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Temporal trends in heavy metals across IM sites

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The mercury in fish report – key findings and policy relevance

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Presentation outline:

- Background and scenario of HM emissions in Europe
- Flashback at 24^{th} Annual Report (2015) and 26^{th} Annual Report (2017)
- Temporal trends in HM fluxes at ICP IM sites: Swedish example
- Land-atmosphere exchange: Important for the mass balance for mercury
- ICP Waters report report 132/2017: Spatial and temporal trends of mercury in freshwater fish in Fennoscandia (1965-2017)
- Summary

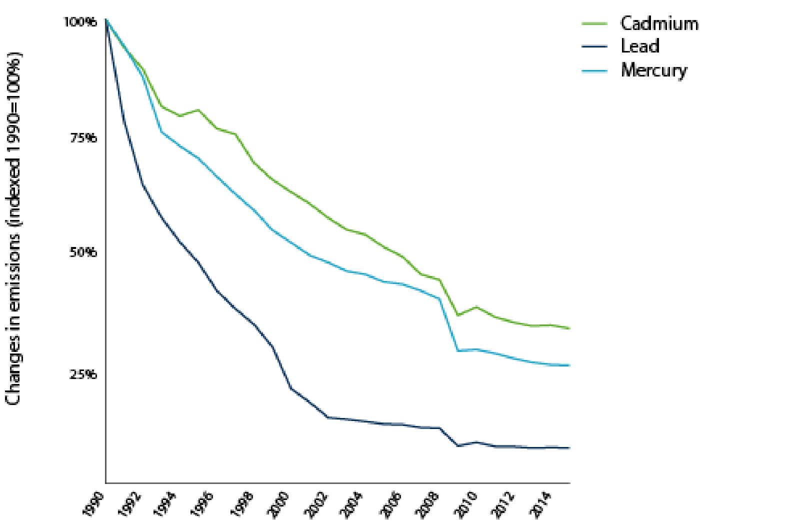
Background

- Forested catchments are important for heavy metal (HM) retention and exposure pathways to aquatic ecosystems
- Do fluxes of HM in deposition and runoff respond to changes in emission reductions in Europe?
- Can temporal trend analysis of HM fluxes provide detailed understanding of responses in HM mass balances to emission reductions and recovery times from atmospherically deposited HM?

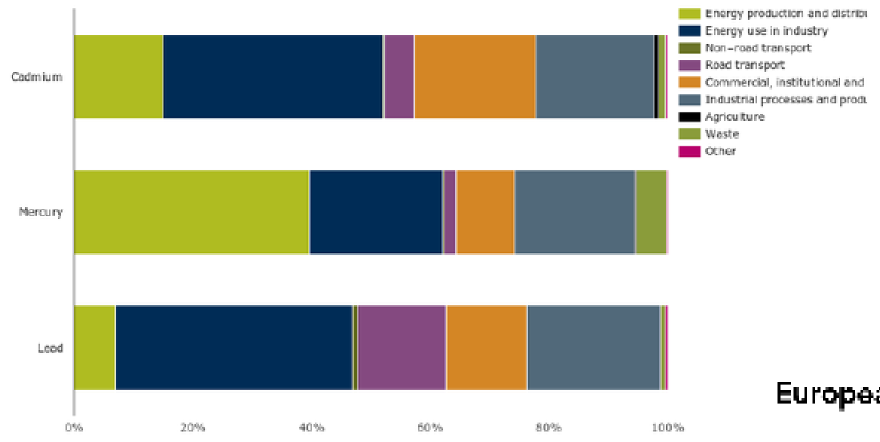
Special attention for Hg

- ICP IM programmes relevant for effectiveness evaluation of the *Minamata Convention on Mercury*

Fig. 1: Trends in emissions of heavy metals



Bar chart



European Environment Agency

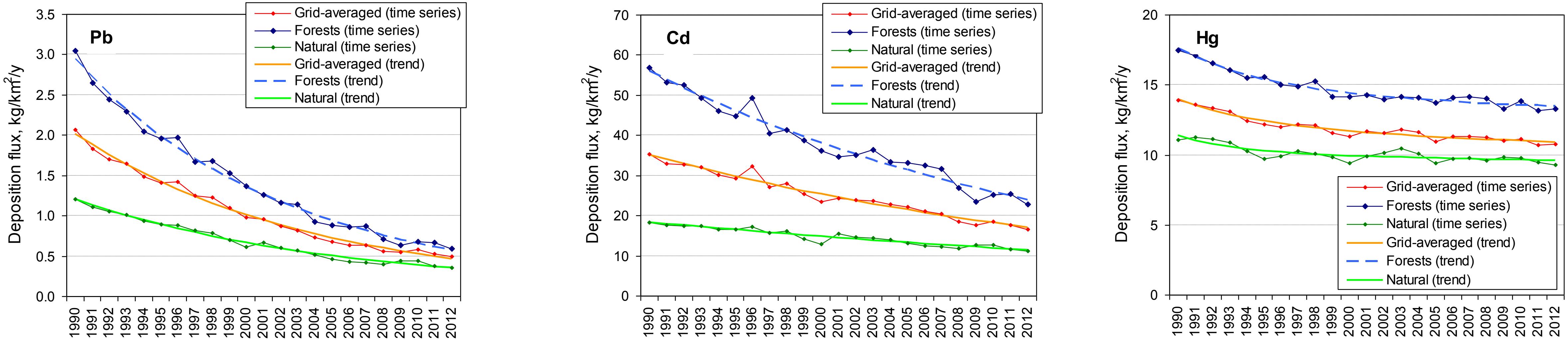


Figure 51: Deposition fluxes of lead (left), cadmium (middle) and mercury (right) and their main component of trends in the EMEP in 1990-2012

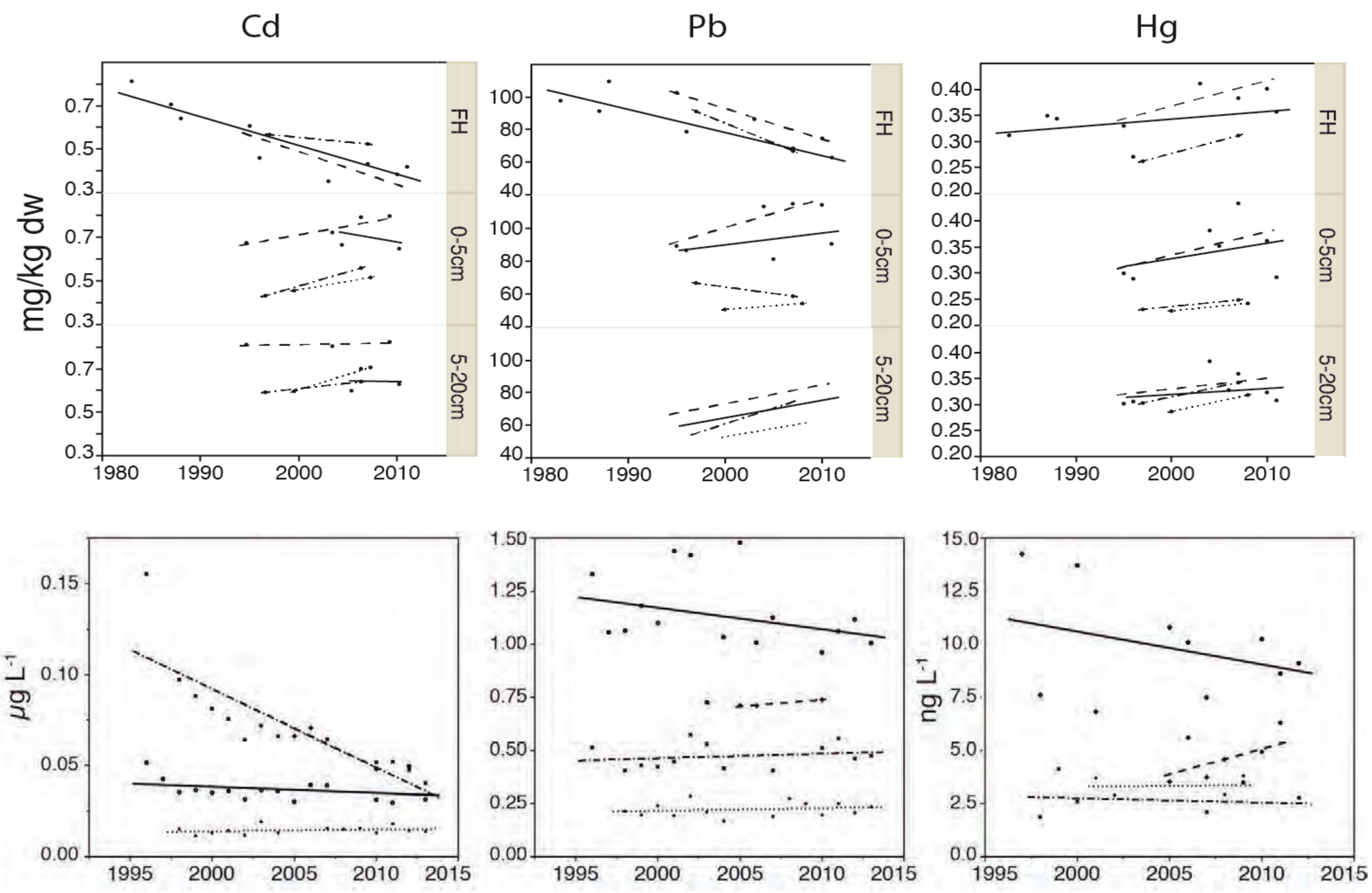
de Wit, H. A.; Hettelingh, J.-P.; Harmens, H. *Trends in ecosystem and health responses to long-range transported atmospheric pollutants*; 2015; p 94.

Flashback #1:

24th Annual Report (2015). Åkerblom & Lundin. Progress report on heavy metal trends at ICP IM sites.

SC

RW



Aneboda (solid line), Gammtratten (dotted line), Gårdsjön (dashed line), Kindla (dotdashed line)

Conlcusion:

- Cd and Pb respond according to decreased rates of deposition while Hg did not
- Translocation of metals to deeper mineral soil horizons
- Changes in runoff concentrations of HM to a small extent correspond to changes in concentrations of HM soil compartments

Flashback #2:

26th Annual Report (2017). Åkerblom & Lundin. Report on concentrations of heavy metals in important forest ecosystem compartments

Conlcusion:

- Summary of concentrations of Cd, Pb, Hg, Cu and Zn in PC, TF, RW, LF and SC

Cadmium (Cd)

Lead (Pb)

Mercury (Hg)

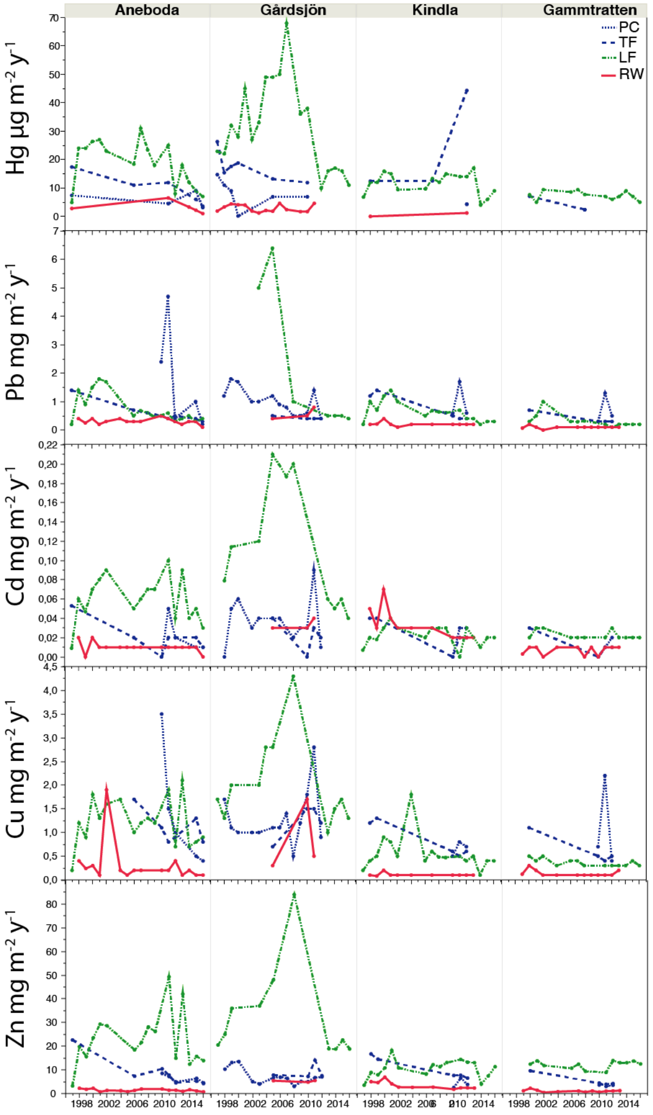
Copper (Cu)

Zinc (Zn)

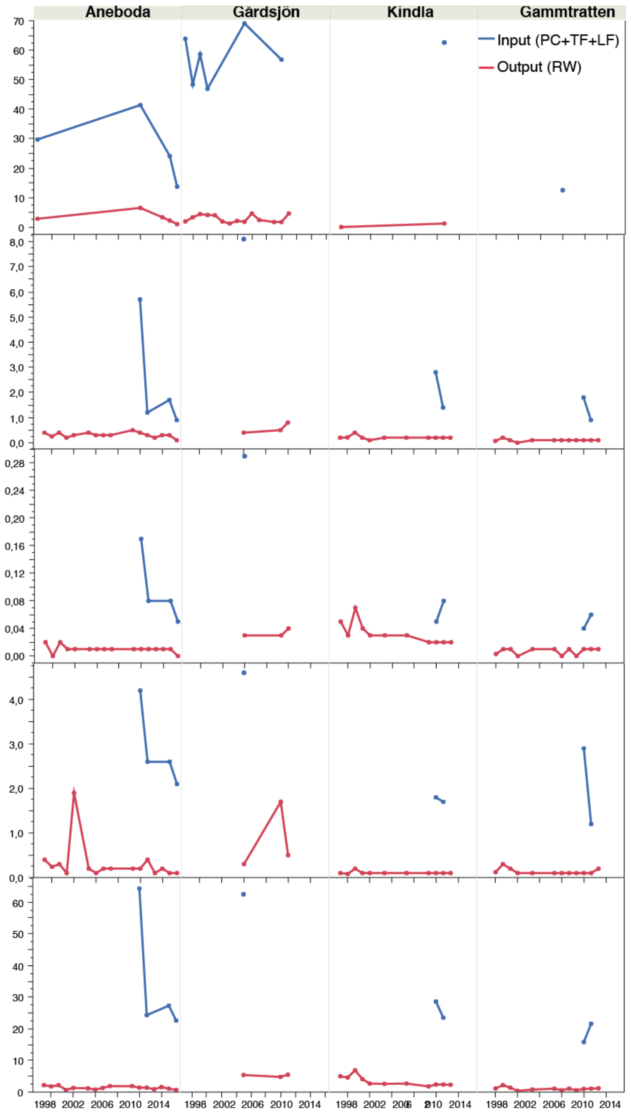
	Median (n)								Temporal coverage				
	Subprogramme												
	PC	TF	RW	LF	SC (soil depth cm)				PC	TF	RW	LF	SC
					OH-litter	0–10	10–30	30–200					
	µg L^{-1}			mg kg^{-1}					between years				
Country													
Austria	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1993–2012	1993–2010	1994–2012	1993–2009	
Belarus	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1998–2005		1996–2014		1995–1998
Czech Republic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1989–2013	1989–2015	1989–2013	2008–2008	
Estonia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28 (17)	13 (10)	13 (22)	1996–2013	1998–2015		1994–2015	1994–2010
Finland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13 (35)	10 (13)	[illegible]	1993–2012	1992–2002	1988–2013	1994–1997	1988–1989
Germany	[illegible]	[illegible]	[illegible]	32.1 (382)	55 (10)	53 (14)	36 (8)	42 (12)	2004–2009			2004–2015	1990–2010
Italy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58 (25)	66 (15)	65 (24)	2005–2010			1994–2000	1995–2011
Latvia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1994–2009	1994–2009	1996–2009	1994–2008	1994–2003
Lithuania	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			2000–2012	1999–2015	1993–2005
Norway	2.5 (567)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Poland	16.1 (58)	35.5 (103)	13.0 (4)	[illegible]	55 (9)	6 (9)	10 (8)	8 (18)	1993–1996	1993–1996	1996–1996		1988–1991
Portugal	16.3 (68)	[illegible]	10.0 (20)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1994–2001		1999–2001		
Russia	9.5 (60)	17.0 (23)			40 (4)	20 (6)	26 (8)	30 (12)	1992–1997	1993–1997			1989–1993
Spain	4.9 (62)	5.6 (70)	4.8 (49)	34.1 (14)	[illegible]	102 (4)	93 (2)	106 (4)	2007–2012	2007–2015	2007–2012	2008–2015	2010–2010
Sweden	5.4 (274)	12.1 (190)	3.6 (474)	81.9 (147)	60 (8)	7 (4)	16 (7)	18 (5)	1995–2012	1995–2012	1999–2013	1996–2015	1984–1997
Switzerland	9.2 (170)	9.0 (75)		36.9 (6)			9 (2)		1988–1999	1993–1999		1993–1998	1993–1997
The Netherlands	6.6 (114)								1988–1997				
United Kingdom	67.5 (6)	19.1 (24)							1991–1992	1991–1993			

Temporal trends in HM fluxes at ICP IM sites: Swedish example

Annual fluxes for ICP IM subprogrammes for precipitation chemistry (PC), througfall (TF), litterfall (LF), and runoff water (RW).



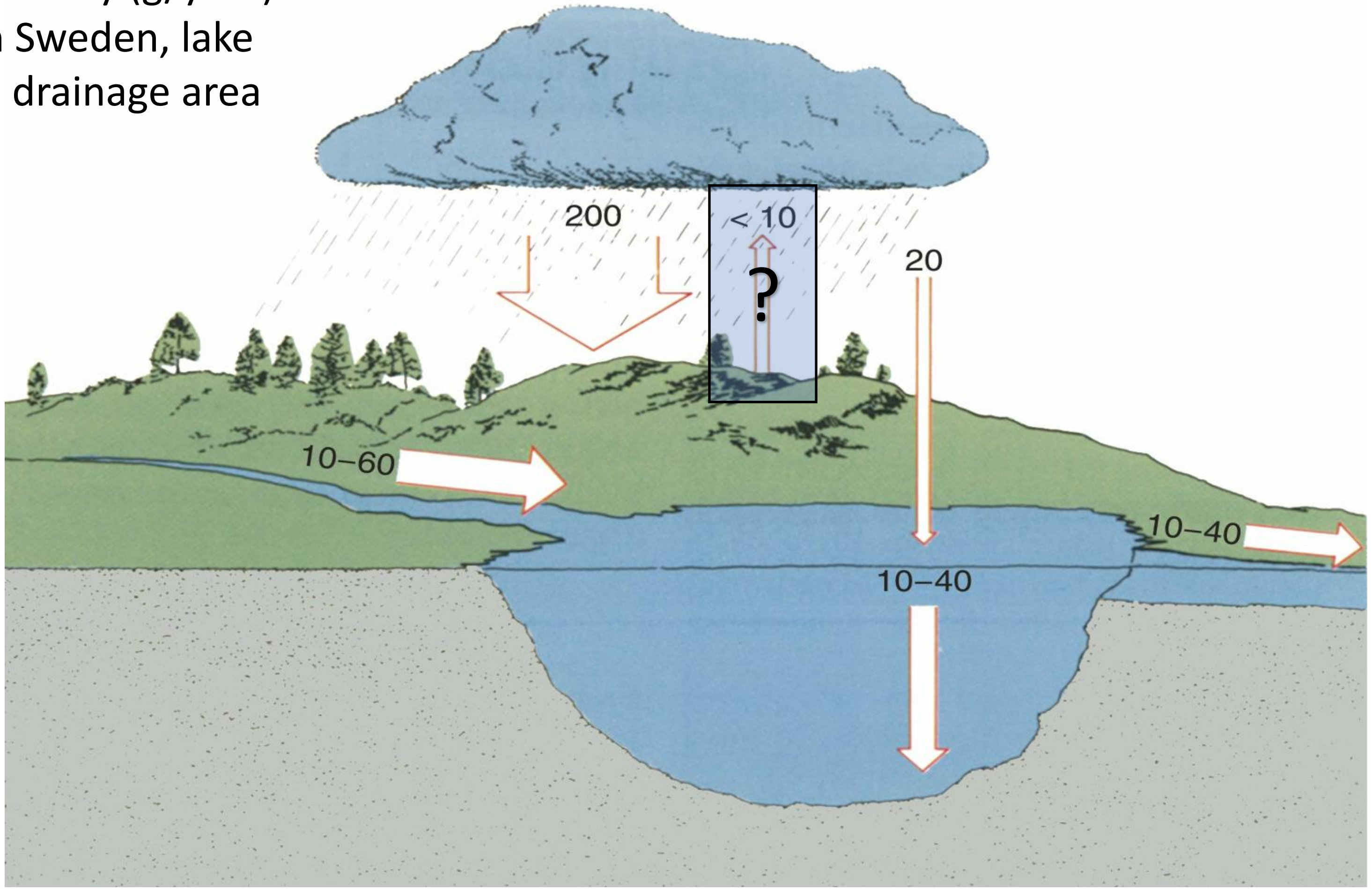
Summary of catchements total input (PC+TF+LF) and output (RW)



- Large exceedences of HM input compared to output (*Bringmark et al. 2013)*
- Differences in relative contribution between PC, TF and LF for HM input between sites and over time
- How consistent are responses in HM mass balances in small forested catchments to changes in HM emissions across Europe? Include relevant forest compartments in the evaluation
- Identify critical characteristics that relates to HM retention in catchments
- Invitation for discussion how to proceed and contribute with data for evaluation

Land-atmosphere exchange:
Important for the mass balance for mercury

Fluxes of mercury (g/year) in southern Sweden, lake area 1 km², drainage area 10 km² :



Traditional view

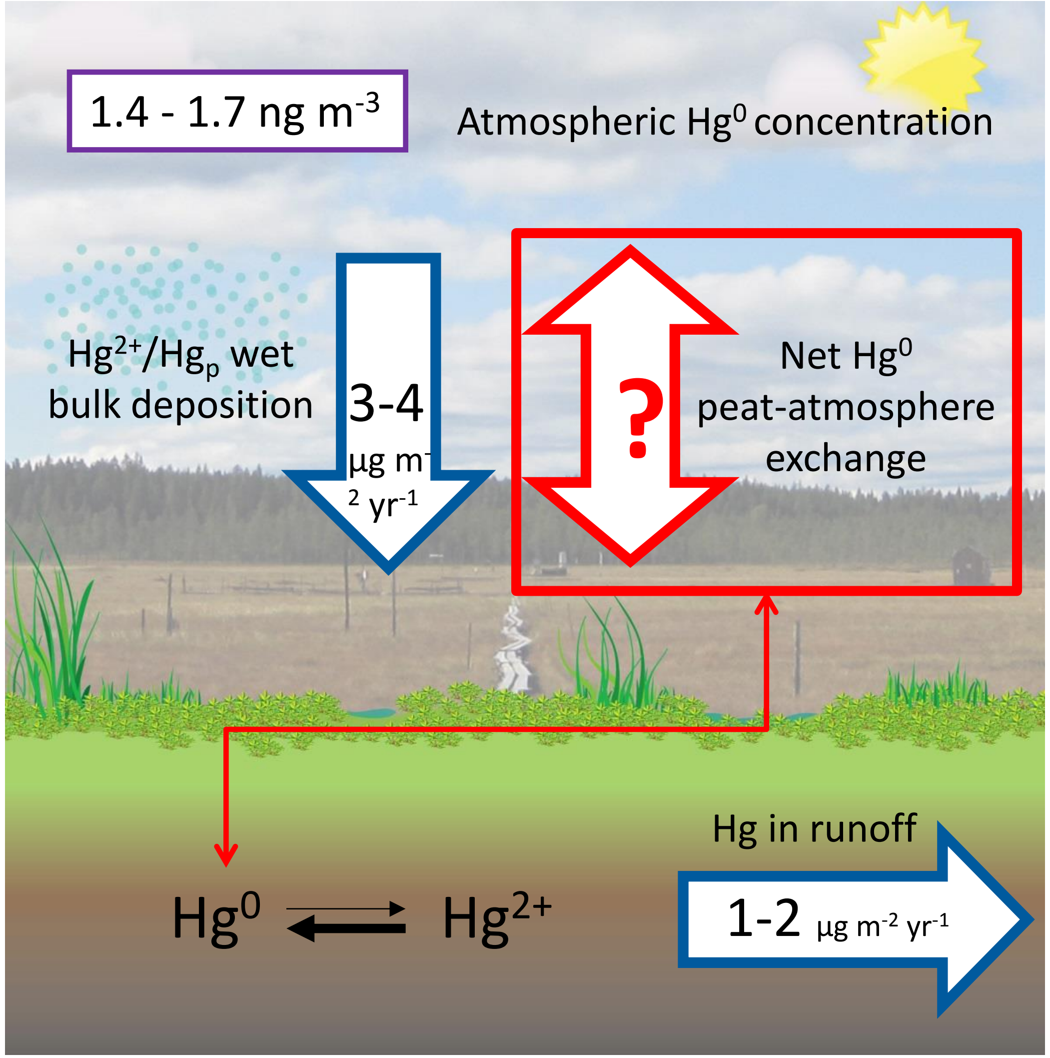
- **Hg stores accumulating**
- **only slowly reversible**

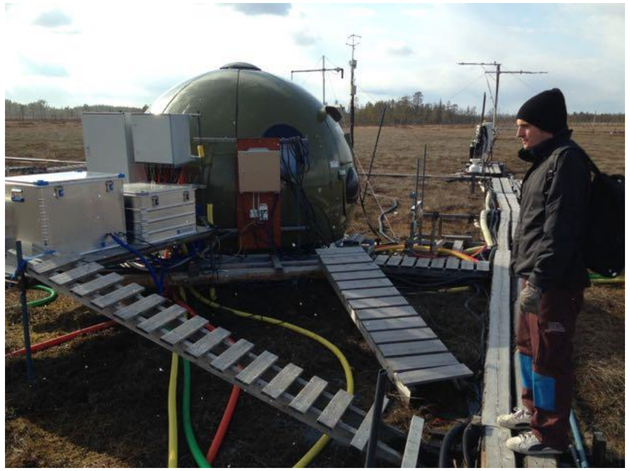
Supported by Bringmark et al. 2013. WASP.

Findings from Degerö stormyr, Northern Sweden

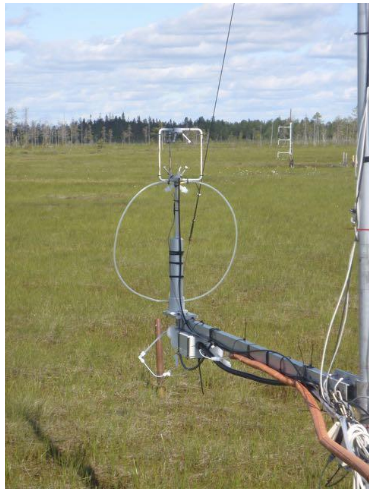
Osterwalder, S.; Bishop, K.; Alewell, C.; Fritsche, J.; Laudon, H.; Åkerblom, S.; Nilsson, M. B., Mercury evasion from a boreal peatland shortens the timeline for recovery from legacy pollution. *Scientific Reports* **2017,** *7*, 16022.

Wet bulk deposition twice the runoff Hg
So peatlands are accumulating Hg –
unless the Hg is evading…





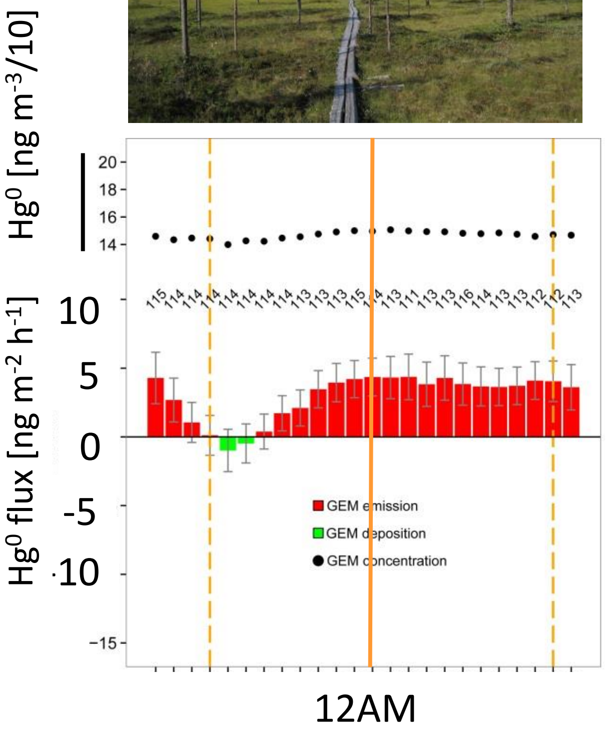
Relaxed Eddy Accumulation:
Collecting up and down-wind Hg over 30 min, *f = 20 s*$^{-1}$



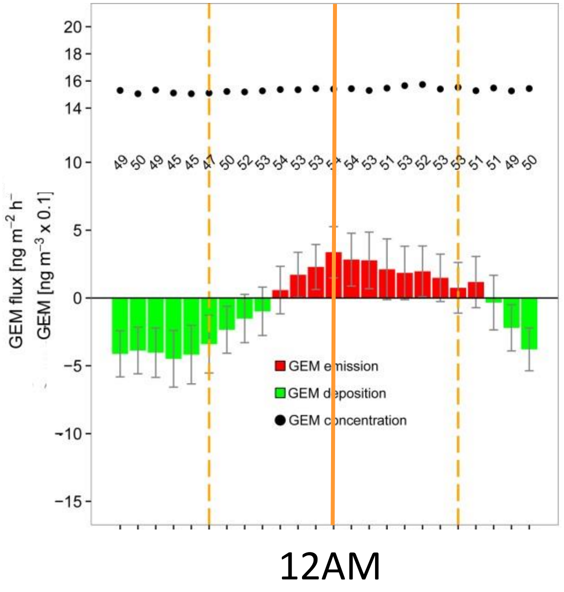
Hg^0 flux and controls

Diurnal patterns of Hg^0 flux

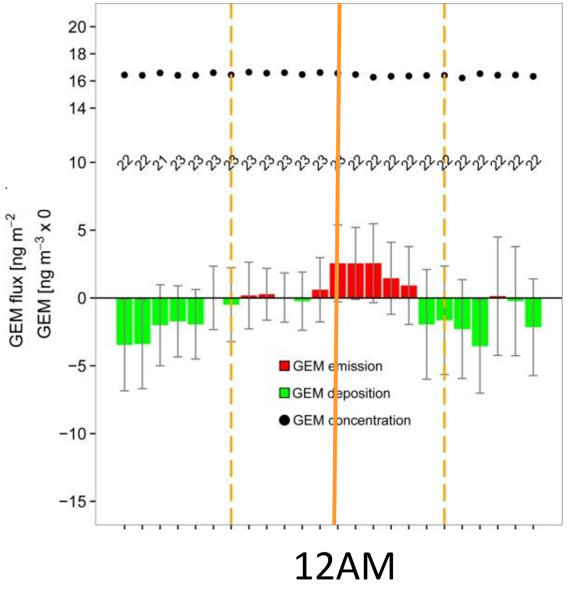
GROWING SEASON
May – Sep



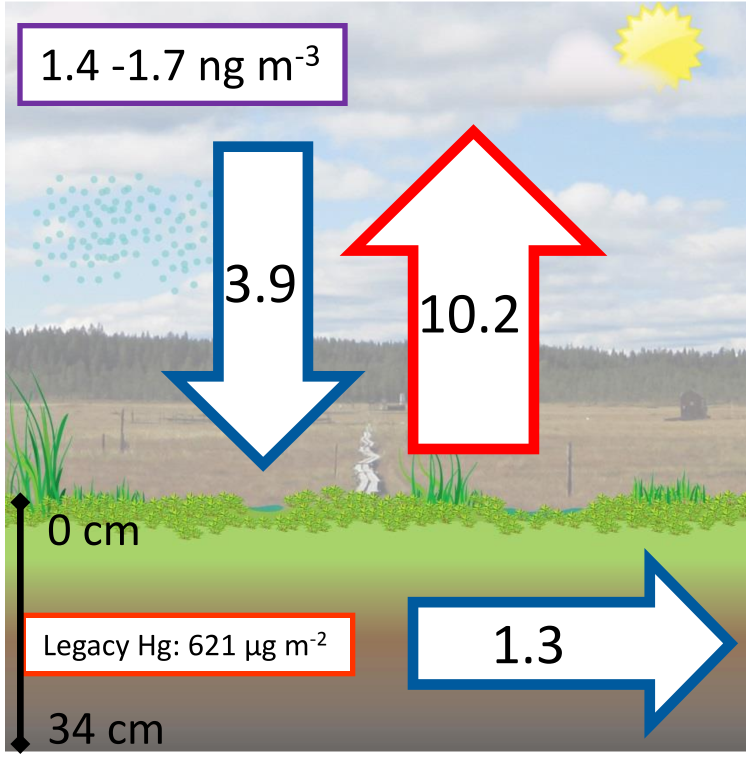
DORMANT SEASON
Apr, Oct, Nov



SNOW COVERED
Mar



Take-home message:



fluxes in µg m^{-2} yr^{-1}

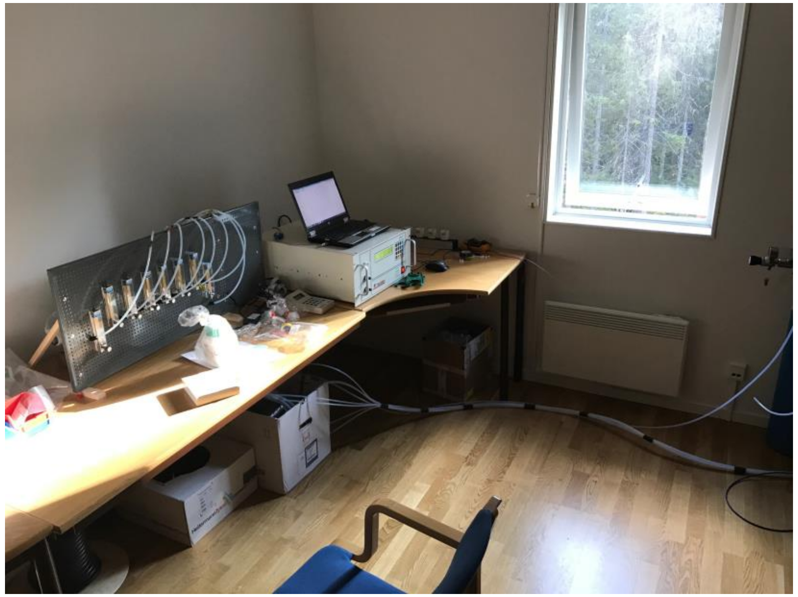
- **Boreal peatland: net Hg source**
  - emission of legacy Hg
- **Hg in runoff declines (-25% by 2050)**
  -> downstream ecosystems recover more rapidly from past Hg pollution
- **Land-atmosphere exchange is required for complete mass-balance calculations on Hg**

research looking on land-atmosphere exchange of Hg over forested catchments 2017-2018

Sino-Swedish Mercury Management Research Framework

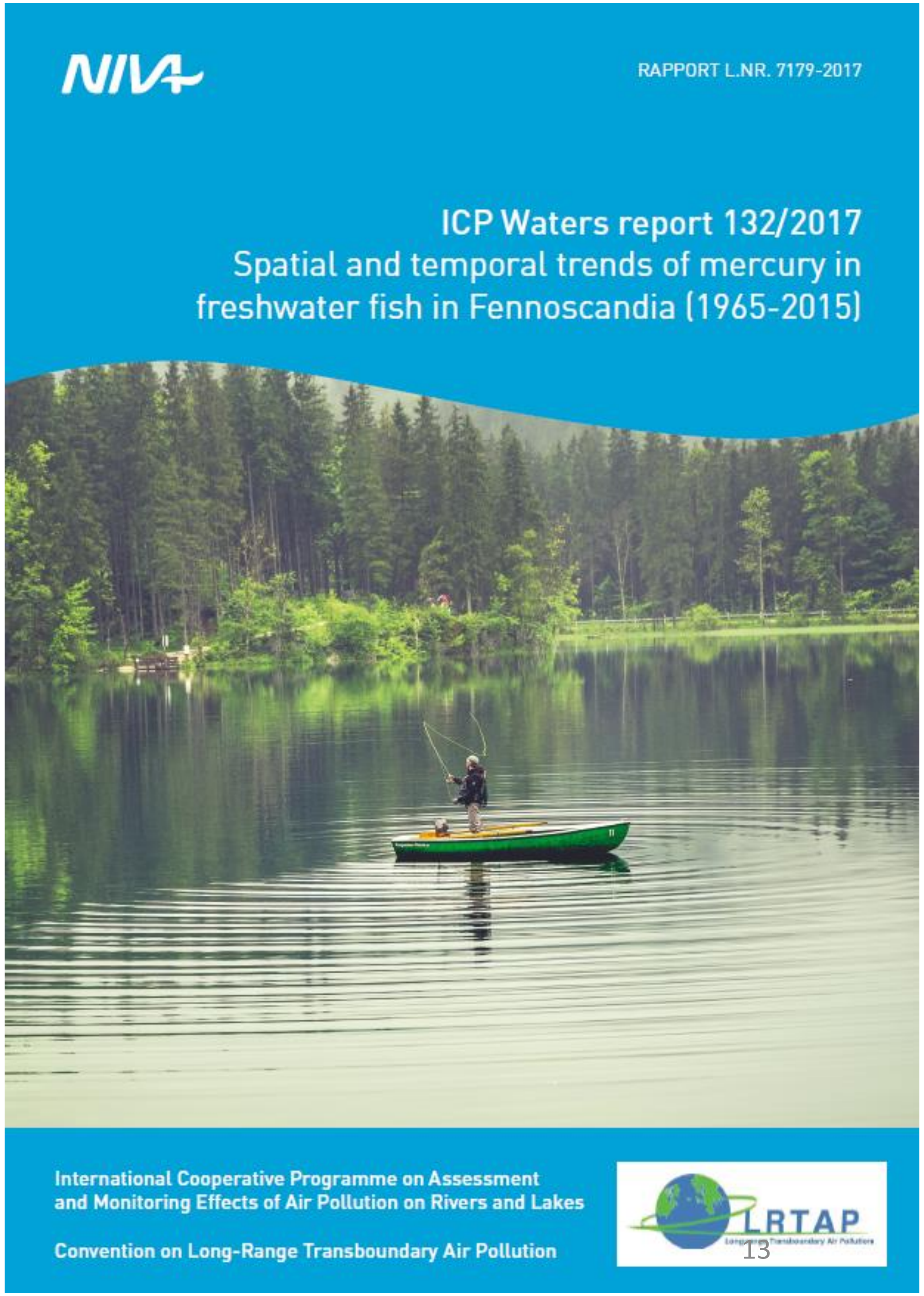
SMaReF

瑞中汞研究框架计划



Spatial patterns and temporal trends of mercury in freshwater fish in Fennoscandia

- *Braaten, Åkerblom et al., 2017*
- *Joint effort ICP Waters – ICP Integrated Monitoring*
- *www.icp-waters.no*

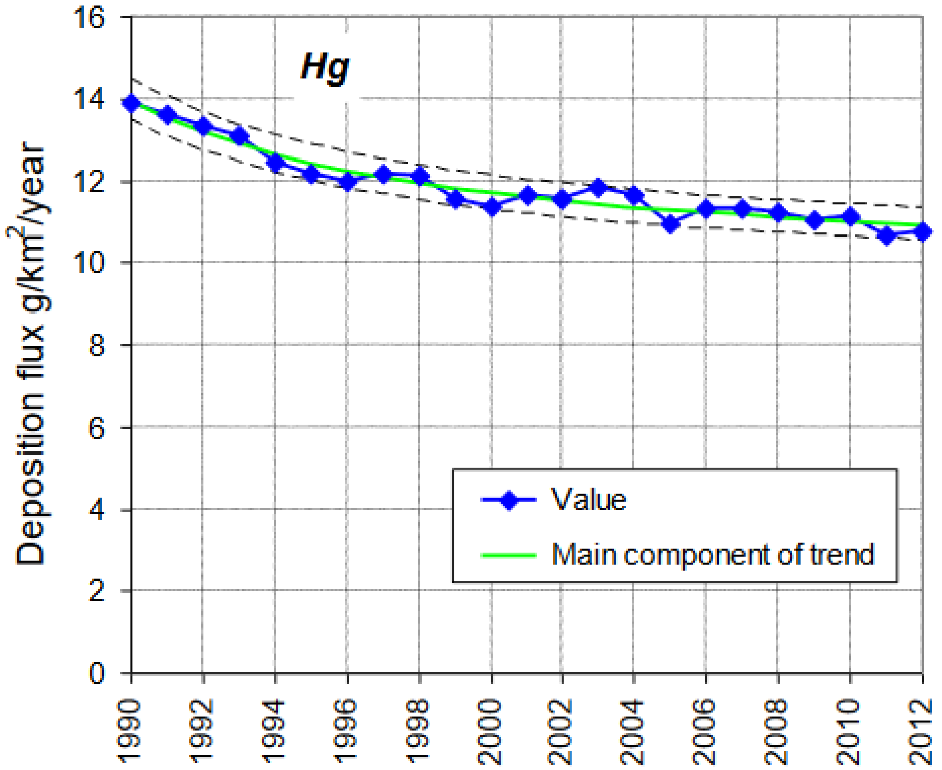


Thanks to many co-authors and to long-term funders of mercury monitoring in fish

- Hans Fredrik Veiteberg Braaten[1], Staffan Åkerblom[2], Heleen A. de Wit[1], Gunnar Skotte[3], Martti Rask[4], Jussi Vuorenmaa[5], Kimmo K. Kahilainen[6], Tommi Malinen[6], Sigurd Rognerud[1], Espen Lydersen[7], Per-Arne Amundsen[8], Nicholas Kashulin[9], Tatiana Kashulina[9], Petr Terentyev[9], Guttorm Christensen[10]

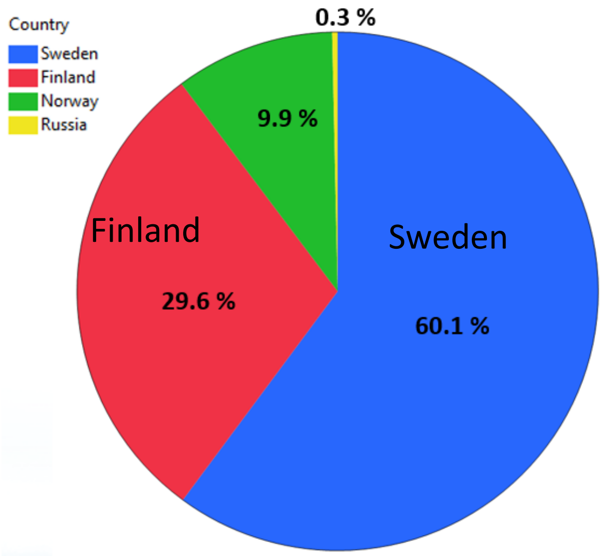
Is mercury in fish impacted by reduced air pollution?

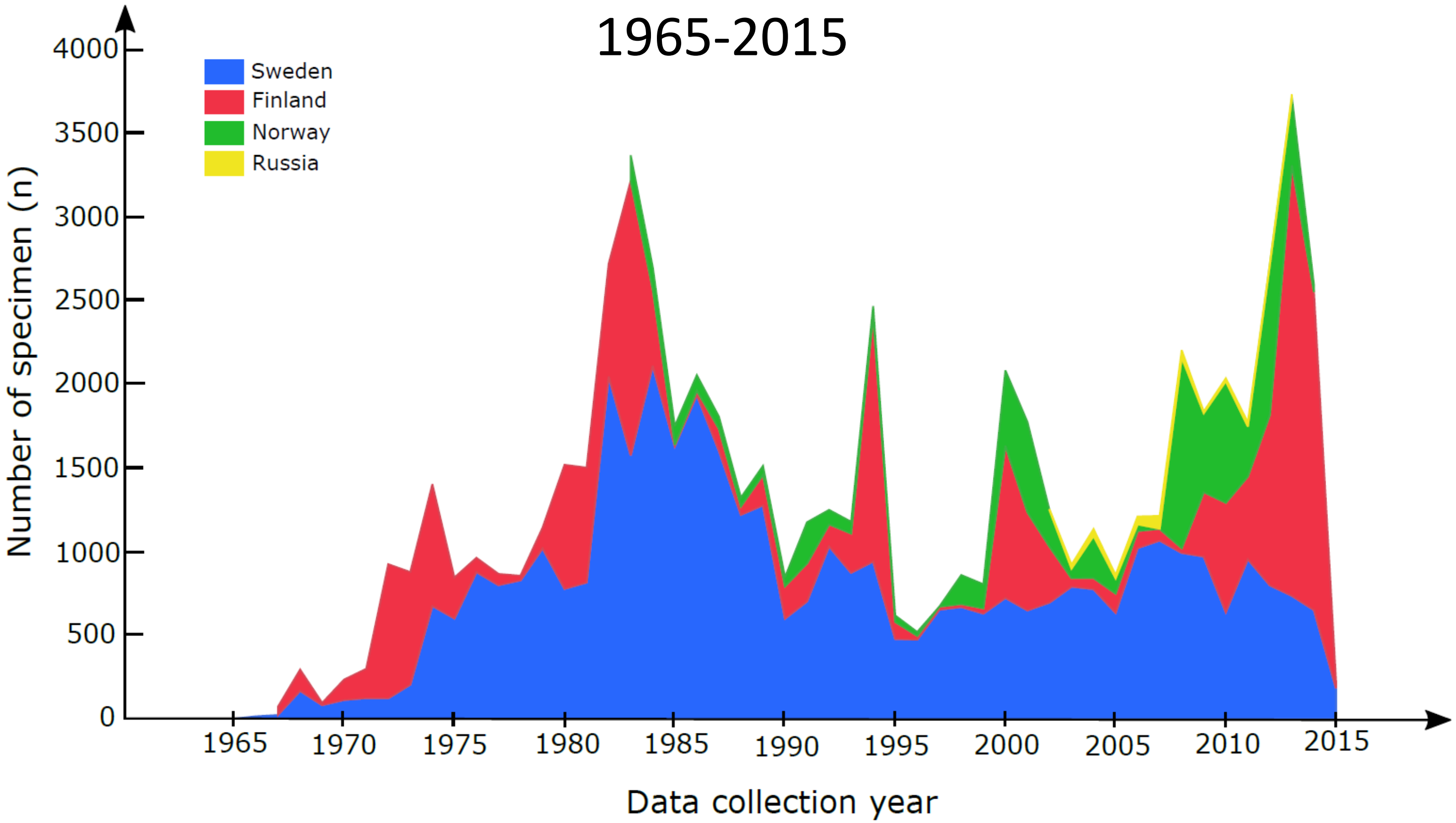
- Hg in fish in boreal lakes originates in many cases from transboundary air pollution
- Do emission reductions of Hg help to reduce Hg in fish?



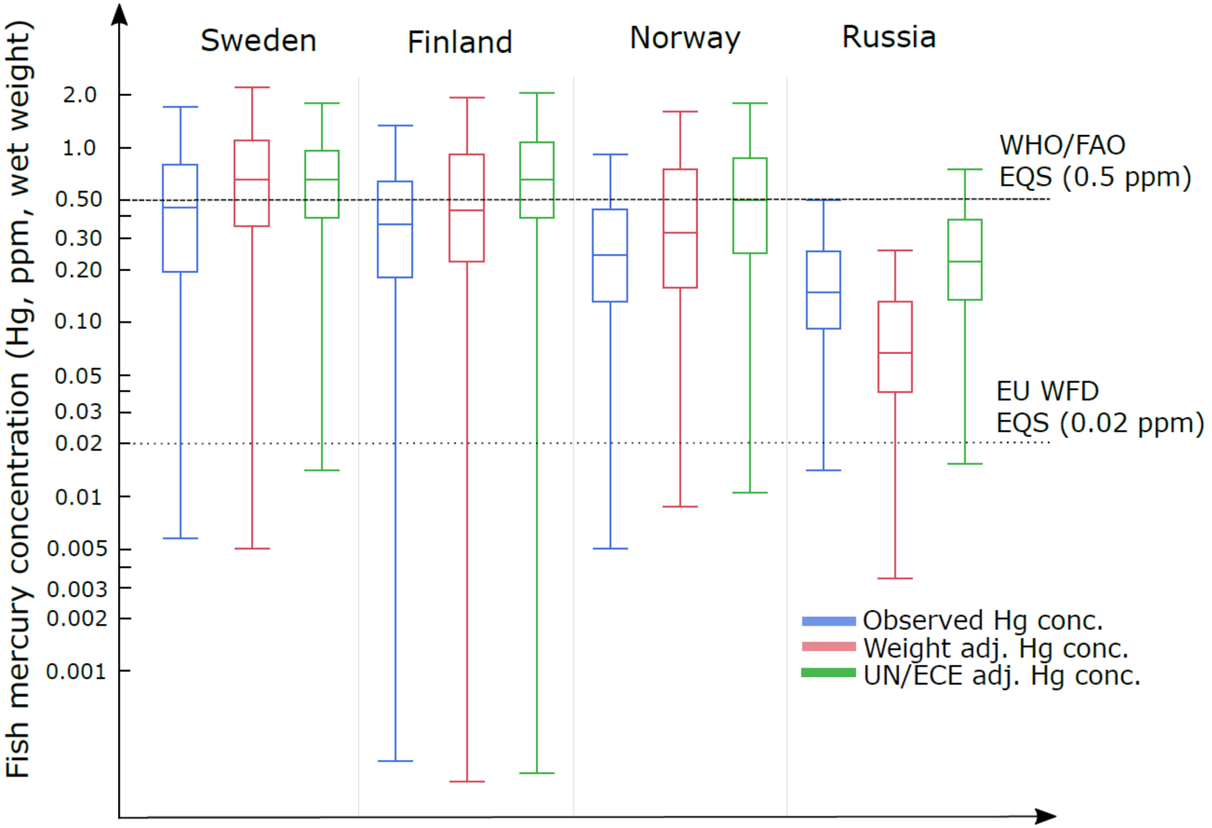
EMEP/CCC Report 1/2016

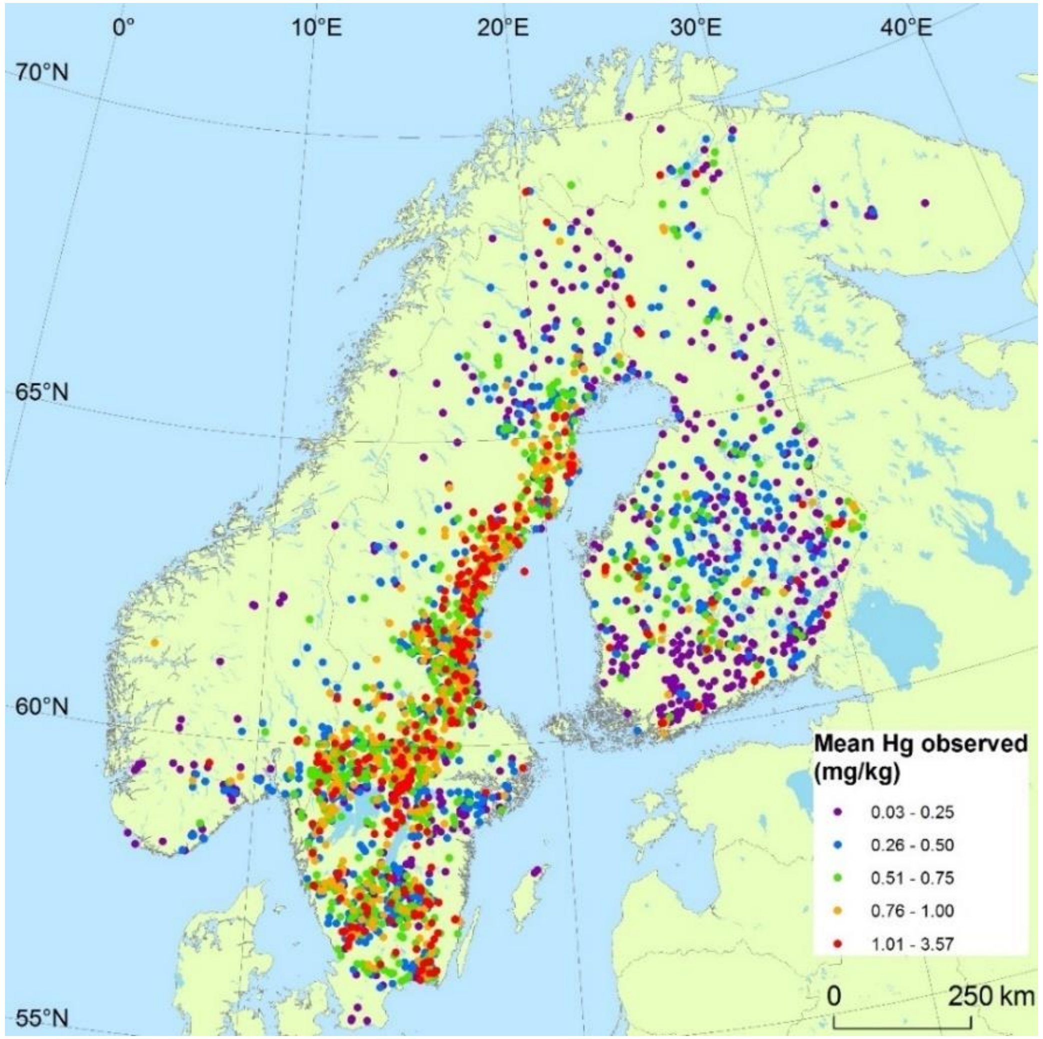
Collation of data from Sweden, Finland, Norway, and Russia





Mercury levels in fish exceed environmental quality factors

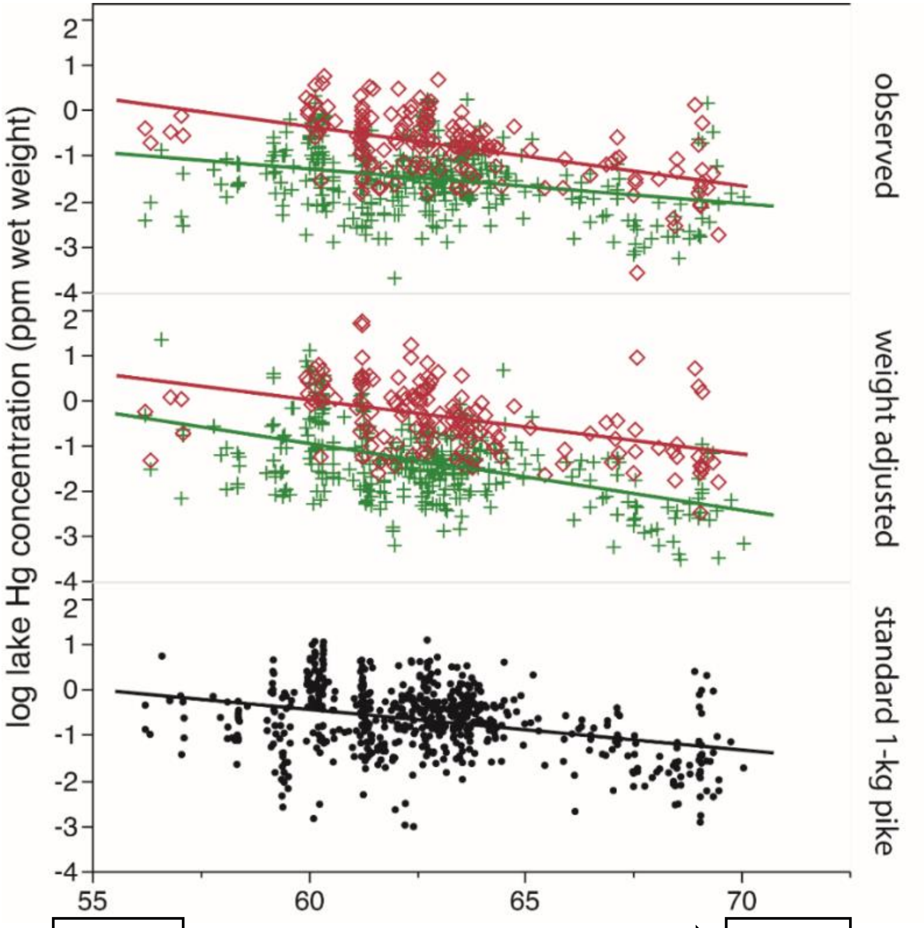




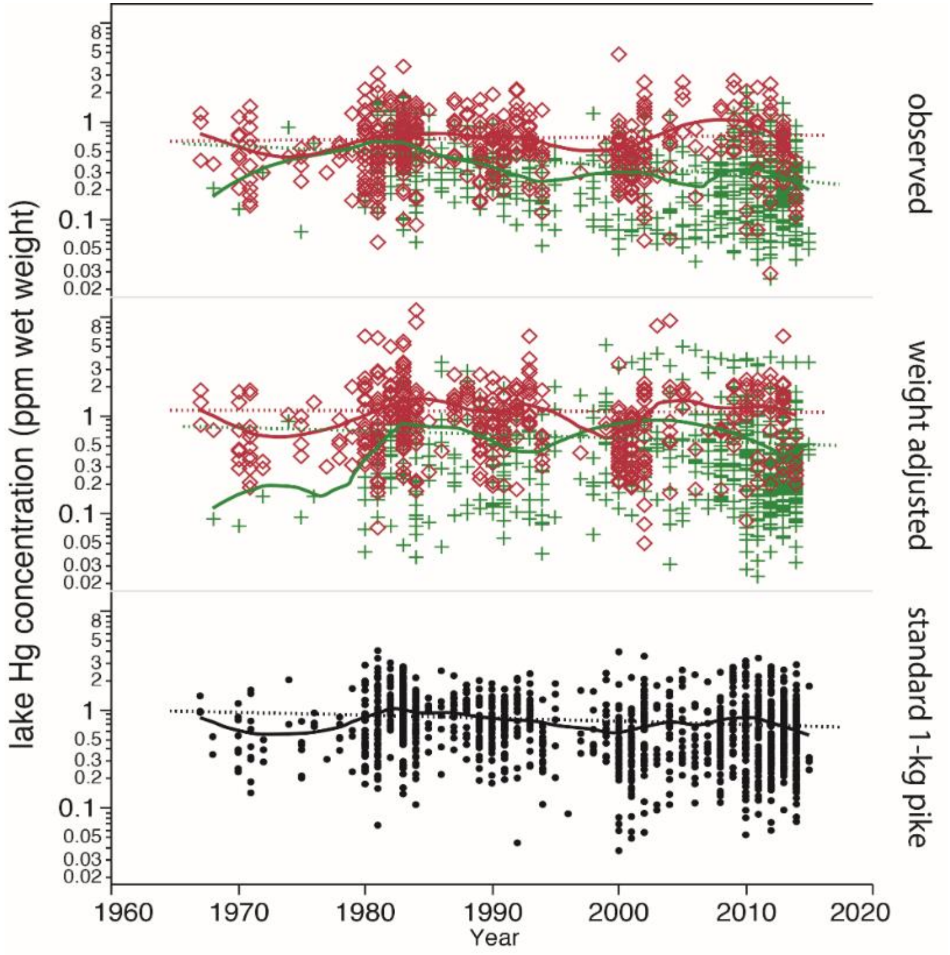
Red: perch
Green: pike
Black: standardized

Only lines mainly affected by atmospheric sources of Hg

Hg



south → north



year

Conclusions

- Goal to summarize available HM data from ICP IM sites across Europe for evaluations of temporal trends:
  - Invitation for participation and discussions (ICP forests!?) for preparation of publication

- Land-atmosphere exchange is not included in mass-balance calculations for Hg at ICP IM sites: A missing link to understand recovery of Hg?

- Data and evaluations on mercury from ICP IM relevant for effectiveness evaluation of the Minamata convention on mercury

Conclusions

- No evidence of declining levels of Hg in fish in lakes impacted by atmospheric Hg sources
  - In lakes that are impacted by local pollution sources, there is a decline
- Minamata Convention has entered into force
  - Database is useful baseline for monitoring of impacts of reducing Hg emissions to air
  - Data are also valuable for evaluating impacts of other (local) emission reductions
- We will continue to analyse the database for relations with environmental drivers