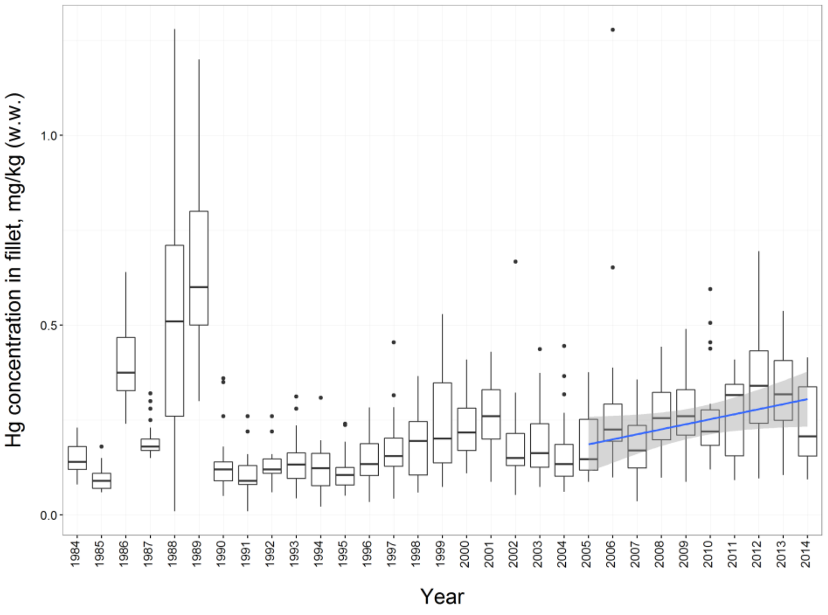

Number of specimen (n)
4000
3500
3000
2500
2000
1500
1000
500
0
Sweden
Finland
Norway
Russia
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Data collection year

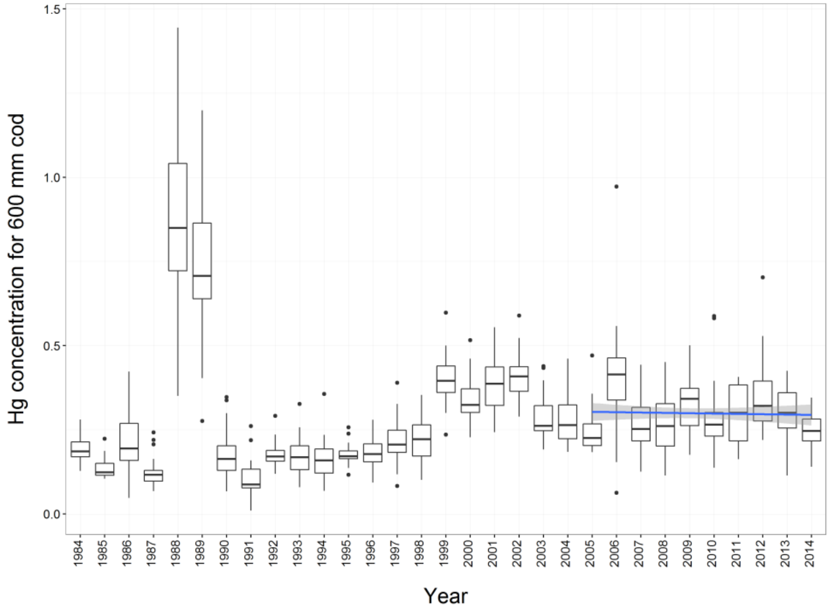
Data transformations





Why size matters…





All figures from: Ruus, Hjermann, Beylich, Green, 2016. SETAC poster, *Mercury trend governed by fish population demography?*

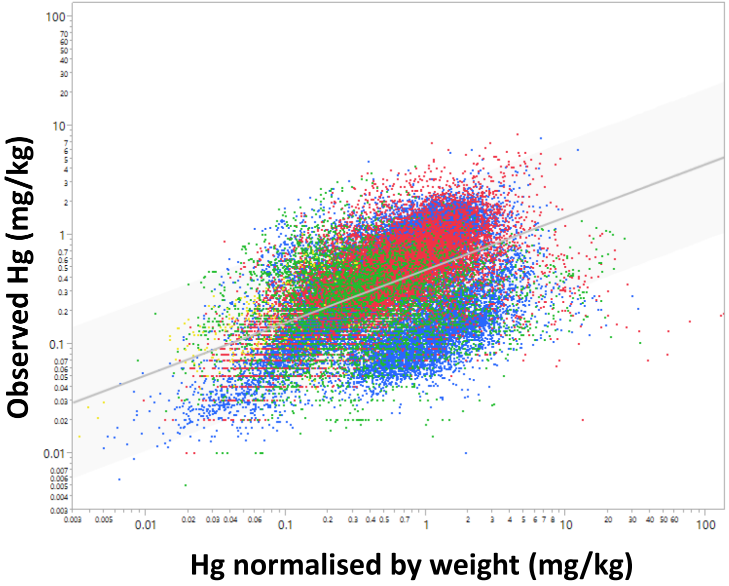
Data calculations

- Several approaches exist for data transformation between:

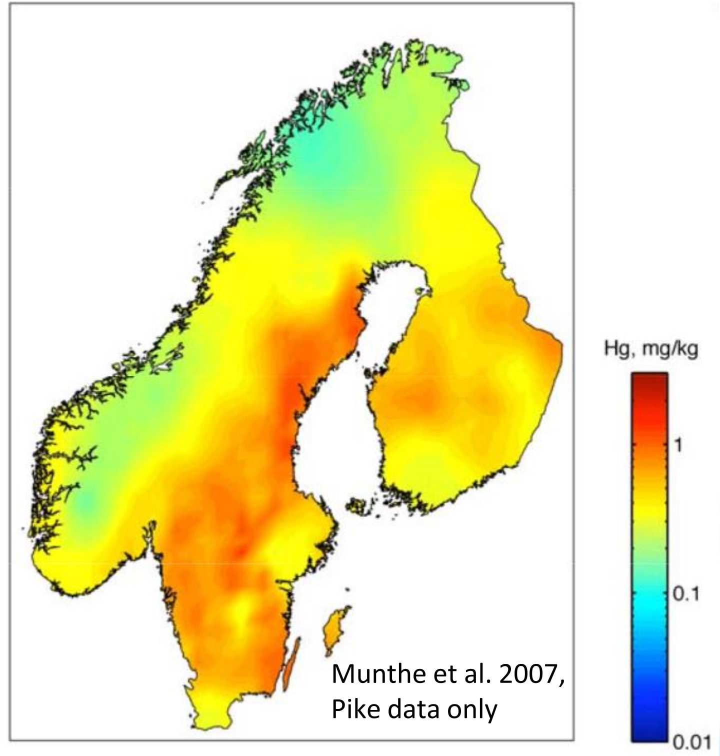
  years, lakes and fish species

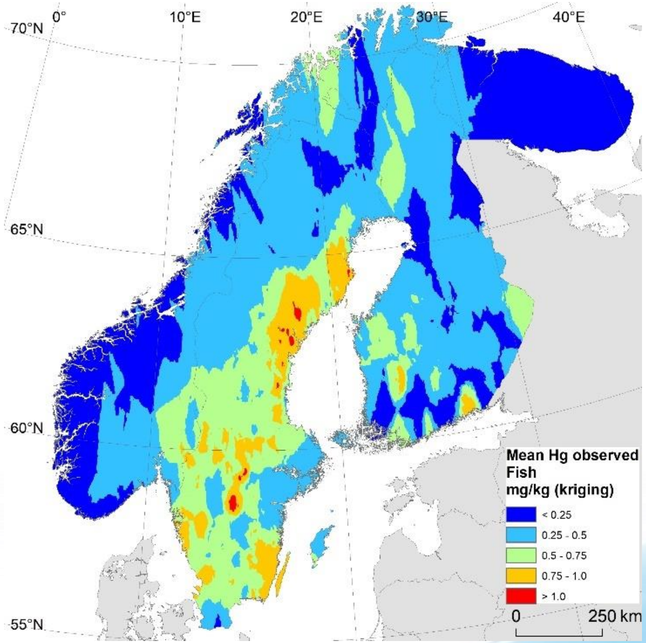
- We follow ***3*** approaches:
  1. *Observed mercury concentrations*
  2. *Weight adjusted mercury concentrations*
  3. *UN/ECE manual transfer function*

$$[Hg]_{std} = [Hg]_{obs} / \left(f_{HgY} + f_{HgW} W^{2/3} \right)$$



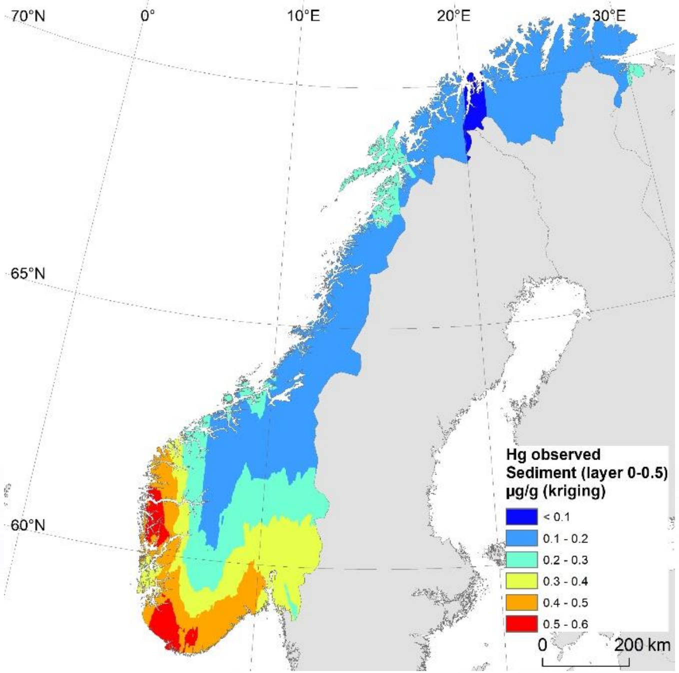
Spatial patterns

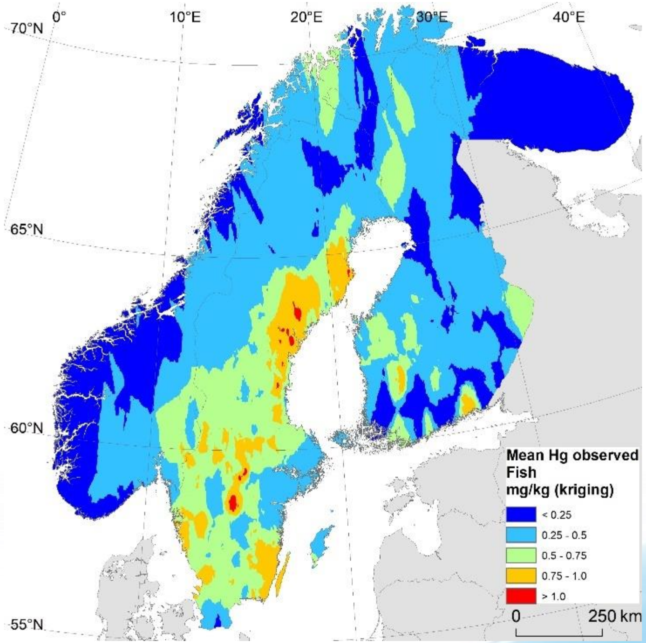




For the complete dataset (1965 – 2015) and all fish species combined

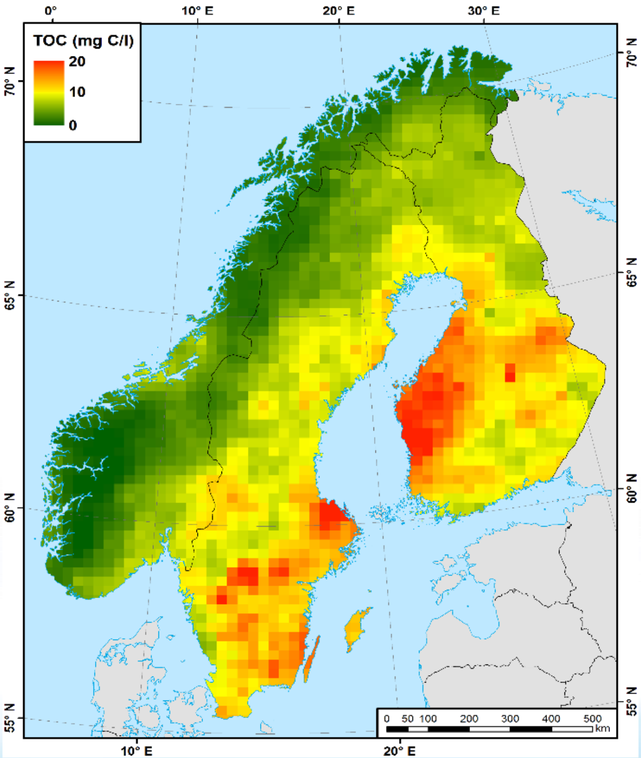
Fish mercury and sediments

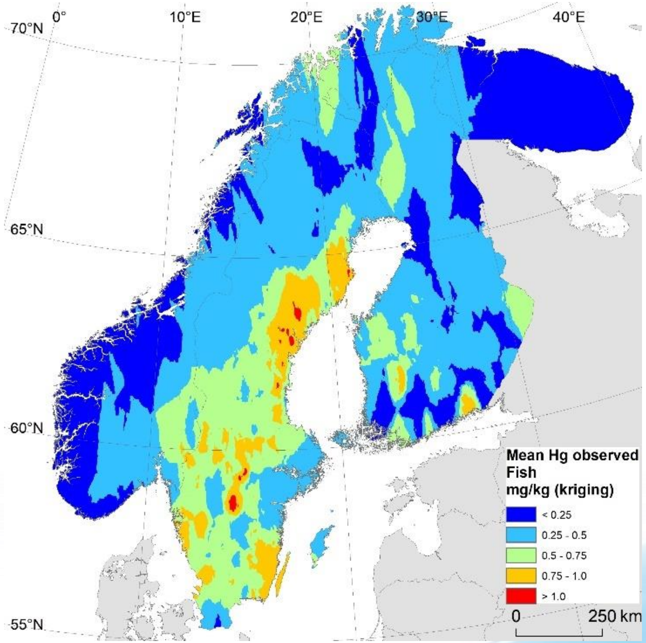




For the complete dataset (1965 – 2015)
and all fish species combined

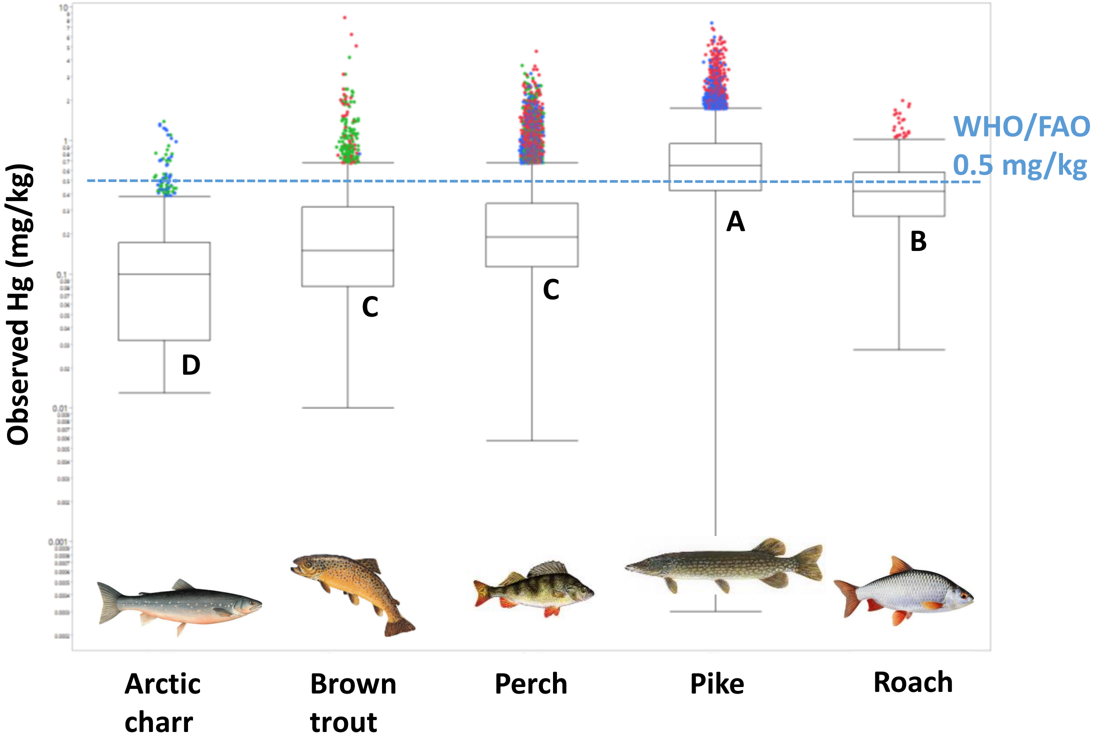
Extrapolated TOC and fish mercury





Investigate changing fish Hg concentrations in lakes with high/low TOC?

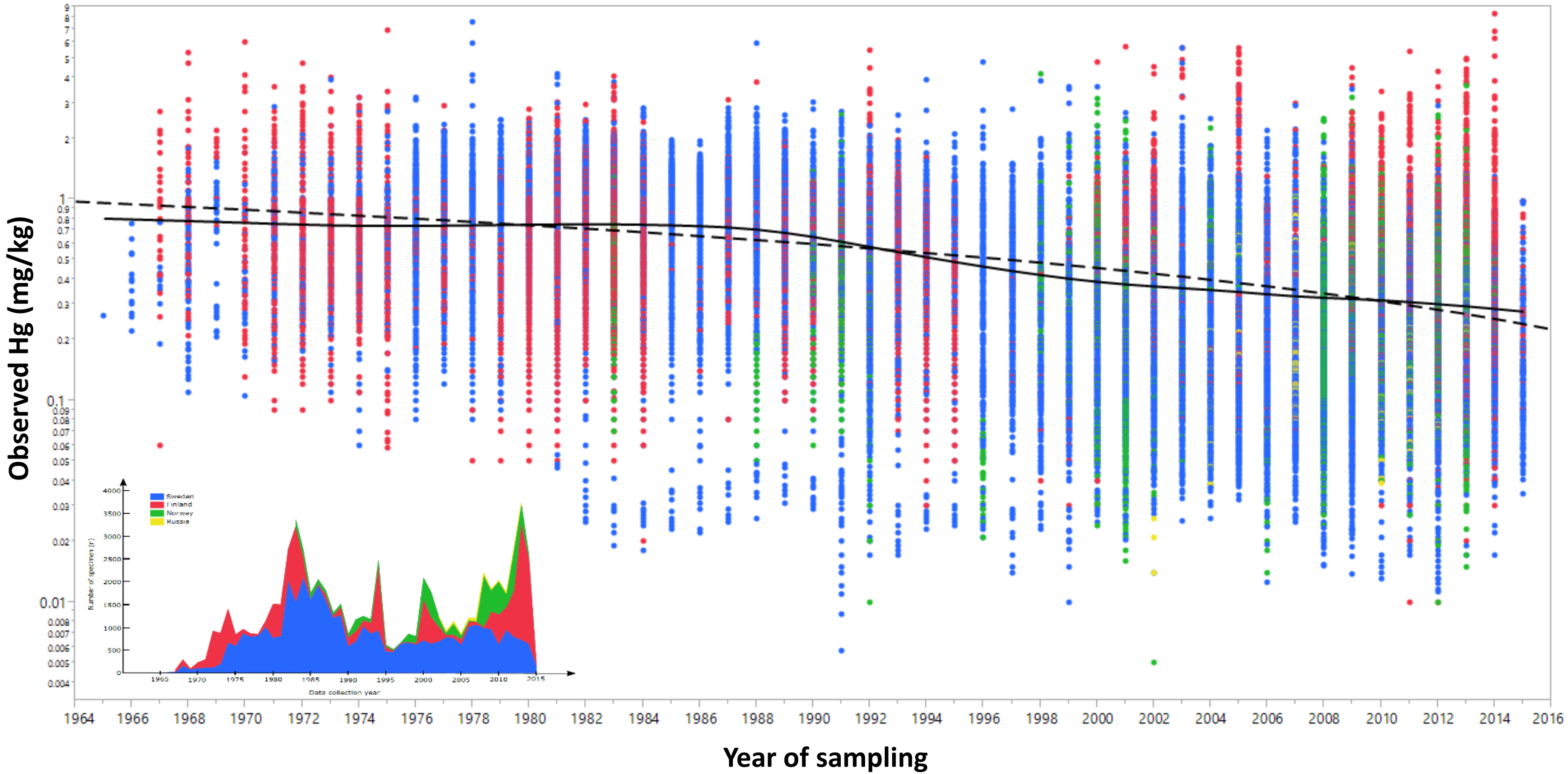
Fish species

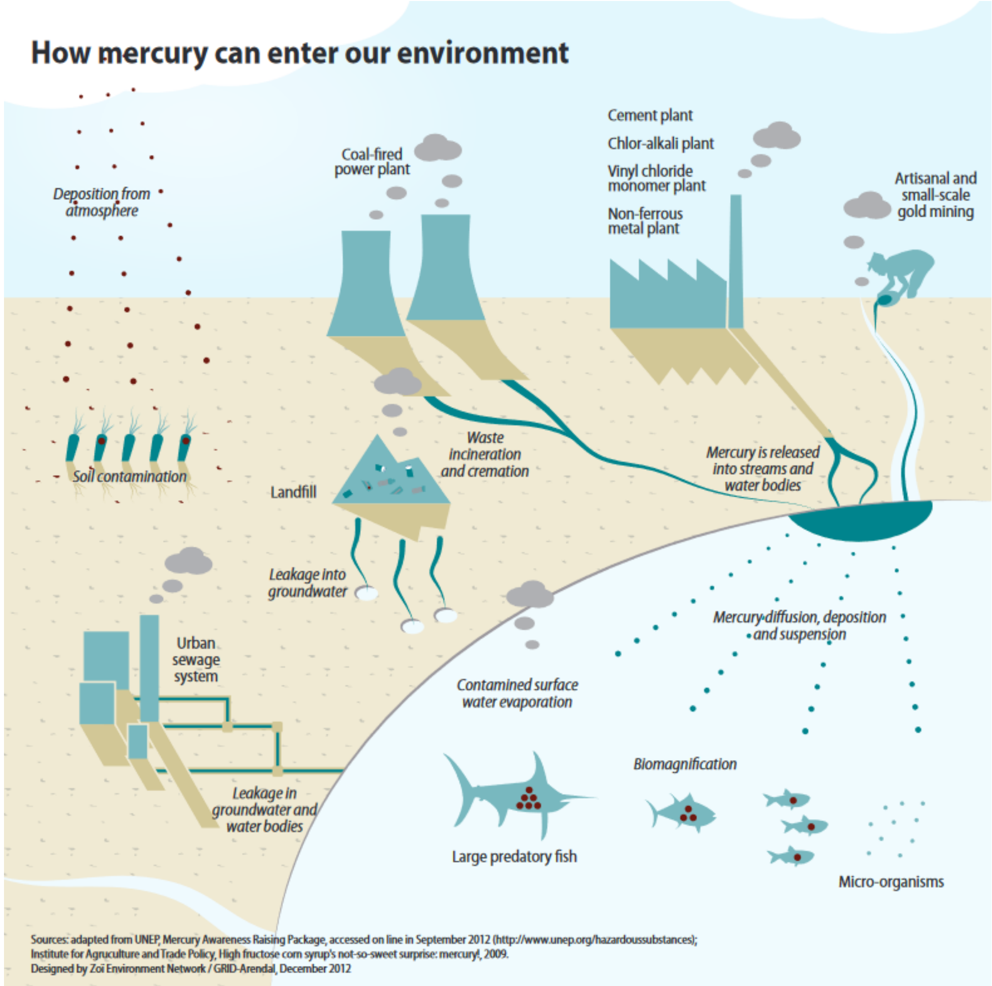


- Concentrations following the theoretical fish trophic level
- Roach higher than expected
- Number of fish in each population > 0.5 mg/kg:

  Arctic charr: n = 43 (5 %)
  Brown trout: n = 310 (15 %)
  Perch: n = 2933 (13 %)
  Pike: n = 18725 (66 %)
  Roach: 325 (37 %)

Temporal trends



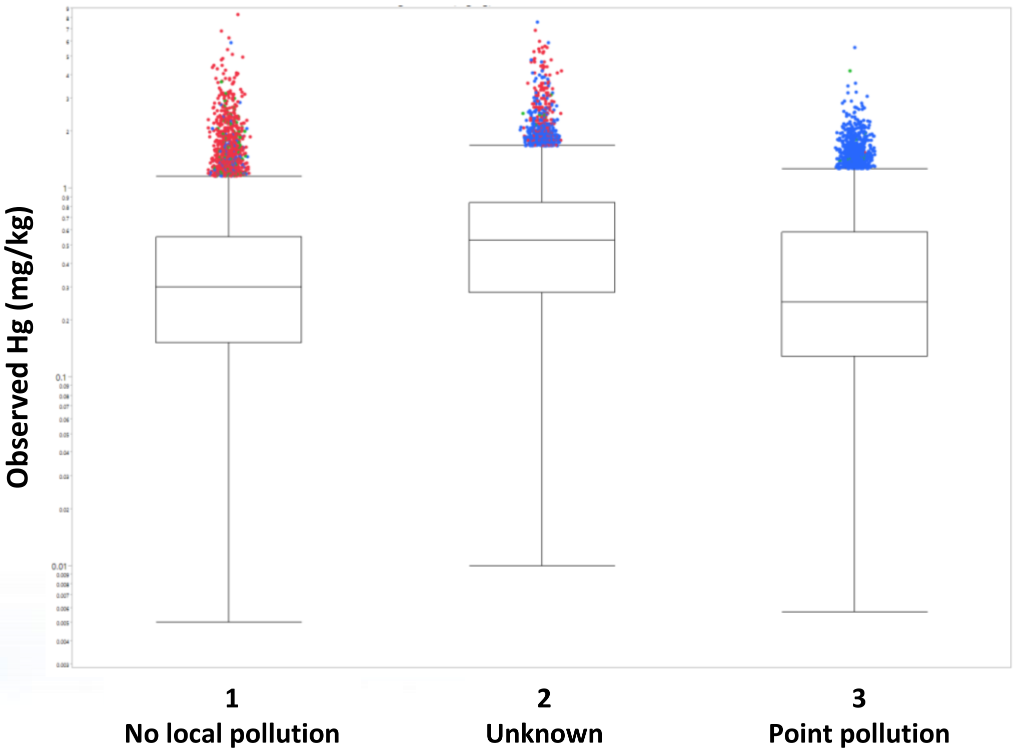


What can explain a declining trend covering the last 35 years? (1980s – 2016)

We have in the database differentiated between:

1. *Lakes only affected by air pollution*
2. *Unknown*
3. *Lakes affected by local point pollution sources*

«At some point polluted – always polluted»



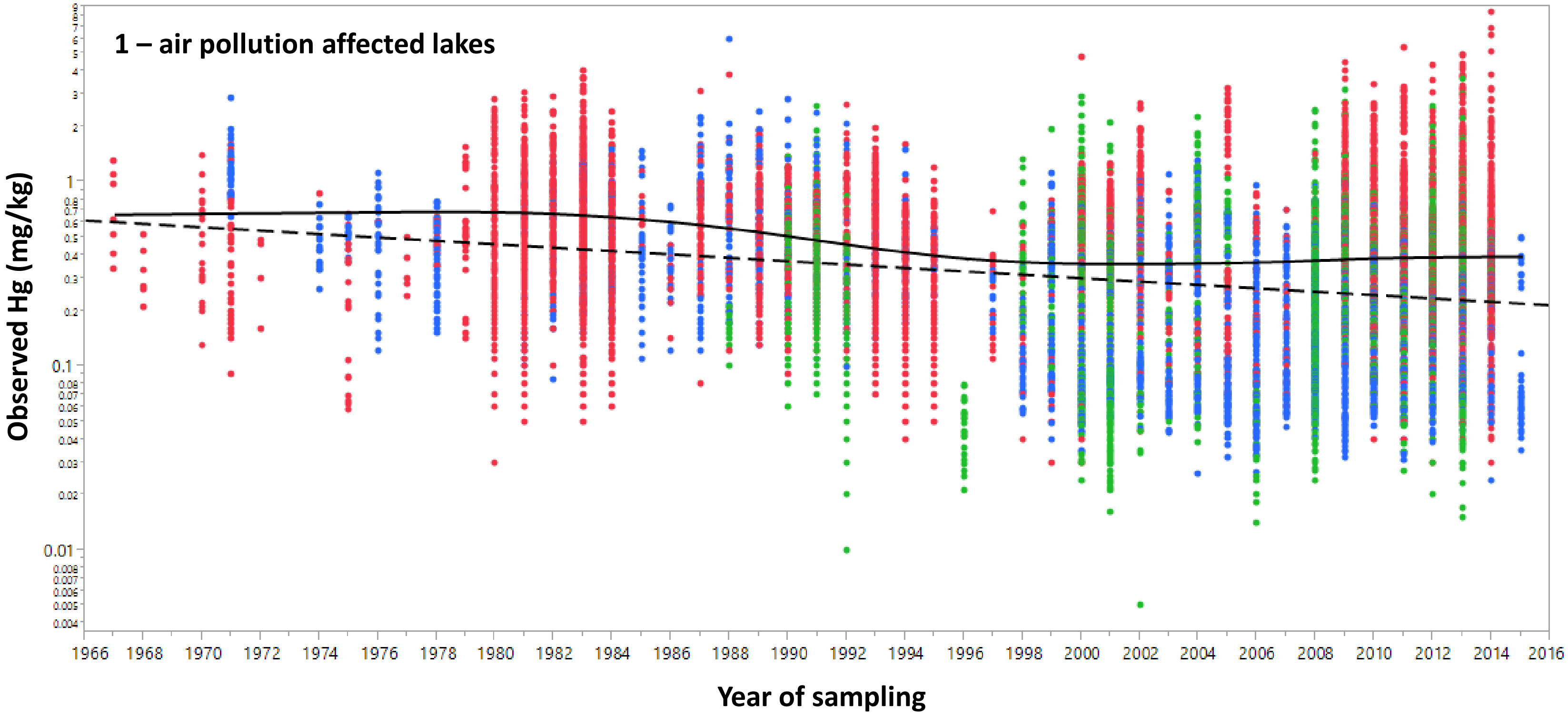
Characteristic	Mean Hg (mg/kg)	Level	*p* (Student's t)
1 (n = 14 062)	0.44 ± 0.46	B	*< 0.0001*
2 (n = 26 535)	0.61 ± 0.47	A	*< 0.0001*
3 (n = 13 938)	0.42 ± 0.41	C	*< 0.0001*

- How do effects from local sources and air pollution differ?
  [local point pollution] < [air pollution]

- **Air pollution contaminate lakes similar to local point pollution sources?**

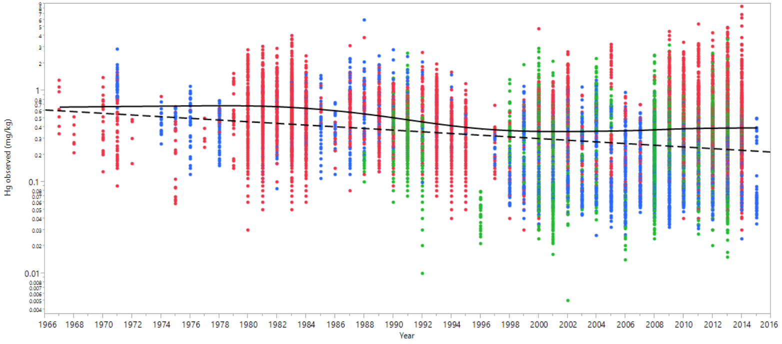
- What do we know about the «unknown» lakes?

Time trends - overall

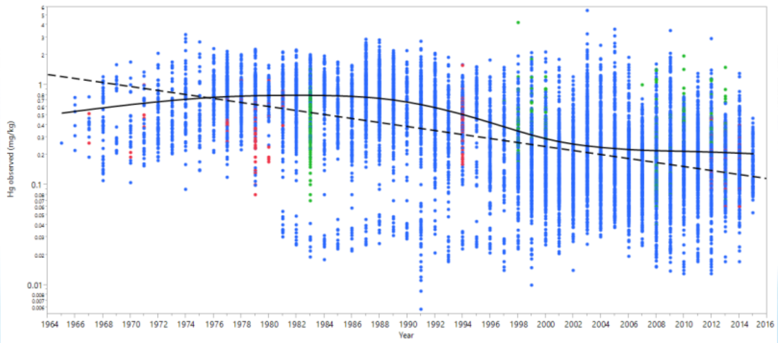


Time trends - overall

1 – air pollution affected lakes



3 – point pollution lakes



Conclusions from time trends and LRAT versus local pollution:

- Similar concentrations overall for local pollution and air pollution influenced lakes

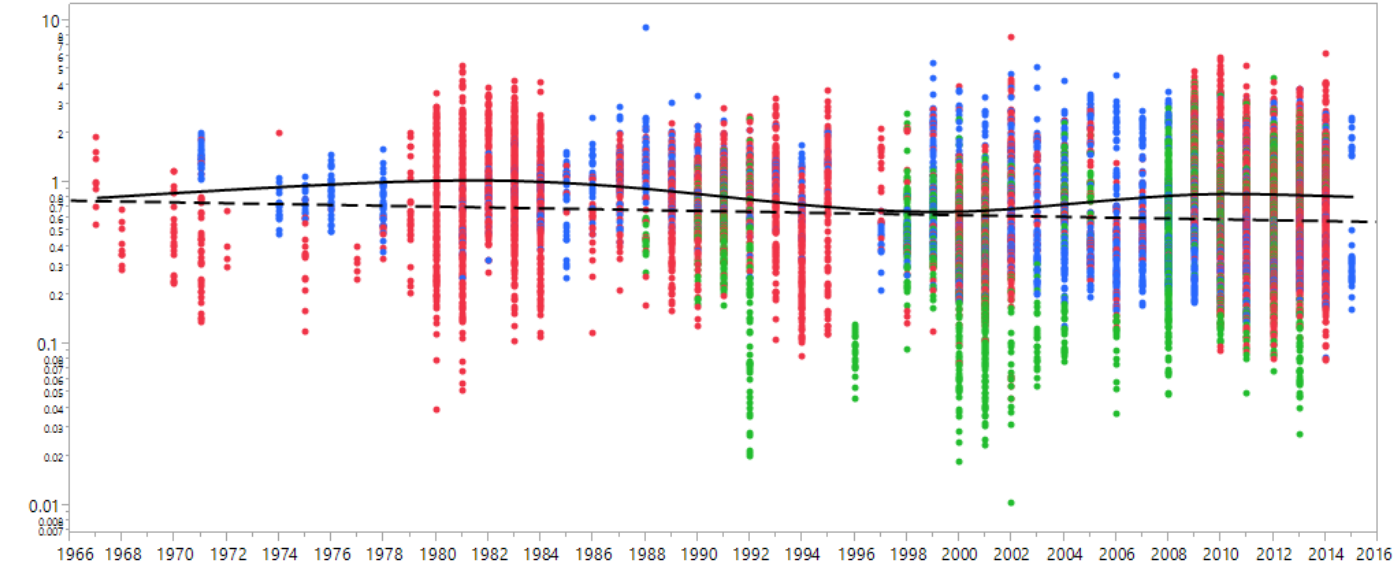
- Brown trout and pike mostly influenced by local pollution

- Point pollution lakes: peak in the mid-to-late 1980s
  Mean 1980-90: 0.79 ± 0.45 mg/kg
  Mean 2000-10: 0.24 ± 0.28 mg/kg
  70 %

- Less of a reduction in LRAT influenced lakes
  Mean 1980-90: 0.69 ± 0.53 mg/kg
  Mean 2000-10: 0.38 ± 0.41 mg/kg
  45 %

Time trends - overall

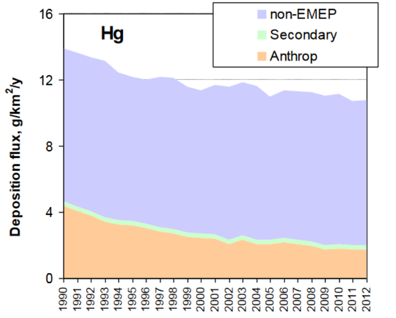
Trends similar between concentration normalisation methods
(here shown for lakes influenced by air pollution)



1 Observed Hg

2 Weight adjusted

3 UN/ECE manual



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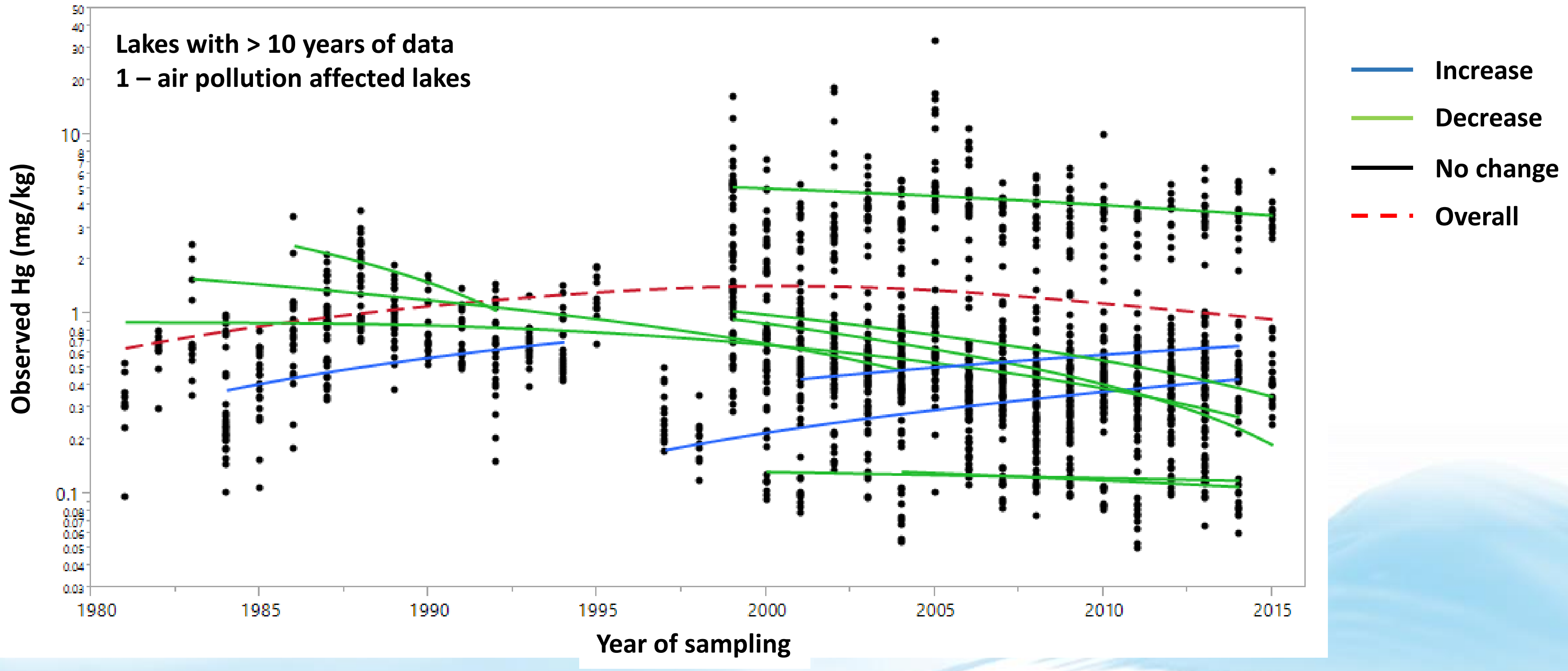
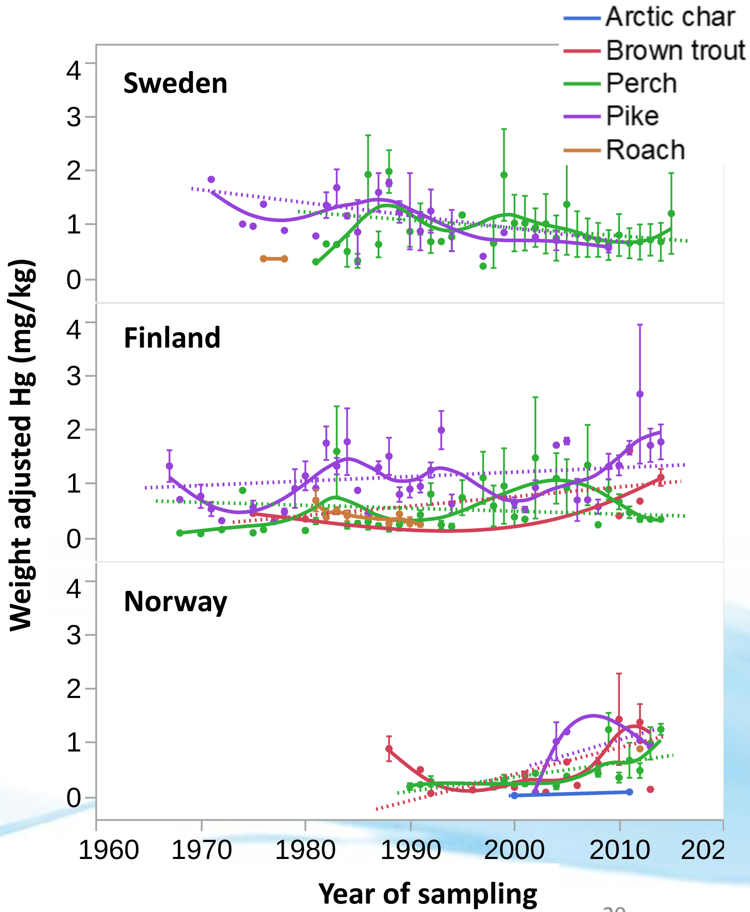
Time trends – individual lakes



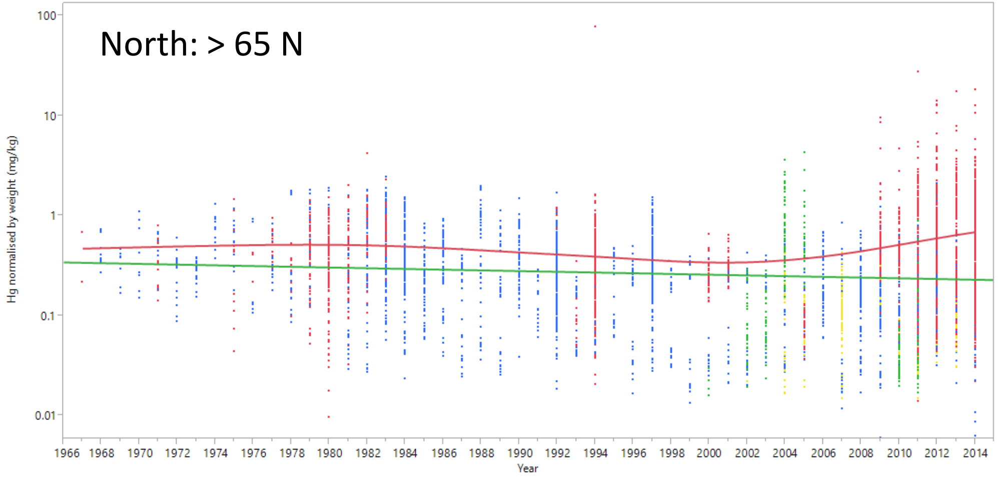
Temporal trends – some conclusions

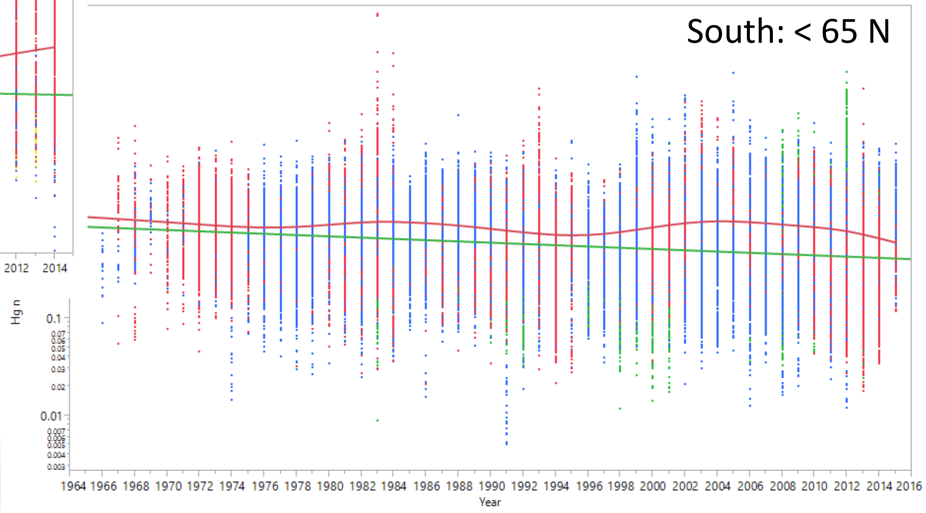
- Peak in the 1980s – ***generally reducing trends the last 3 decades***
- ***No differences*** seen ***between normalisation*** techniques for overall trends
- ***A lot of individual variance inbetween lakes***
- ***How we treat the data is not irrelevant***
  - Sweden decrease
  - Finland/Norway increase
- Analyse on ***individual species***; ***climate regions***; ***deposition patterns***?



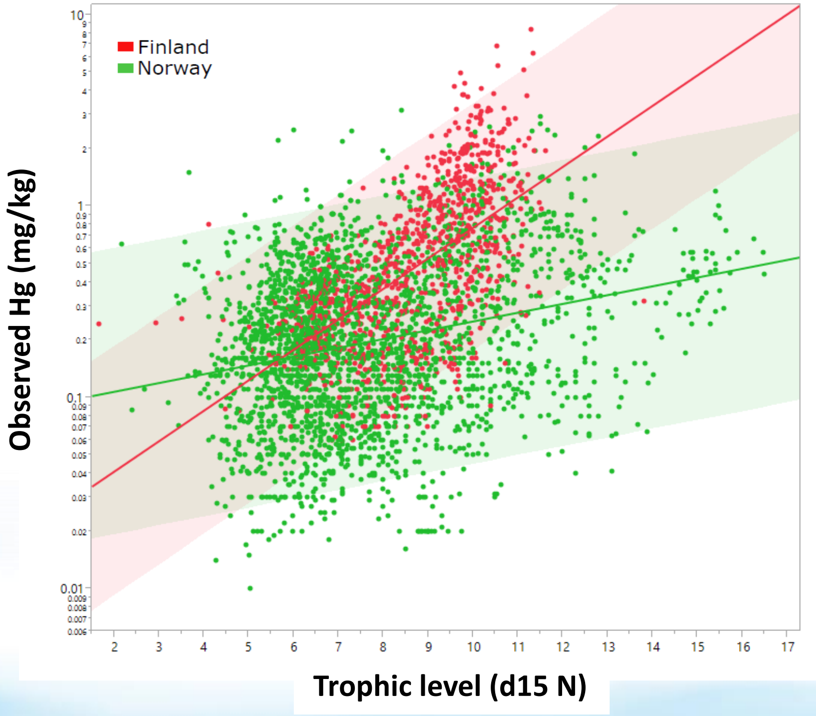
Examples for further exploration

Analyse on climate and deposition gradients





Examples for further exploration



Why is the Trophic Magnification Slope higher for Finnish lakes compared to Norwegian lakes?

Increased accumulation in Finnish lakes may be a result of colder temperatures, which gives:

- Reduced excretion of MeHg; and
- Reduced fish growth.

Finnish lakes are generally located at a higher latitude than Norwegian lakes:

- Norway: 58N to 62N;
- Finland: 66N to 69N

Main conclusions

- Spatial patterns reveal effects from air and local pollution
- Temporal trends reveal generally reducing trends, but differences observed between regions and fish species
- Treatment of data has strong effects on conclusions
- Individual lakes with long time series and only affected by air pollution will be subject to further hypotheses testing

Report on "***Spatial and temporal trends of mercury concentrations in Fennoscandian freshwater fish***" finalized September 1st 2017.

The database has enormous potential for further exploration of relevant research questions

Thank you!