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Ecotoxicological risk assessment of Ostrobothnian river estuaries affected by acidity and metals leached from acid sulphate soils

Anna K. Karjalainen

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7th International Acid Sulfate Soil Conference

29th August, 2012

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Background I

UNEP 2012 Foresight:

21 Emerging Environmental Issues for the 21st Century

Main category	Issue title	Ranking *
Climate change issues	New Challenges for Climate Change Mitigation and Adaptation: Managing the Unintended Consequences	7
Freshwater and marine issues	New Insights on Water-Land Interactions: Shift in the Management Paradigm?	6
Cross-cutting issues	Broken Bridges: Reconnecting Science and Policy	4

* Ranking from 1-21 based on scoring by the UNEP Foresight Panel and after considering the polling results of more than 400 scientists worldwide

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Background II

CATERMASS -project ‘s goal:

“to specify and mitigate environmental risks of ASSs under changing climate”

- Finland has the largest acid sulphate soil (ASS) area in Europe
- Draining of AASs:

  → oxidation of sulphide layers

  → formation of sulphuric acid and leaching of metals
- Acid runoff and high concentration of dissolved metals:

  → deterioration of ecological status of water bodies along the Western cost of Finland
- Knowledge on ASSs impacts in estuaries (vs. rivers) is scarce

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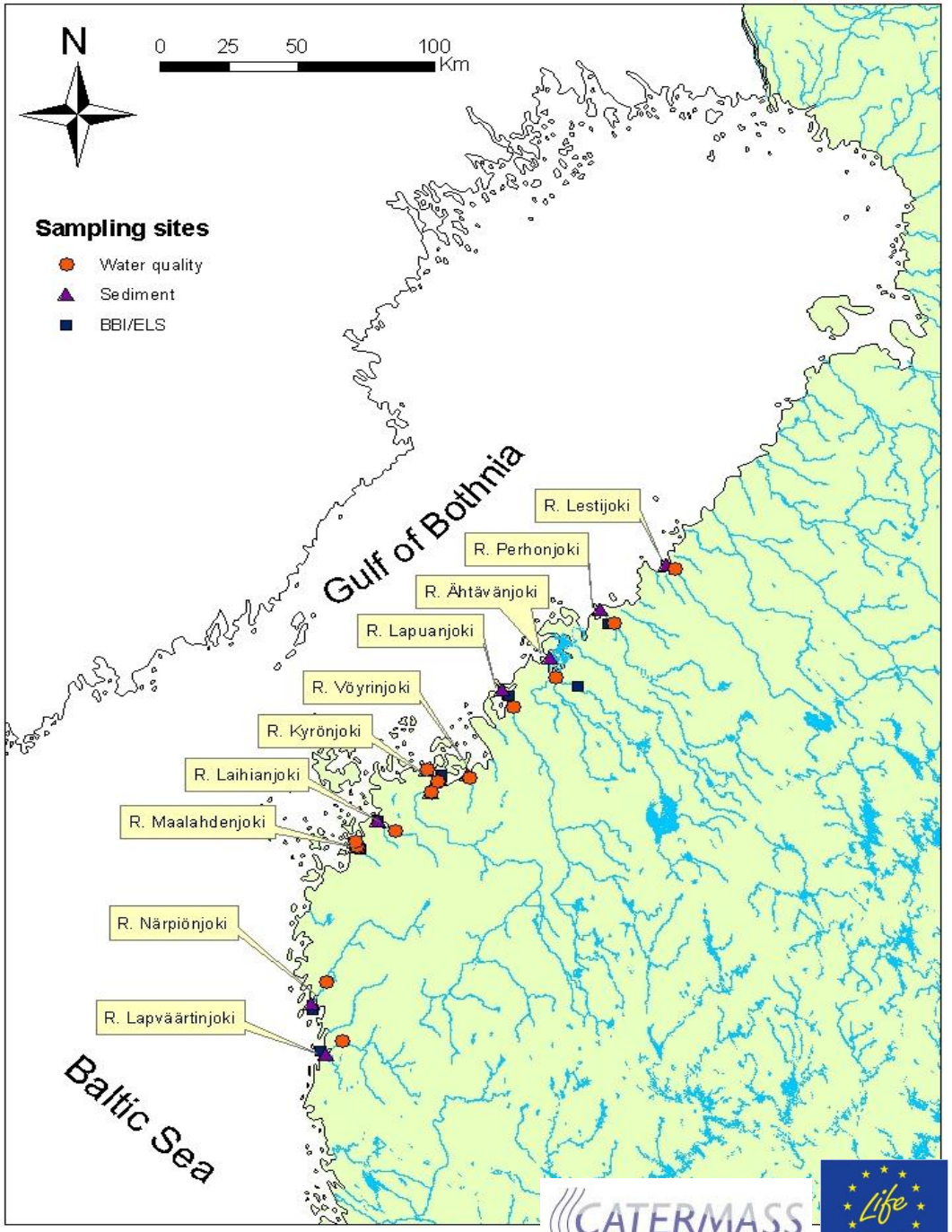
Ostrobothnian river estuaries

River estuary	Sediment sample spots, n
R. Lestijoki	1
R. Perhonjoki	1
R. Ähtävänjoki	1
R. Lapuanjoki	1
R. Vöyrinjoki	1
R. Kyrönjoki	3
R. Laihianjoki	1
R. Maalahdenjoki	3
R. Närpiönjoki	1
R. Lapväärtinjoki	1



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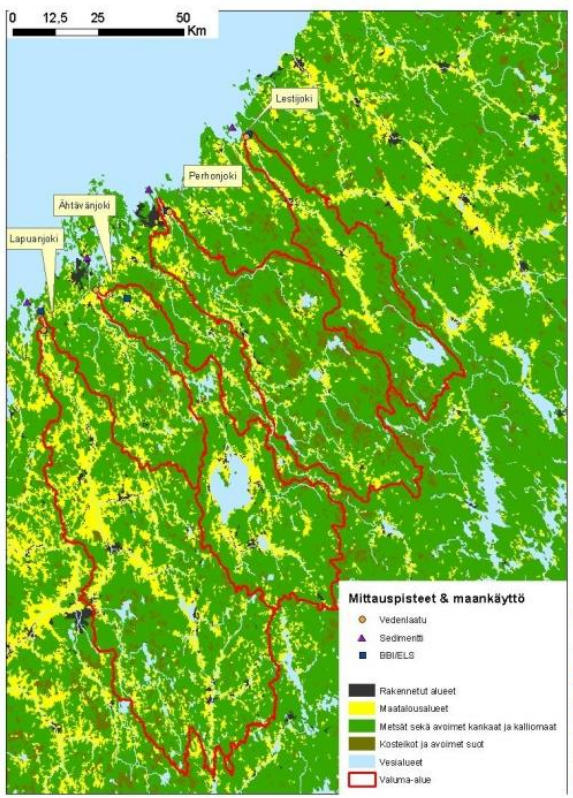
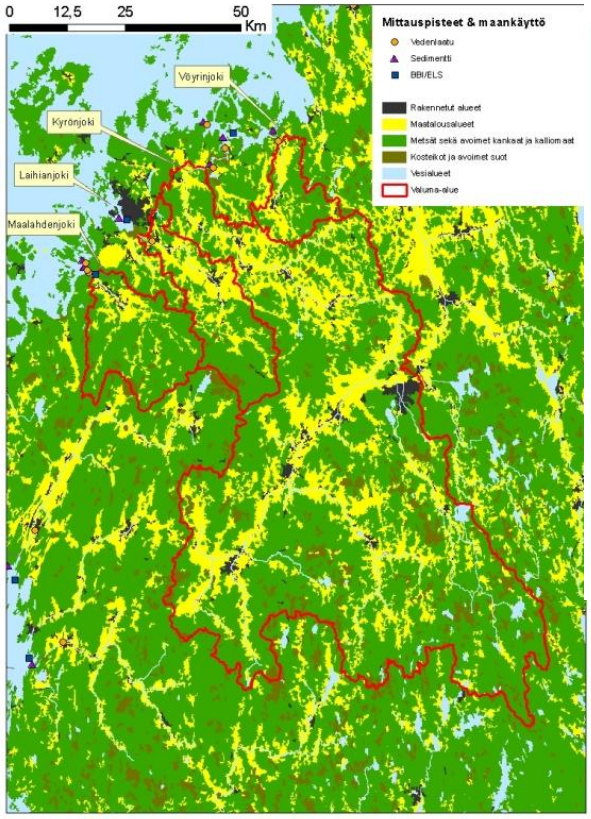
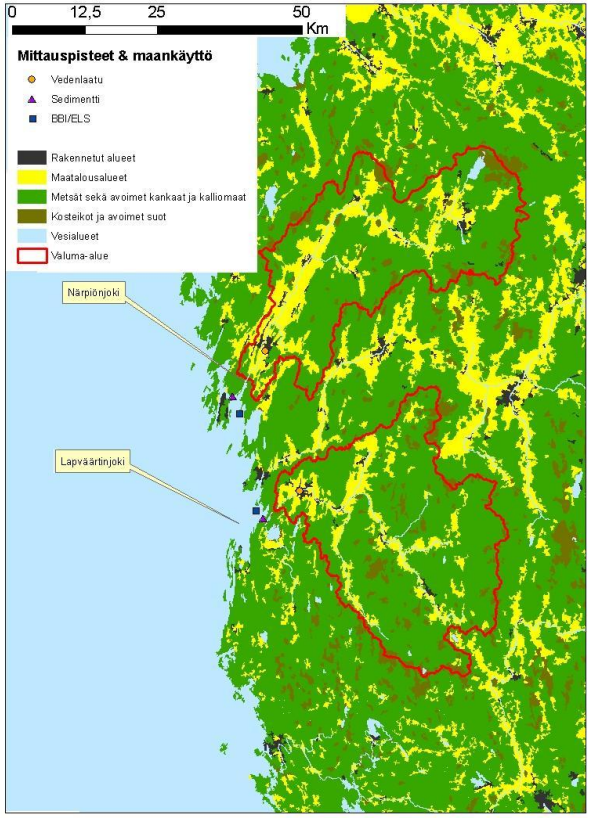
Cathment areas & landuse activities



	Urban areas
	Agricultural areas
	Forests and forestry
	Wetlands, open bogs
	Waters
	Catchments





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Material & Methods I

Ostrobothnian rivers estuary sediments

- Surface sediment samples (0–3 cm, summer & autumn) in 2010 from the 14 locations
- Sediment metal concentrations: ICP-MS
- Comparison to environmental quality standards EQs for Cd, Ni, Zn, As, Cr, Cu, Co
- Acute and chronic toxicity tests in the ASS-affected estuary sediments :
  - Kinetic luminescent bacteria test: ISO 21338
  - Chironomid toxicity test: OECD 218
    - Emergency time and total emergency
    - Head capsule mentum deformity incidence

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Material & Methods II

USEPA Ecotox Database → HQ derivation for river waters

- Surface water pH, TOC concentration, conductivity and metal concentrations were derived from SYKE database → comparison to EQs (VN 868/2010) for Cd, Ni, Pb
- Relevant EC_{50}-values (water exposures) for Al, Zn, Cd by expert judgement, selection criteria:
  - pH: < 5,9
  - $CaCo_3$ mg/L: ≤ 50,5 (≤ 0,5 mmol/l)

  Left after expert judgement:
  - Temperature: 8 – 25°C
  - DOC mg/L: N/A – 6,7
  - Species: Mayflies, Caddisflies, Chironomids, fish i.a. Rainbow trout and *Hyalella azteca*, *Ceriodaphnia dubia* & *Pseudokircheneriella subcapitata*
- The 5th percentile derived from the approved EC_{50} –values: $P5_{EC_{50}}$
- Hazard Quotient in estuary waters calculated:

$$HQ = \frac{EC_{\max}}{P5_{EC_{50}} + C_b}$$

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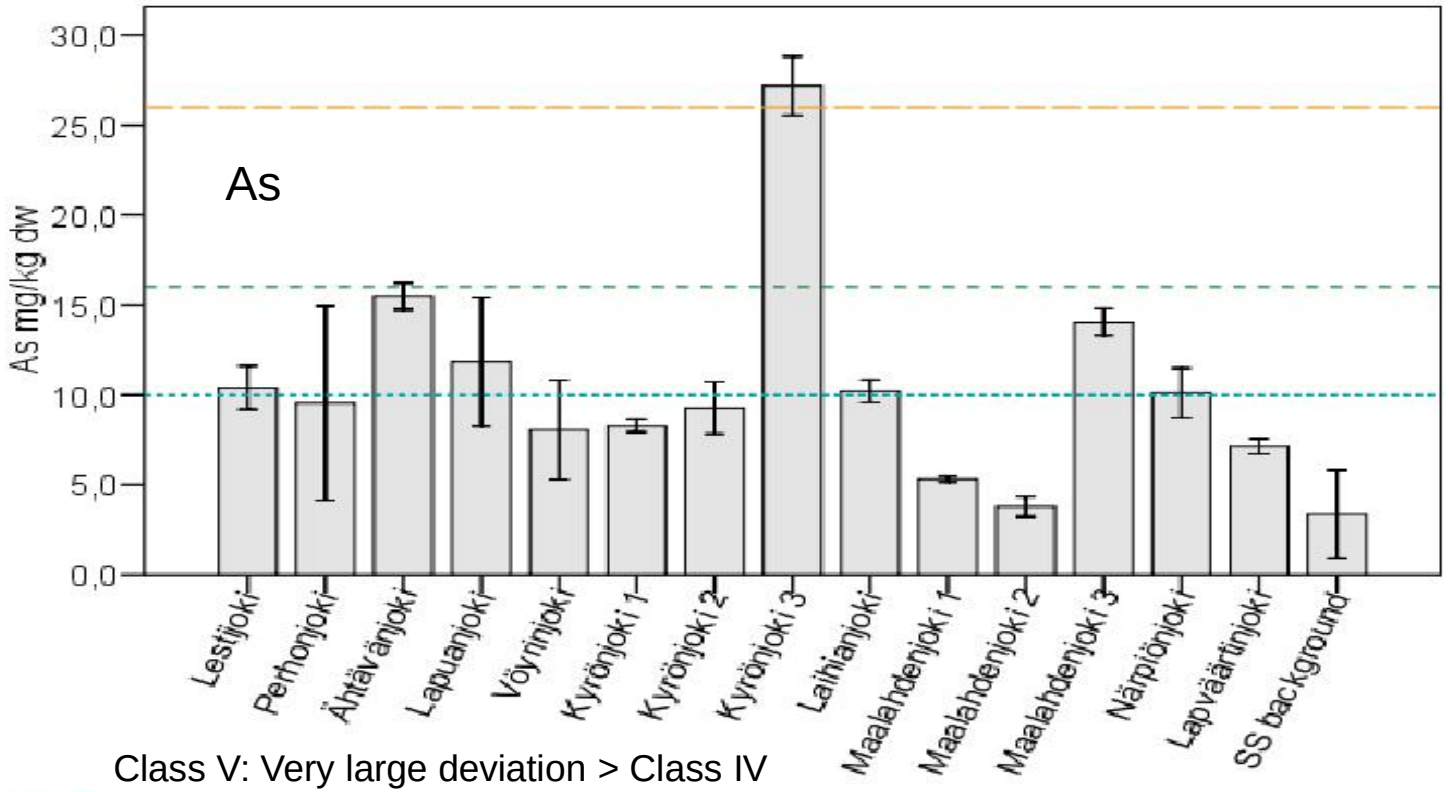
Results

Metal concentrations (mg/kg dw) in the ASS-affected estuary sediments



Class V: Very large deviation > Class IV
Class IV: Large deviation
Class III: Clear deviation
Class II: Small deviation
Class I: No/very small deviation

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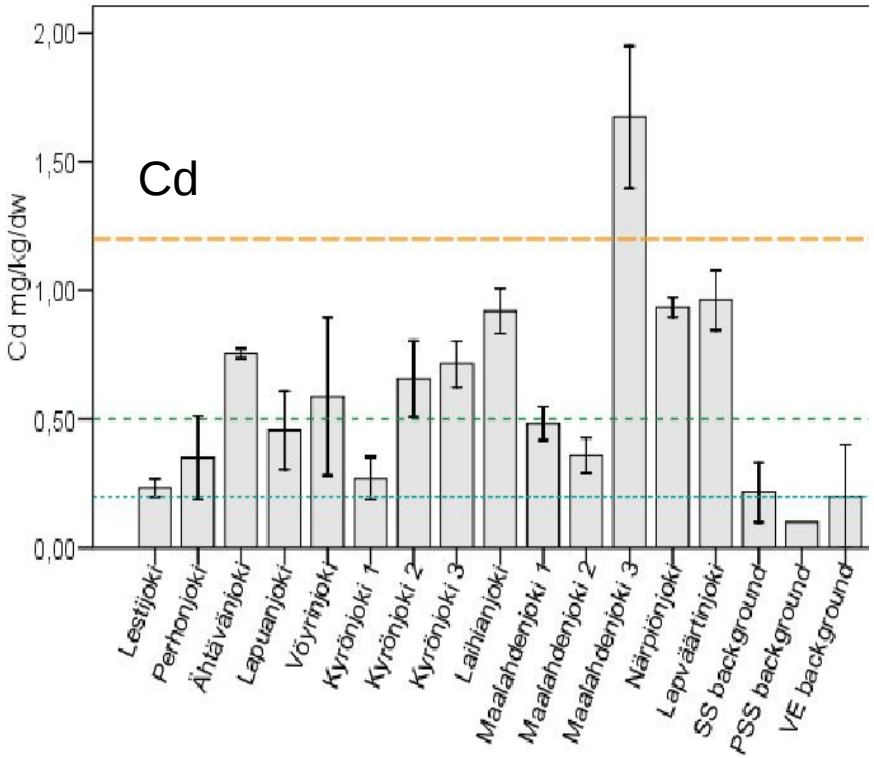

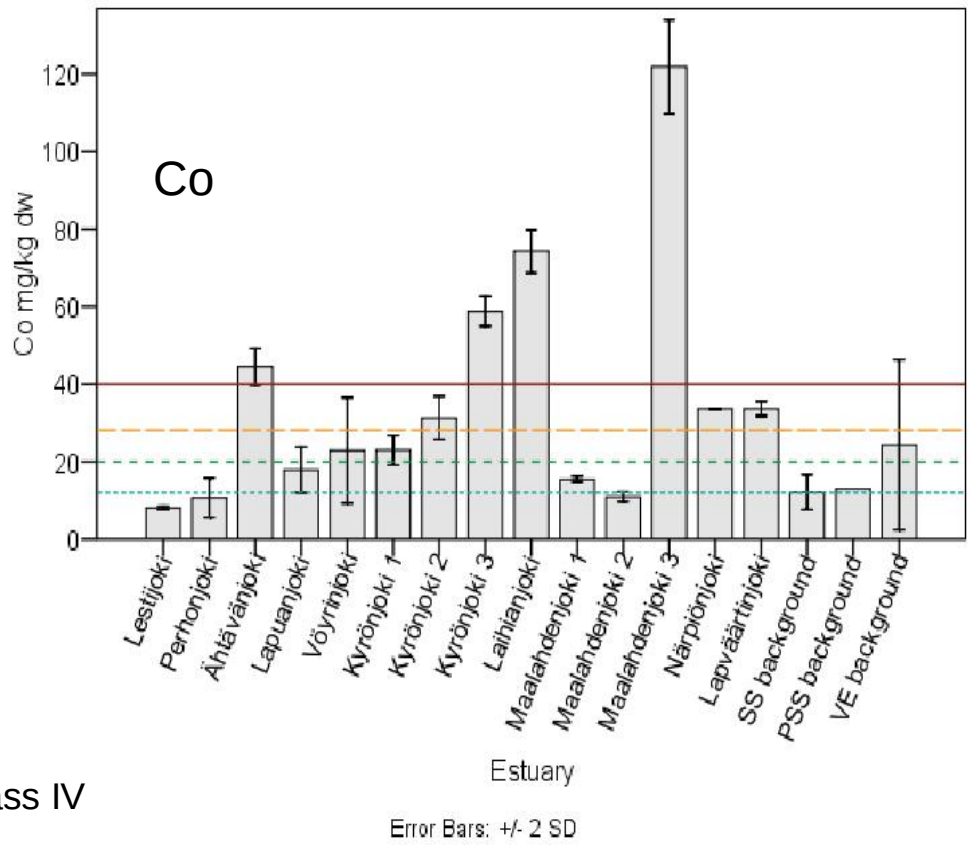

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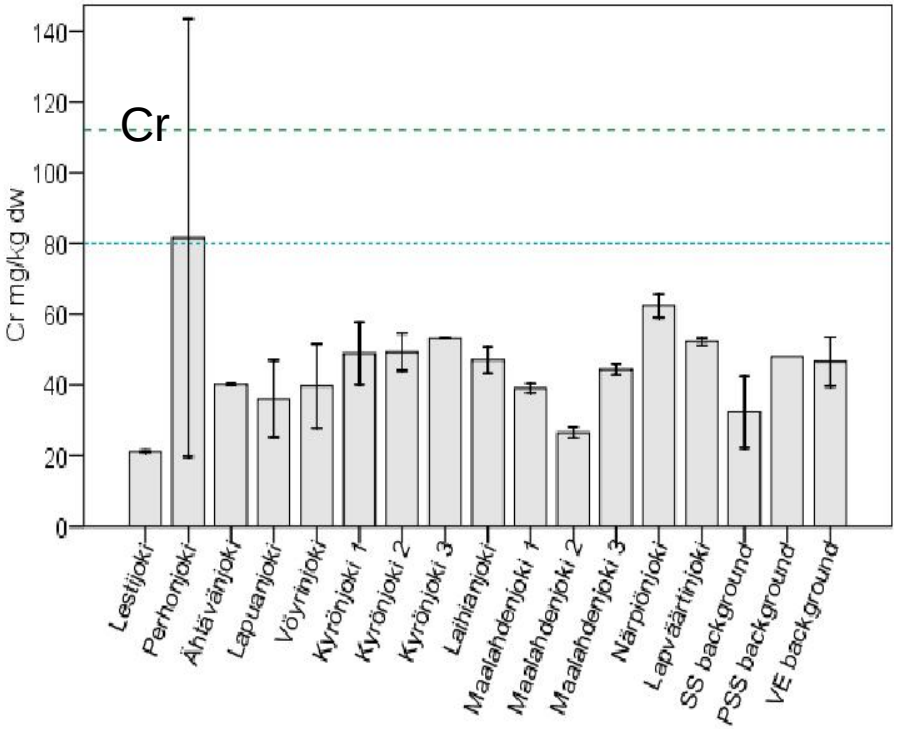

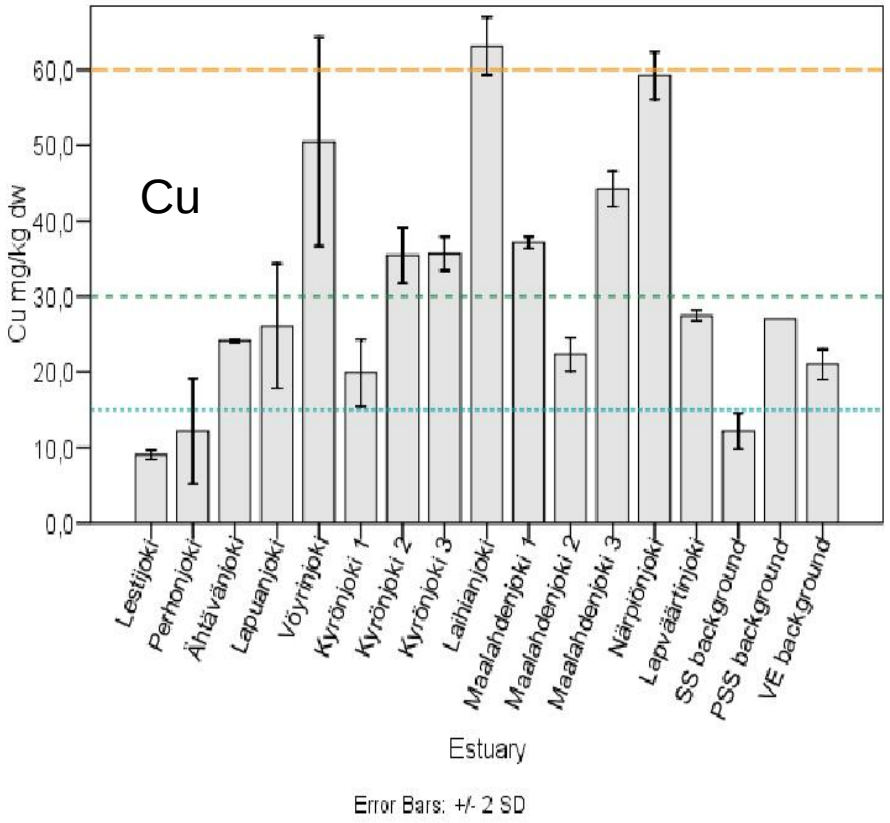

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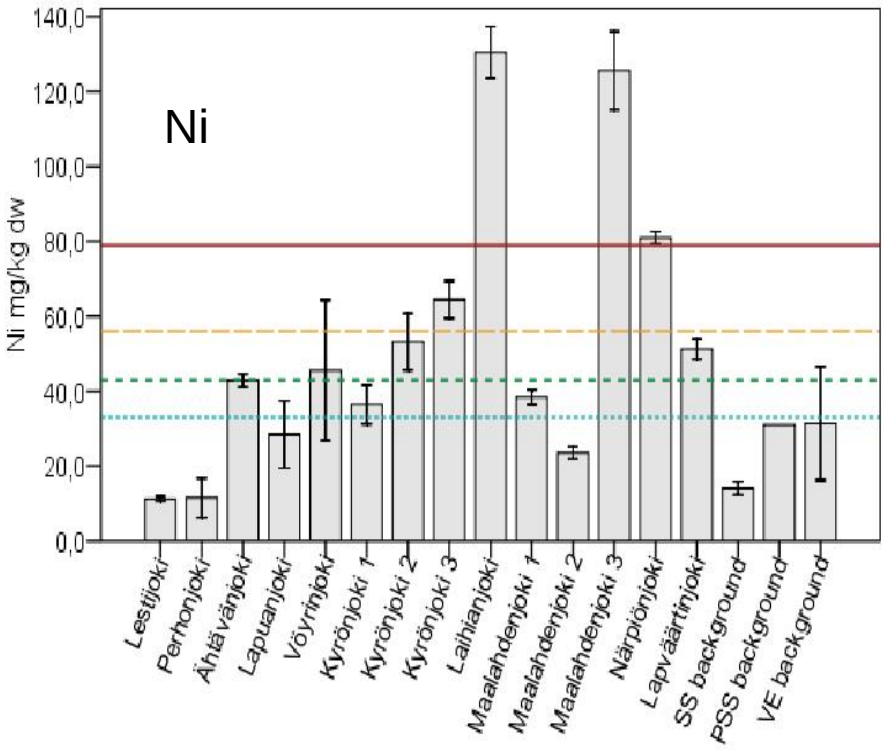

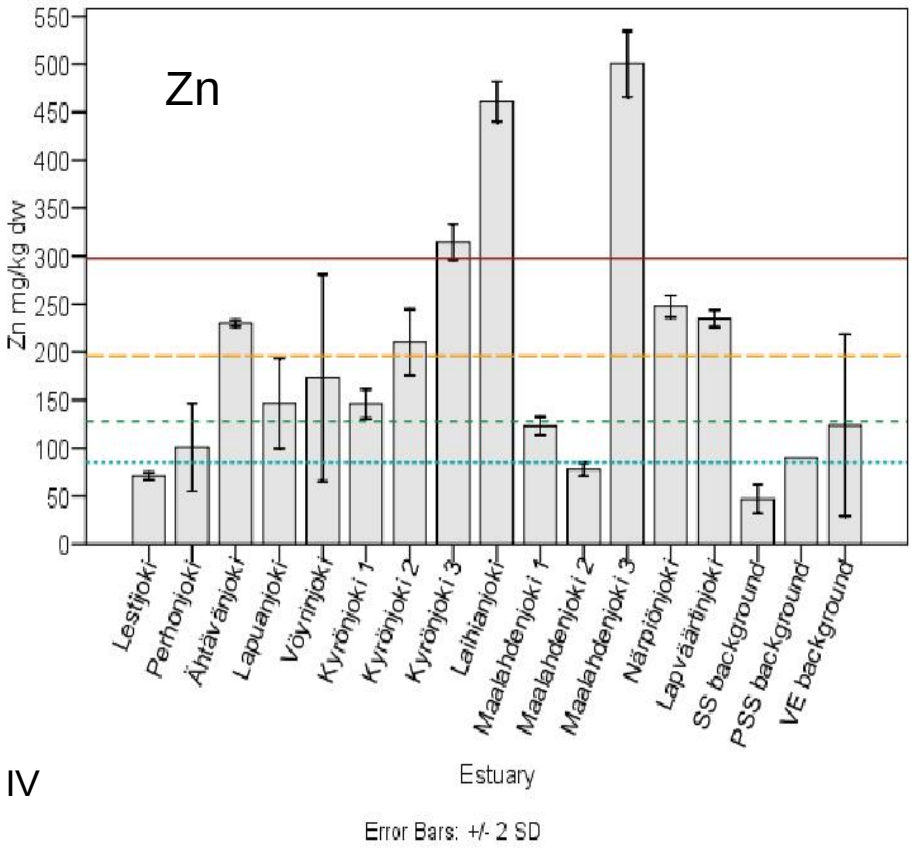

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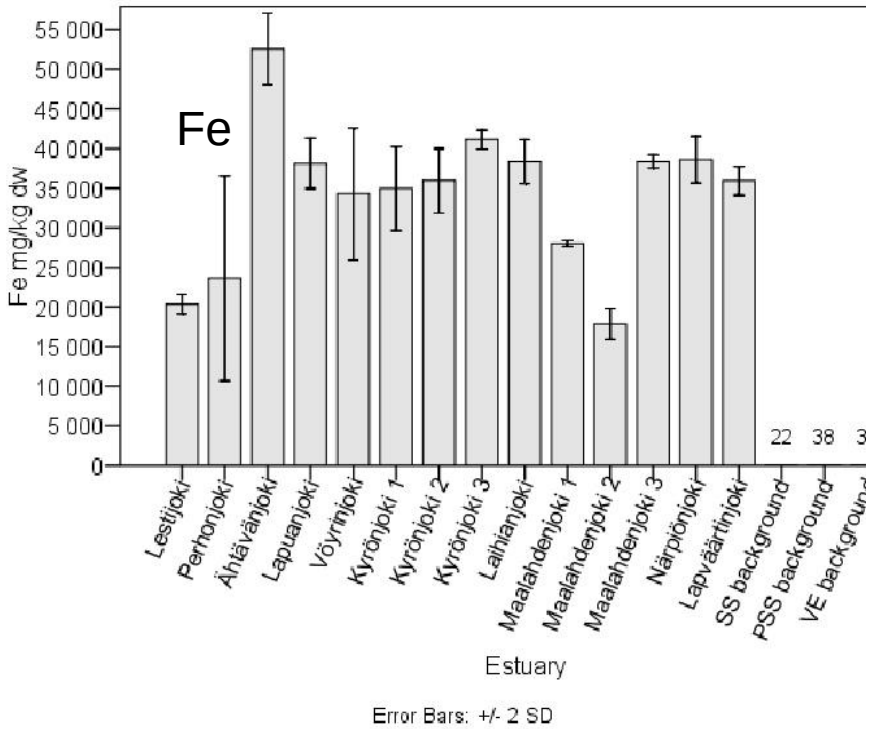

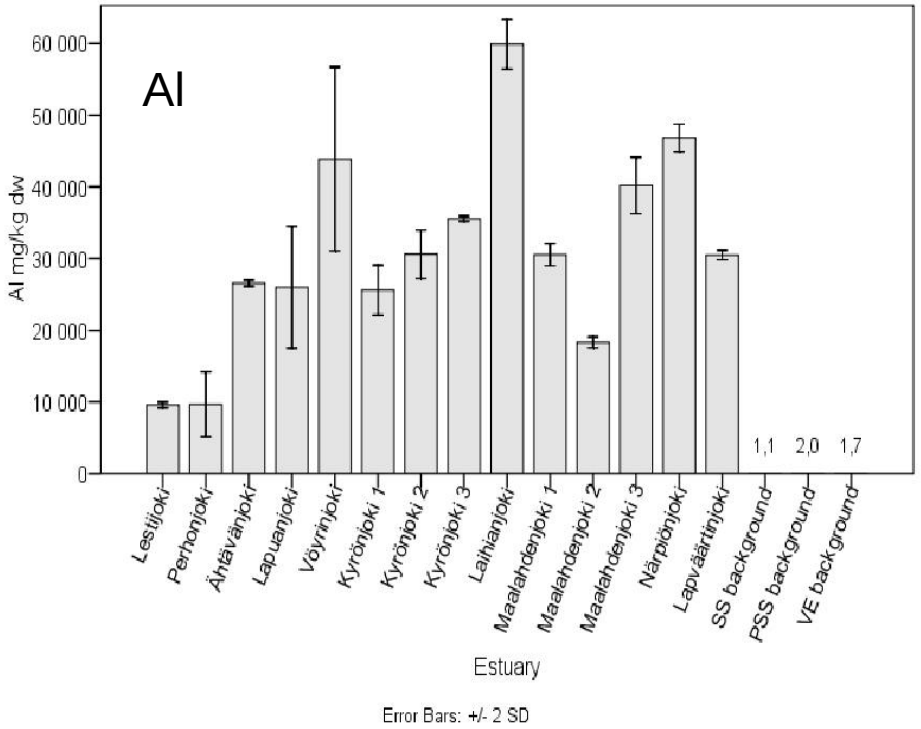

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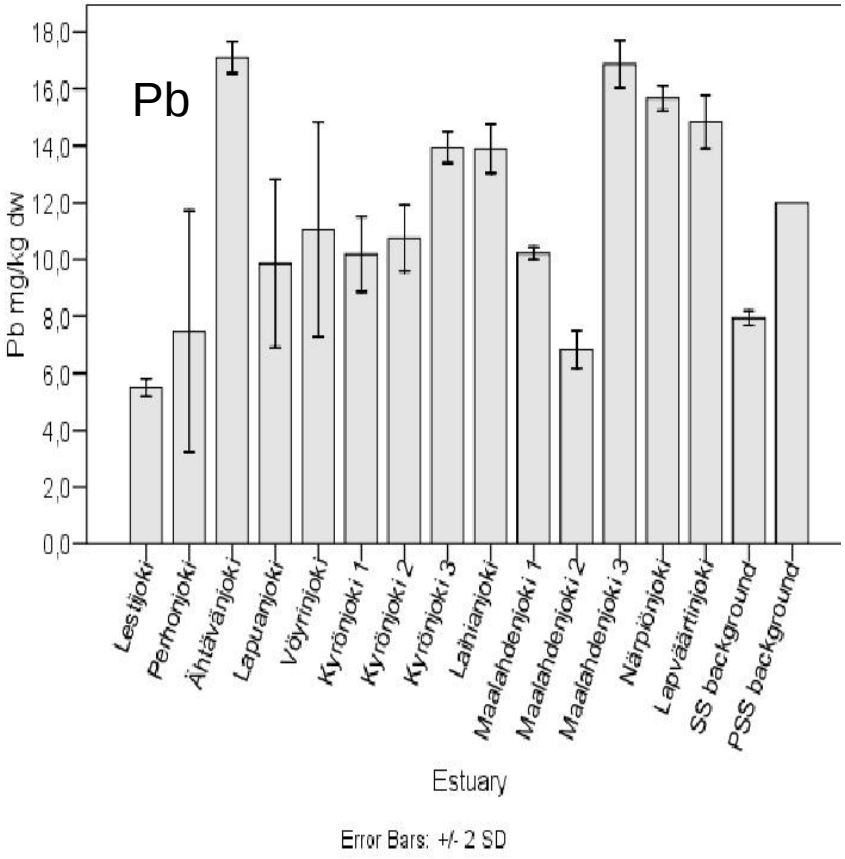

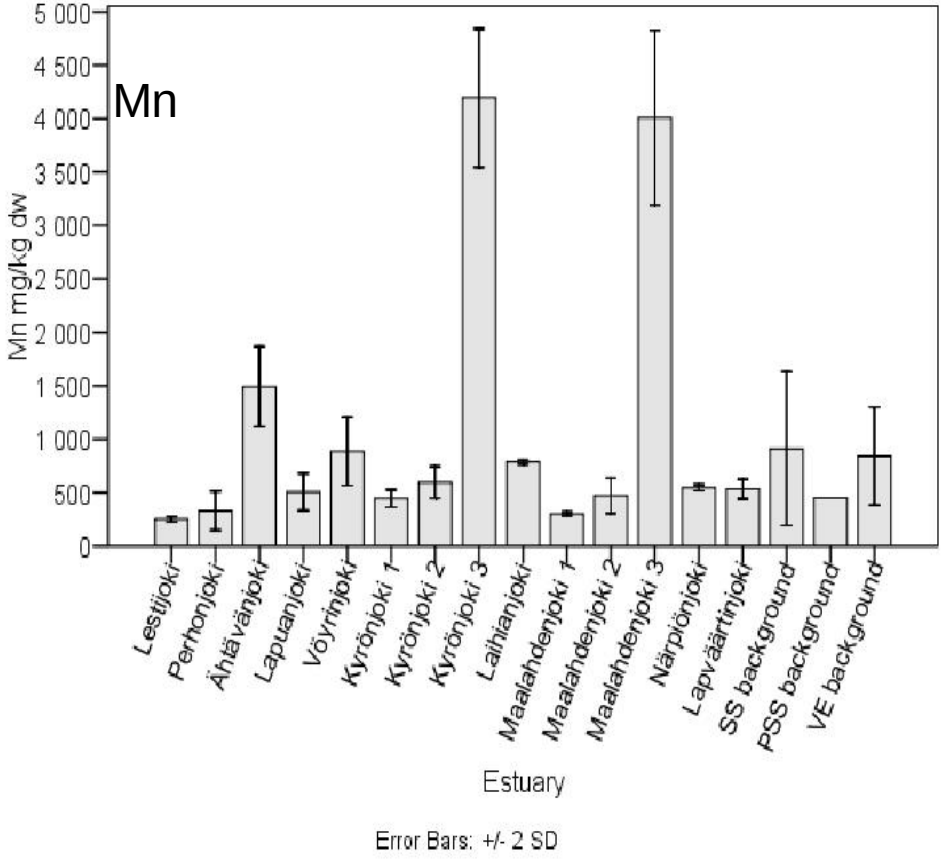

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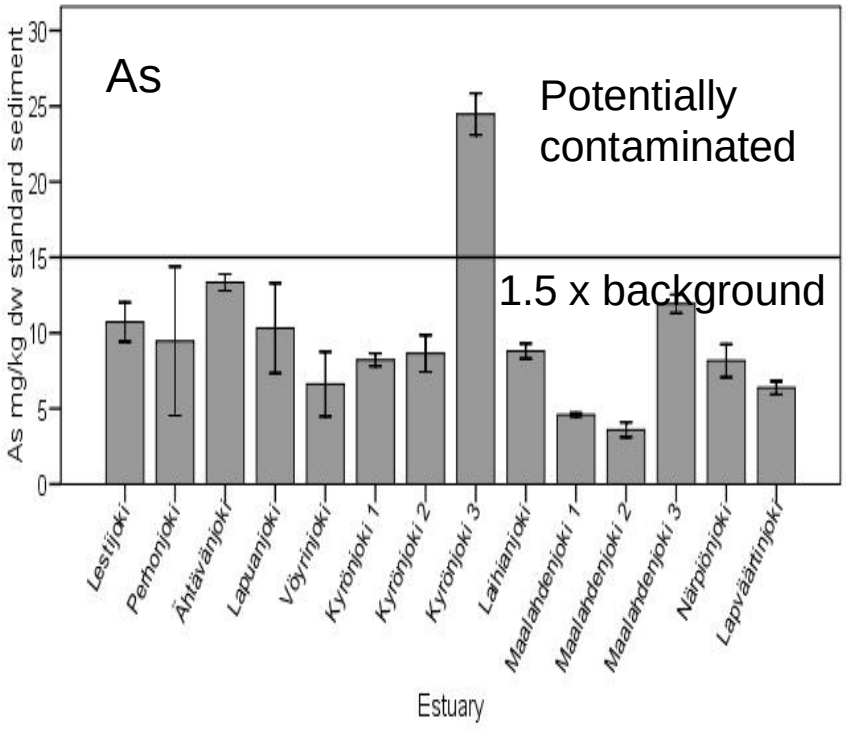
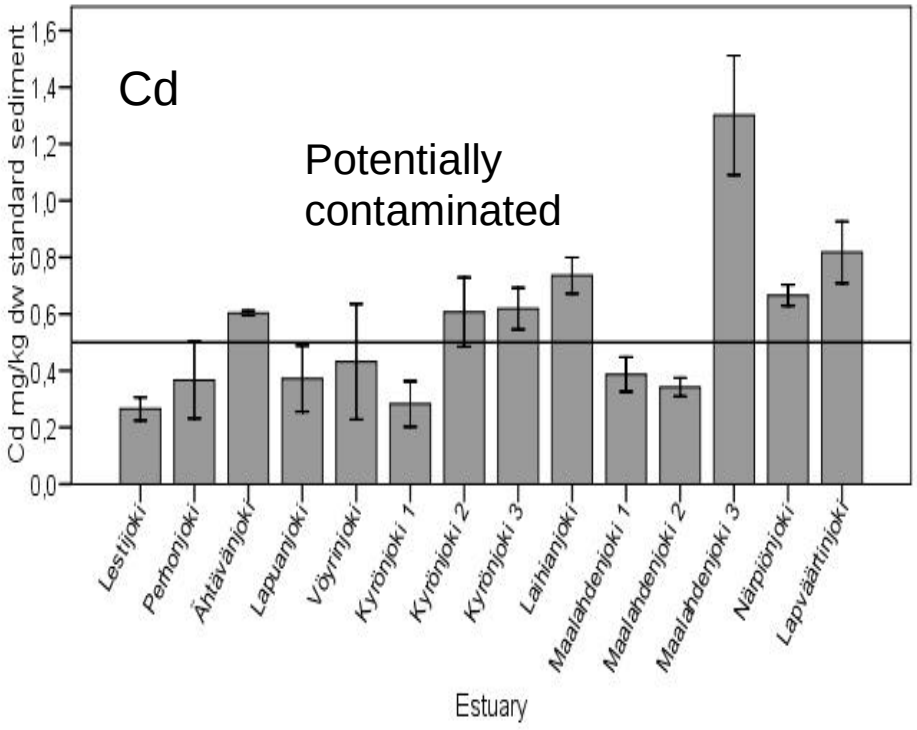
Results

SOM-normalized metal concentrations (mg/kg dw standard sediment) in the ASS-affected estuary sediments





Standard sediment: 10% SOM and 25% clay on a dw basis

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Results

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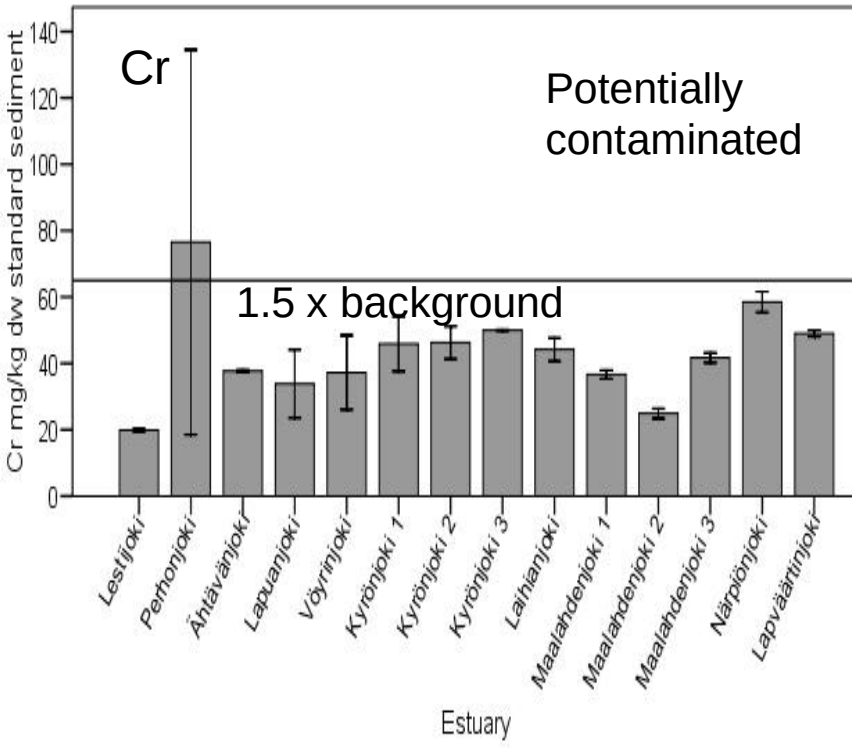

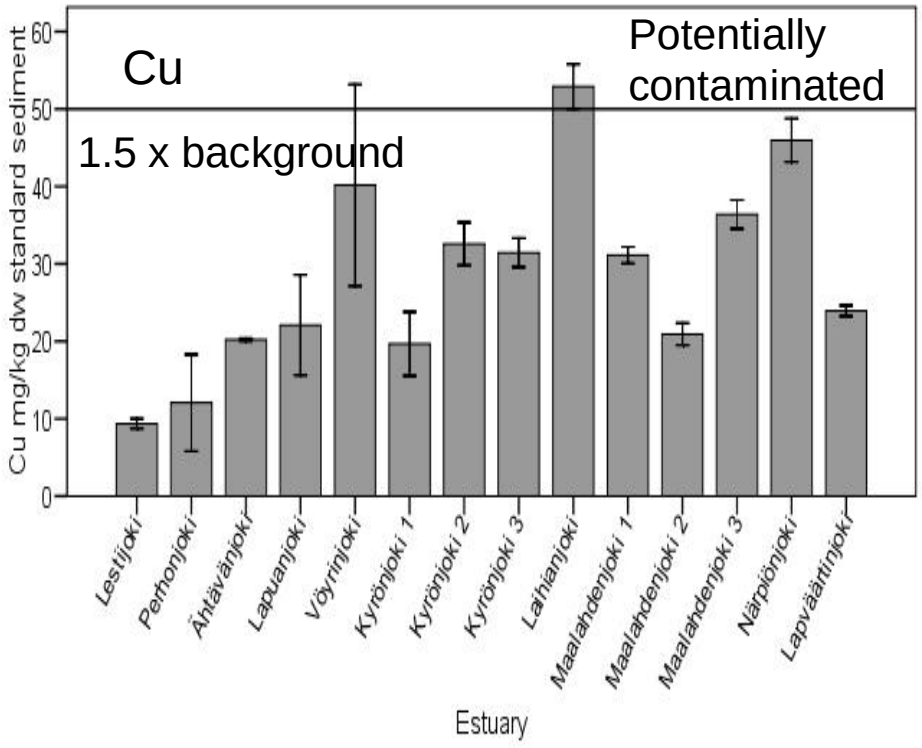

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Results

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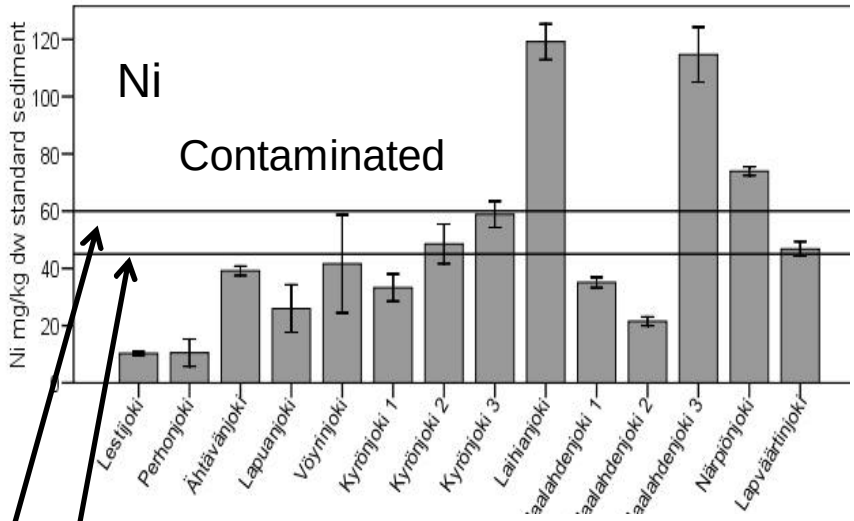
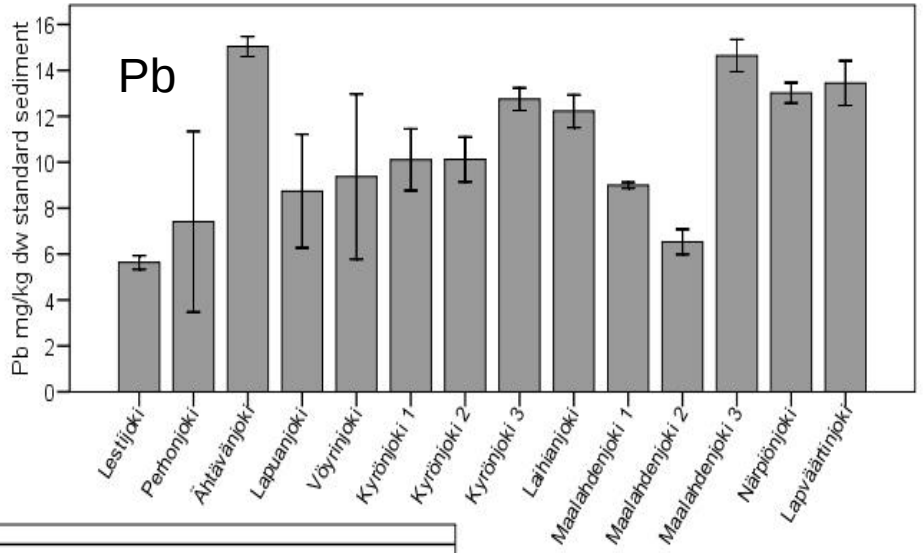
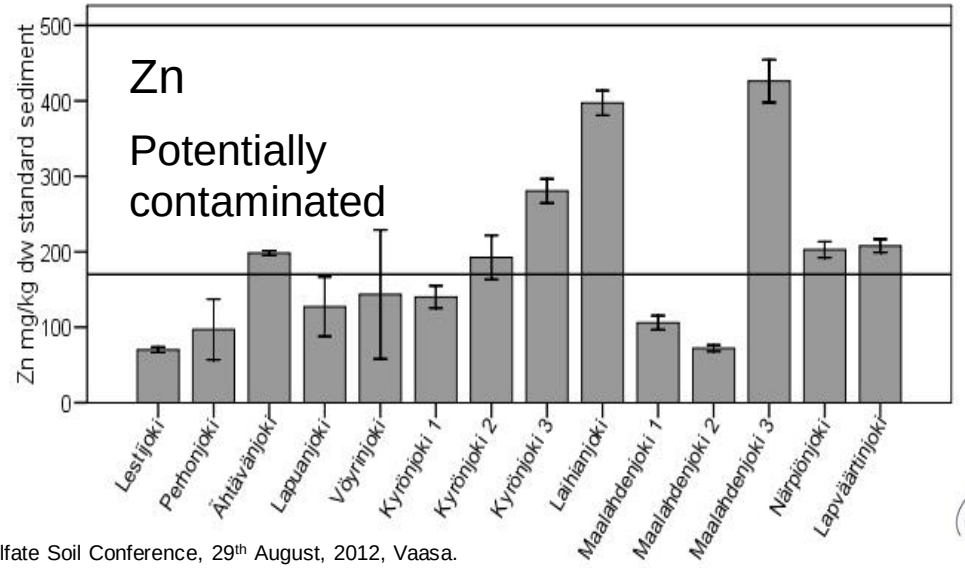




1.5 x bakground

Potentially contaminated



1.5 x background

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Kinetic luminescent bacteria (*Vibrio fischeri*) test: ISO 21338

Metal concentration mg/kg dw

	EC_{50}	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
EC_{50}	1	-0.26	-0.17	-0.26	-0.38*	-0.28	-0.25	-0.48**	-0.31	-0.27	-0.46**	-0.32*
Al		1	0.21	0.77**	0.75**	0.40**	0.96**	0.58**	0.66**	0.91**	0.66**	0.79**
As			1	0.36*	0.56**	0.22	0.13	0.76**	0.62**	0.37*	0.51**	0.55**
Cd				1	0.87**	0.42**	0.75**	0.66**	0.71**	0.89**	0.88**	0.90**
Co					1	0.46**	0.66**	0.82**	0.85**	0.92**	0.89**	0.98**
Cr						1	0.28	0.38*	0.27	0.48**	0.44**	0.54**
Cu							1	0.48**	0.56**	0.85**	0.61**	0.71**
Fe								1	0.81**	0.68**	0.83**	0.80**
Mg									1	0.75**	0.75**	0.81**
Ni										1	0.80**	0.94**
Pb											1	0.87**
Zn												1

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Range for estuary sediments: 30 min EC_{50}: 0.03-9.4% (95%CL: 0.02-16.4)[1]

Ref tox Zn → normal sensitivity: 30 min EC_{50}: 2.8-8.0 mg/L (95%CL:2.5-10.2)

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Results

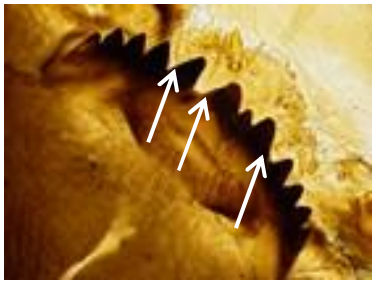
C. riparius head capsule mentum deformity incidence, DI

Estuary	DI, mechanical damages	DI, real deformities	DI, mechanical +deformities
Controls	0.32 (±0.12)	0.11 (±0.14)	0.35 (±0.10)
R. Kyrönjoki Pudimofjärden	0.27 (±0.11)	0±0	0.27 (±0.11)
R. Kyrönjoki Vassor M1	0.18 (±0.22)	0±0	0.18 (±0.22)
R. Kyrönjoki Tottesund	0.44 (±0.14)	0.04 (±0.06)	0.48 (±0.11)
R. Maalahdenjoki Stenskärlinjen 3	0.32 (±0.13)	0.13 (±0.14)	0.35 (±0.10)
R. Maalahdenjoki Svartö hålet	0.24 (±0.13)	0±0	0.24 (±0.13)
R. Maalahdenjoki Åminne	0.37 (±0.14)	0.06 (±0.07)	0.43 (±0.13)
R. Lapväärtinjoki	0.26 (±0.12)	0.04 (±0.06)	0.30 (±0.12)

Nonparametric Kruskall-Wallis Test

	DI, mechanical damages	DI%, Real deformities	DI%, mechanical +deformities
Chi-Square	6.263	7.267	8.926
df	7	7	7
Asymp. Sig.	0.509	0.402	0.258

Normal mentum



Abnormal mentum:
3 teeth lacking
(1 middle, 2 inner lateral)

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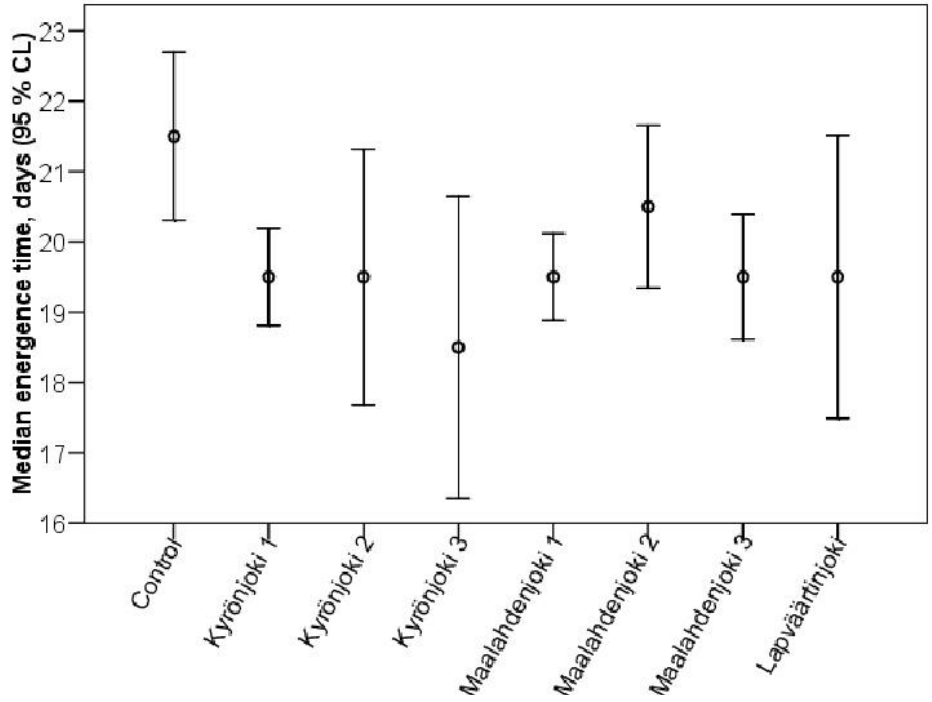
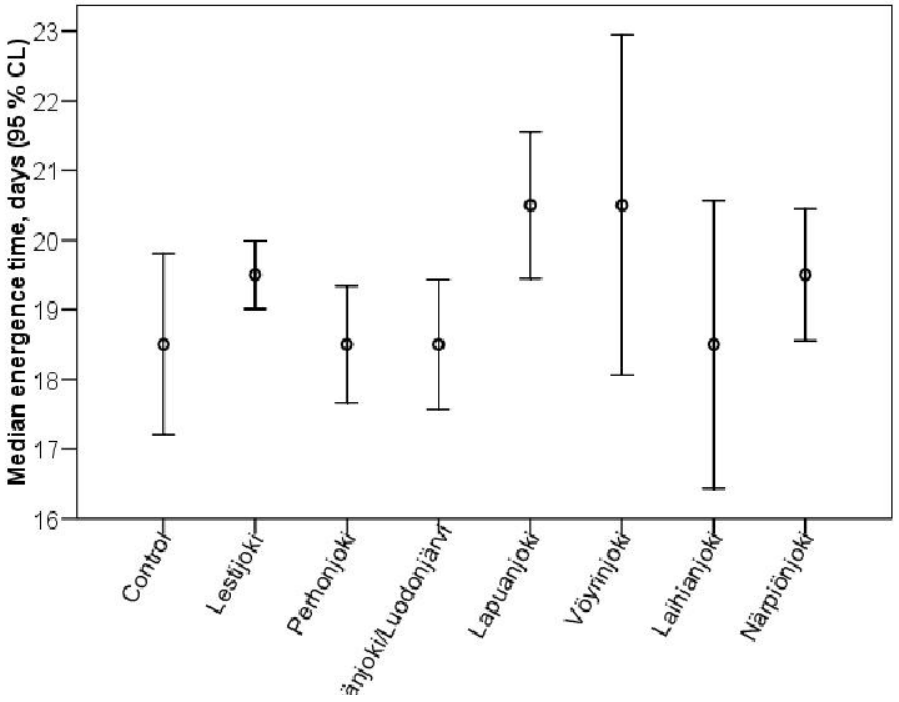
Results

C. riparius emergency time comparisons in the control and the ASS-affected estuary sediments





Kaplan-Meier survival analysis: Overall nonparametric Log rank (Mantel-Cox) comparisons

	Chi-Square	df	Sig.
Part 1	16.335	7	0.022
Part 2	12.376	7	0.089

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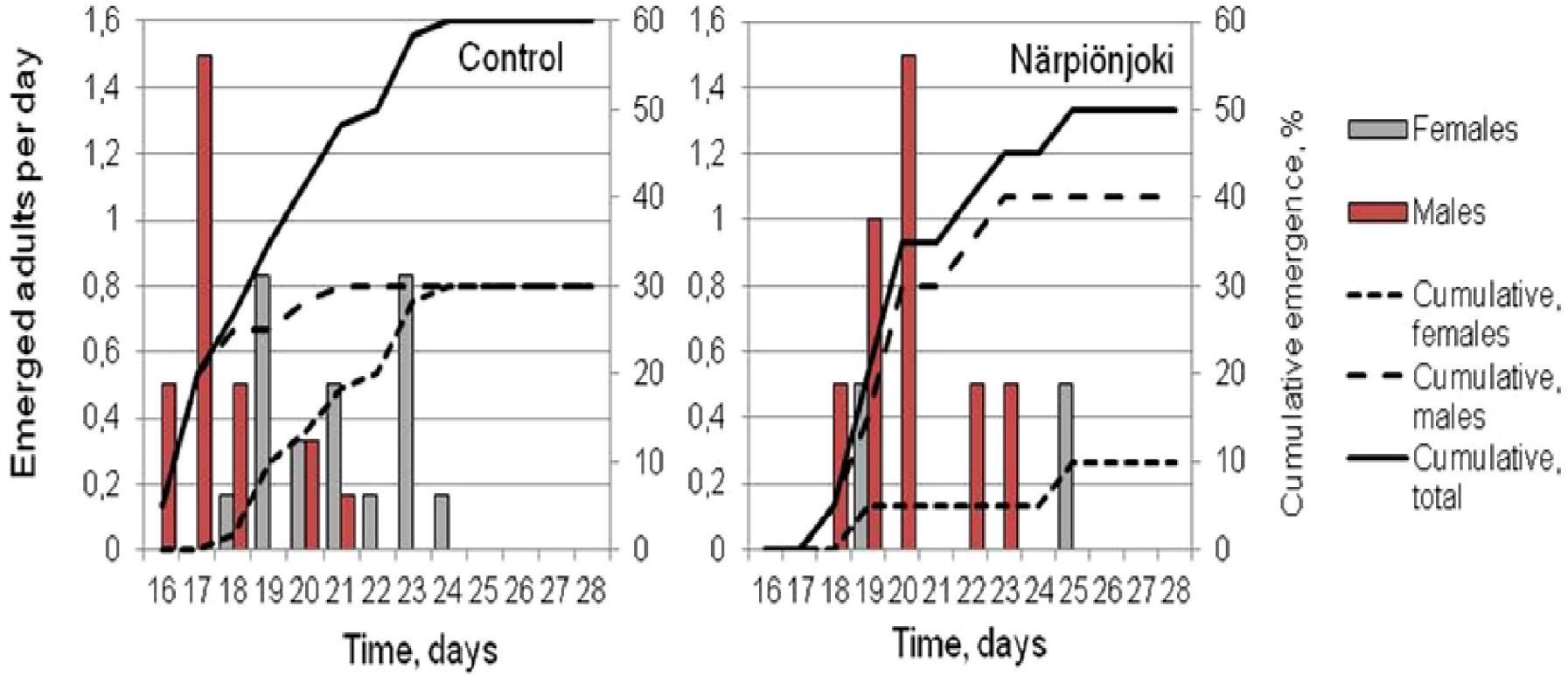
Cumulative (%) and mean daily (individuals/d) emergency of *C. riparius* in the control sediment and the ASS-affected R. Närpiönjoki estuary sediment



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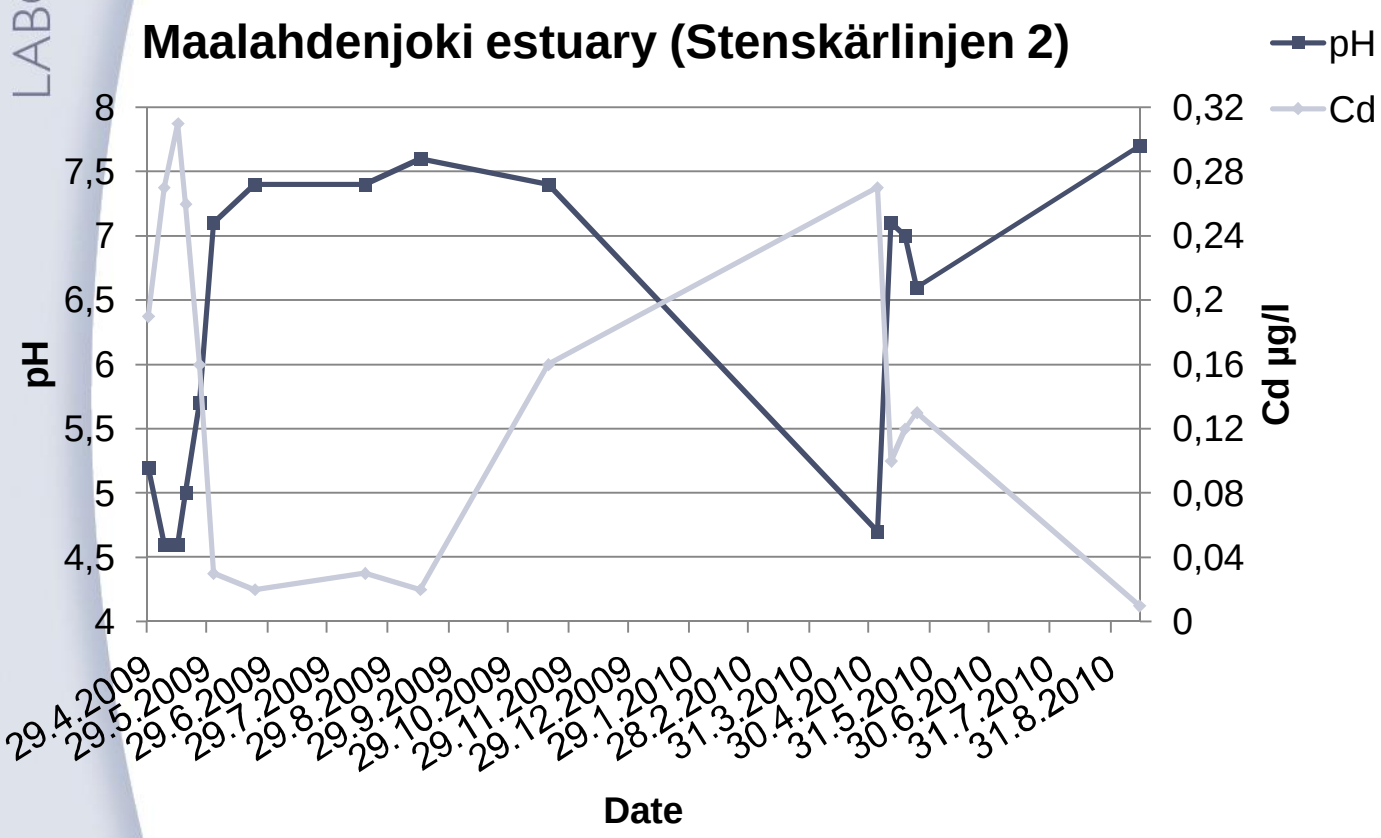
pH and concurrent Cd concn. in the ASS-affected estuary waters



Estuary	pH min.
R. Lestijoki	5,7
R. Perhonjoki	5,4
R. Ähtävänjoki	5,1
R. Lapuanjoki	4,9
R. Vöyrinjoki	4,3
R. Kyrönjoki 1	5,0
R. Kyrönjoki 2	5,0
R. Kyrönjoki 3	6,4
R. Laihianjoki	4,4
R. Maalahdenj. 1	4,6
R. Maalahdenj. 2	5,8
R. Maalahdenj. 3	6,8
R. Närpiönjoki	5,5
R. Lapväärtinjoki	5,5

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EQs overrun/underpid (+/-) of the River/Estuary waters at high discharge

	Cd µg/l						Ni µg/l			Pb µg/l		
Estuary	Mean	AA-EQS	+/-	Max	MAC-EQS	+/-	Mean	AA-EQS	+/-	Mean	AA-EQS	+/-
R. Lestijoki	0,02	0,10	-0,08	0,04	0,45	-0,41	5	21	-16	0,34	7,70	-7,36
R. Perhonjoki	0,03	0,10	-0,07	0,09	0,45	-0,36	9	21	-12	0,41	8,70	-8,29
R. Lapuanjoki	0,08	0,10	-0,02	0,19	0,45	-0,26	13	21	-8	0,46	9,70	-9,24
R. Vöyrinjoki	0,41	0,10	0,31	0,41	0,45	-0,04	67	21	46	0,66	10,70	-10,04
R. Kyrönjoki, Vassor M1	0,11	0,10	0,01	0,22	0,45	-0,23	18	21	-3	0,52	11,70	-11,18
R. Kyrönjoki, Tottesund	0,12	0,10	0,02	0,27	0,45	-0,18	16	21	-5	0,46	12,70	-12,24
R. Kyrönjoki, Pudimofjärder	0,08	0,10	-0,02	0,15	0,45	-0,30	9	21	-12	0,26	13,70	-13,44
R. Maalahti, Stenskärlinjen	0,14	0,10	0,04	0,31	0,45	-0,14	17	21	-4	0,41	14,70	-14,29
R. Maalahti, Stenskärlinjen	0,10	0,10	0,00	0,17	0,45	-0,28	11	21	-10	0,42	15,70	-15,28
R. Maalahti, Svartö hålet	0,07	0,10	-0,04	0,18	0,45	-0,27	8	21	-13	0,34	16,70	-16,36
R. Närpiönjoki	0,10	0,10	0,00	0,16	0,45	-0,29	15	21	-6	0,53	17,70	-17,17
R. Lapväärtinjoki	0,08	0,10	-0,02	0,05	0,45	-0,40	3	21	-18	0,36	18,70	-18,34
Ähtävänjoki	0,04	0,10	-0,07	0,04	0,45	-0,42	4	21	-17	0,11	21,70	-21,60
R. Laihianjoki	0,32	0,10	0,22	0,32	0,45	-0,13	59	21	38	0,75	20,70	-19,95

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Time-conditional Hazard Quotients HQs

	HQ		
Estuary	Al	Zn	Cd
R. Lestijoki	14.1	0.1	0.1
R. Perhonjoki	4.9	0.1	0.1
R. Ähtävänjoki	0.0	0.0	0.0
R. Lapuanjoki	13.2	0.6	0.3
R. Vöyrinjoki	42.1	1.4	0.6
R. Kyrönjoki, Vassor M1	12.1	2.3	0.3
R. Kyrönjoki, Tottesund	11.5	0.6	0.4
R. Kyrönjoki, Pudimofjärden	7.5	2.3	0.2
R. Laihianjoki	0.0	0.0	0.0
R. Maalahti, Stenskärlinjen 2	19.6	0.6	0.4
R. Maalahti, Stenskärlinjen 3	17.3	0.5	0.2
R. Maalahti, Svartö hålet	9.8	0.3	0.3
R. Närpiönjoki	13.2	0.4	0.2
R. Lapväärtinjoki	8.6	0.5	0.1

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Conclusions

Time-conditional ERA Summary on all the assessment tools used

	Endpoint							
Estuary	Swedish SQGs	Finnish dredging guideline	Water EQSs	Water HQs	pH minimum	*V. fischeri*	*C. rip*	Summary
R. Lestijoki	-/+	-/+	-/+	+	-/+	+	-/+	-/+
R. Perhonjoki	-/+	+	-/+	+	+	+	-/+	+
R. Ähtävänjoki	+	+	-/+	-/+	+	+	-/+	+
R. Lapuanjoki	+	-/+	-/+	+	++	+	-/+	++
R. Vöyrinjoki	+	-/+	++	++	+++	+	-/+	+++
R. Kyrönjoki 1	+	-/+	+	++	++	+	-/+	+++
R. Kyrönjoki 2	+	+	+	+	++	+	-/+	+++
R. Kyrönjoki 3	++	+	-/+	++	-/+	+	-/+	++
R. Laihianjoki	++	+	-/+	-/+	+++	+	-/+	+++
R. Maalahdenjoki 1	+	-/+	+	+	++	+	-/+	++
R. Maalahdenjoki 2	+	-/+	+	+	-/+	+	-/+	+
R. Maalahdenjoki 3	++	+	-/+	+	-/+	+	-/+	++
R. Närpiönjoki	+	+	+	+	+	+	-/+	++
R. Lapväärtinjoki	+	+	-/+	+	+	+	-/+	++