



PFAS in Baltic herring used by industry and farmed fish

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Contents

- 1. What PFAS are?**
2. Health effects and maximum levels in fish
3. Background and aims of the study
4. PFAS in Bothnian Sea herring
5. PFAS in farmed fish
6. PFAS transfer from feed to farmed fish
7. Conclusions

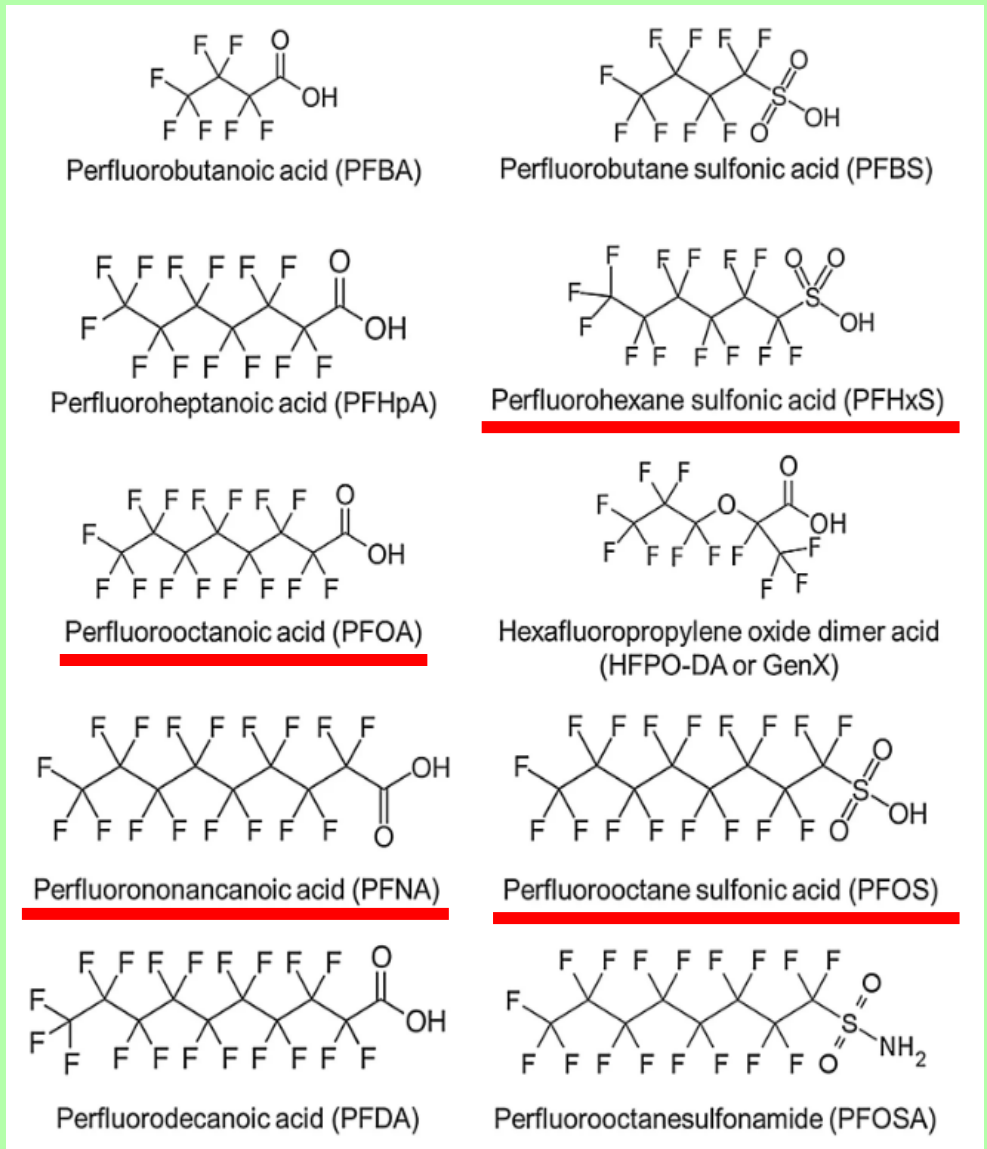
What PFAS are

- Previously referred to as perfluorinated compounds, used with a SO₃ or CO₂ group at the end (e.g. PFOS and PFOA)
- This project monitored PFAS compounds like the one in the right image
- 4 PFAS compounds (=PFAS4) with the most exposure data in the EU
- OECD 2021 PFAS definition covers a large number of “new” PFAS compounds:
 - At least one fluorinated methyl (-CF₃) or methylene (-CF₂-) group (~7M compounds)
 - Classification tool, definition not intended for hazard assessment

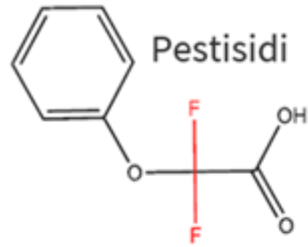


The structure of common PFAS molecules, Blake and Fenton, 2020, Toxicology

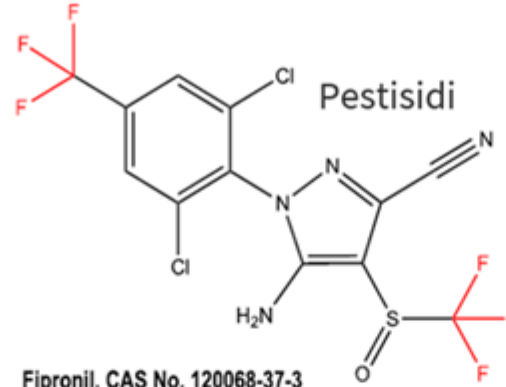
Examples:



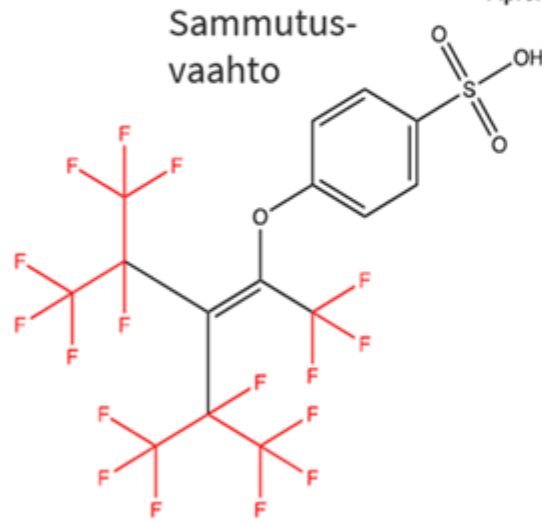
Examples of OECD-2021 structures and uses



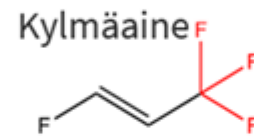
CAS No. 24210-45-5



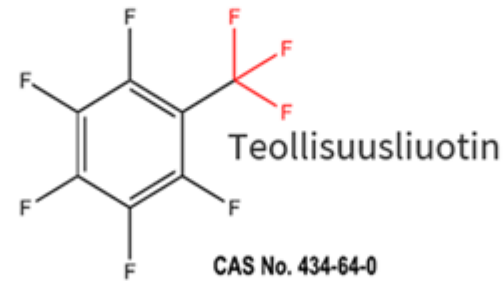
Fipronil, CAS No. 120068-37-3



CAS No. 271794-15-1



HFO-1234ze, CAS No. 29118-24-9



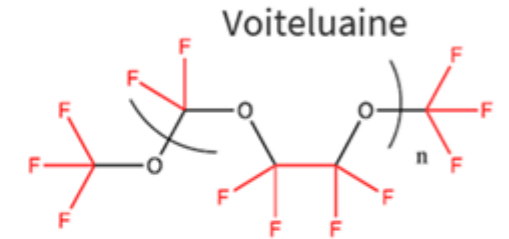
CAS No. 434-64-0



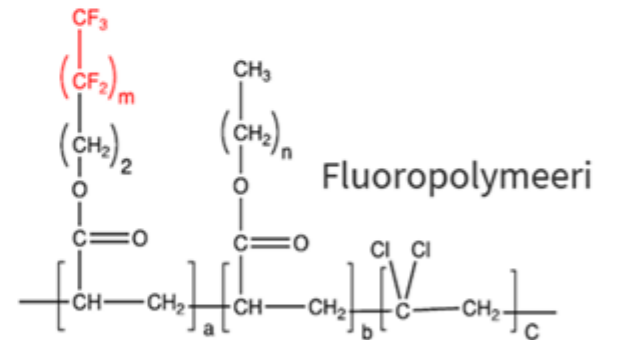
CAS No. 75-73-0



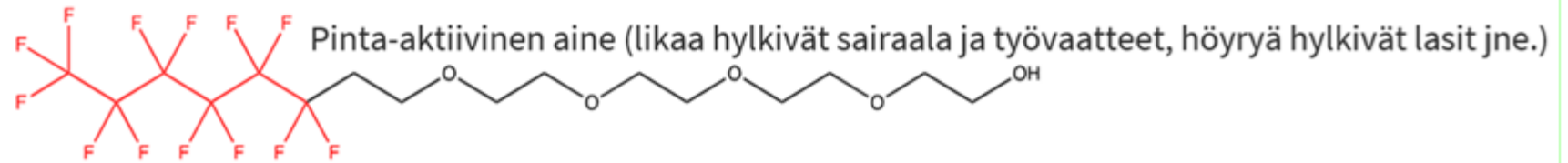
PTFE



an example of perfluoropolyethers



an example of side-chain fluorinated polymers

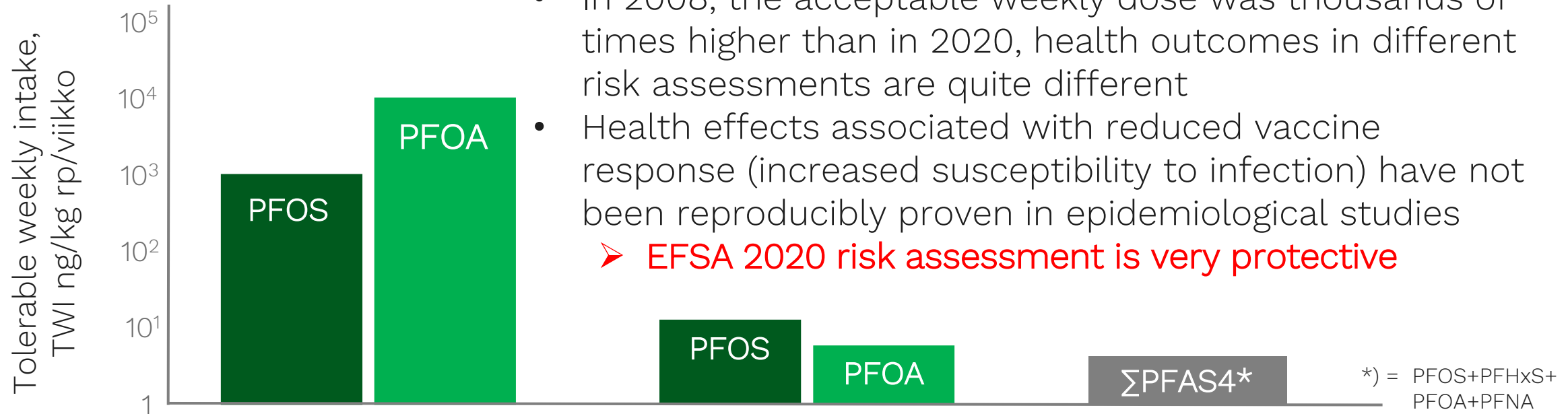




Contents

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Tolerable intake levels of the European Food Safety Authority (EFSA) 2008 - 2020



- In 2008, the acceptable weekly dose was thousands of times higher than in 2020, health outcomes in different risk assessments are quite different
- Health effects associated with reduced vaccine response (increased susceptibility to infection) have not been reproducibly proven in epidemiological studies
 - **EFSA 2020 risk assessment is very protective**

2008

Liver and develop. effects

2018

Increased cholesterol, impaired vaccine response

2020

Impaired vaccine response in children

Biological response behind TWI



Maximul levels in foods

- Regulation (EU) 2023/915 sets maximum levels for PFOA, PFNA, PFHxS, PFOS and their sum
- Three separate maximum levels depending on the species and intended use of the fish
- Farmed fish in group 1, other species in group 2 or 3 depending on the data provided by Member States to the Commission when Regulation (EU) 2023/915 was drafted
- Data is currently being collected to set maximum levels for fishmeal and fish feed

PFAS-yhdiste	PFOS	PFOA	PFNA	PFHxS	ΣPFAS4
Ryhmä 1: Yleinen kalanlihan enimmäismäärä, sekä kalanliha imeväisten ja pikkulapsien elintarvikkeiden valmistukseen	2,0	0,20	0,50	0,20	2,0
Ryhmä 2: Silakka, kilohaili, jne., kun se ei ole tarkoitettu imeväisten ja pikkulapsien elintarvikkeiden valmistukseen	7,0	1,0	2,5	0,20	8,0
Ryhmä 3: Lahna, kuha, ahven, särki, kuore, siika, jne., kun se ei ole tarkoitettu imeväisten ja pikkulapsien elintarvikkeiden valmistukseen	35	8,0	8,0	1,5	45

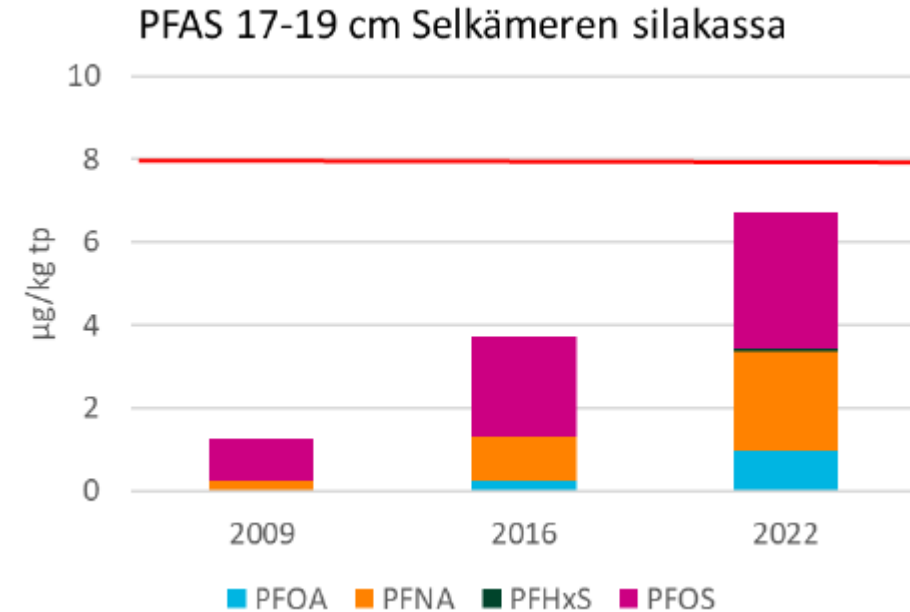
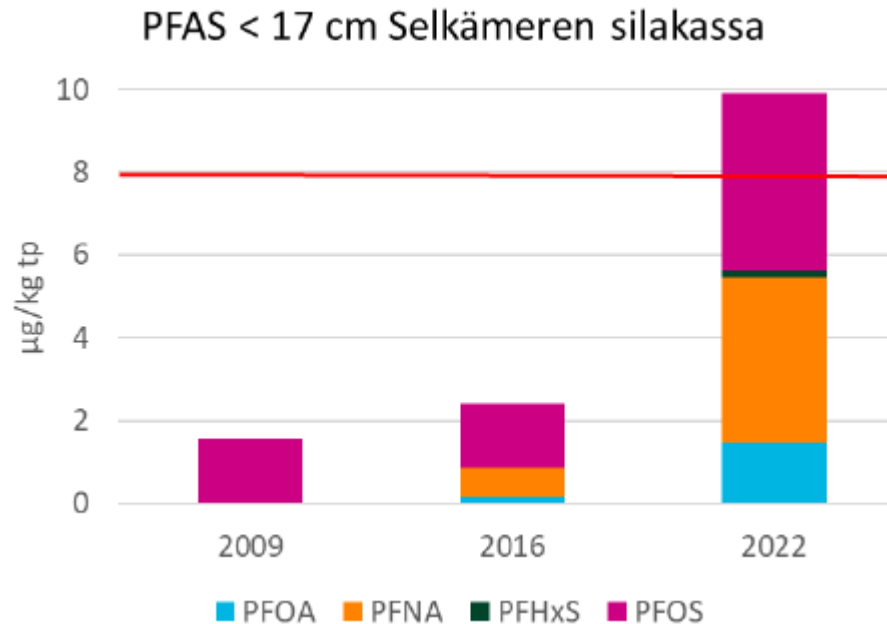




Contents

1. What PFAS are?
2. Health effects and maximum levels in fish
- 3. Background and aims of the study**
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Background and aims of the study



- PFOA and PFNA increased sharply in Bothnian Sea herring from 2009 to 2022
 1. More extensive sampling of herring from the Bothnian Sea used by the food industry
- Because herring is an important feed ingredient for farmed fish:
 2. Measure PFAS in domestic rainbow trout and whitefish purchased from a fish counter
 3. Investigate the accumulation of PFAS in rainbow trout (meat, roe, filleting residue), feeding with 3 different PFAS-concentration feeds for 6 months
 3. Investigating change in PFAS level using 4 months of High feed followed by 2 months of Low feed

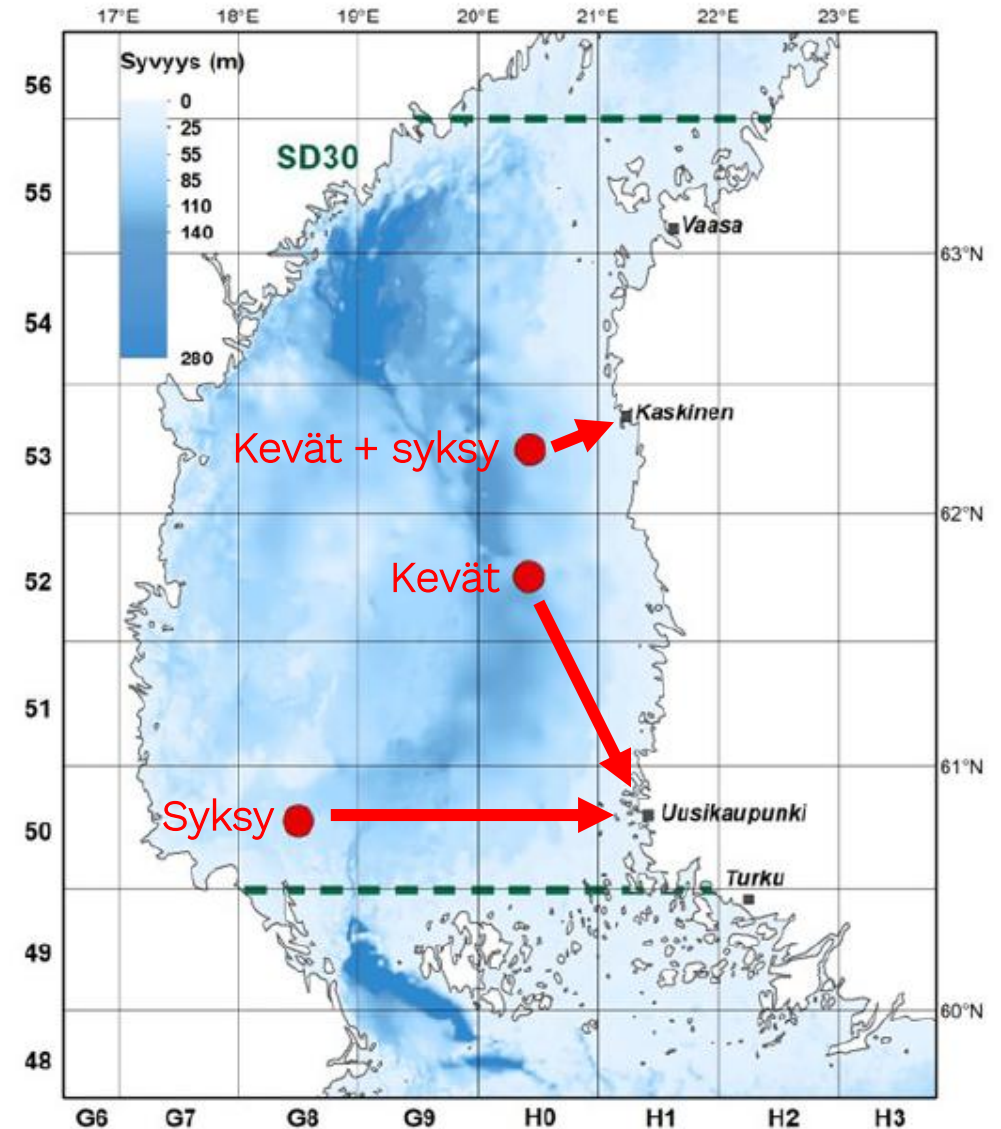


Contents

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PFAS in Bothnian Sea herring - sampling

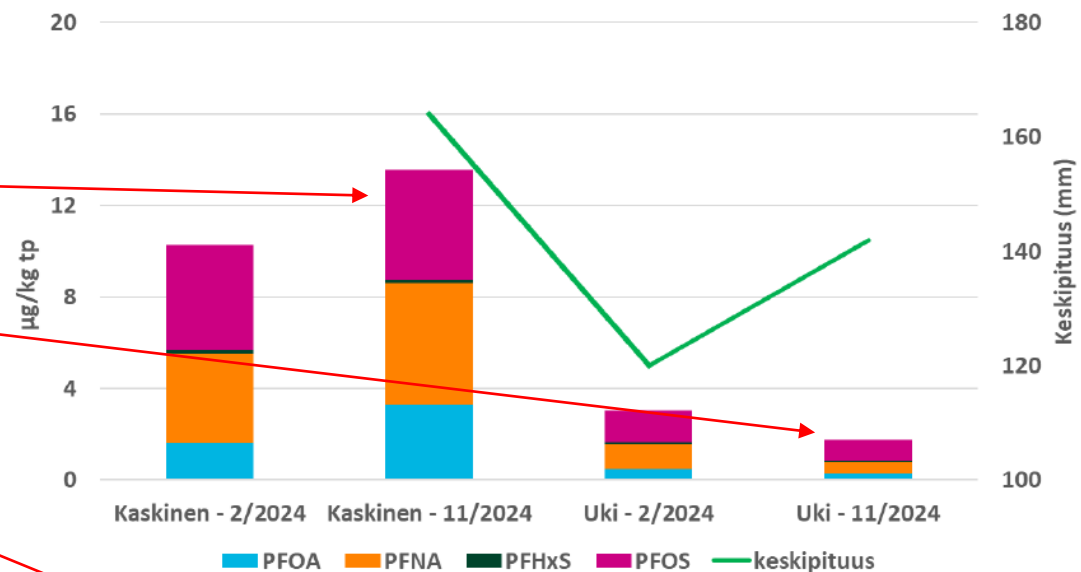
- Herring samples from the trawl were landed from Kaskis square 53H0 (2/2024 and 11/2024) and from Uki square 52H0 (2/2024) and 50G8 (11/2024)
- **Size class III (9–12 cm):** unsorted whole herring for fishmeal plant or food use
- **Size class II (12–15 cm):** sorted whole herring for export
- **Size class 0/I (17–19 cm/15–17 cm):** fillet for consumption or further processing AND filleting/trimming residue for fishmeal plant or feed center



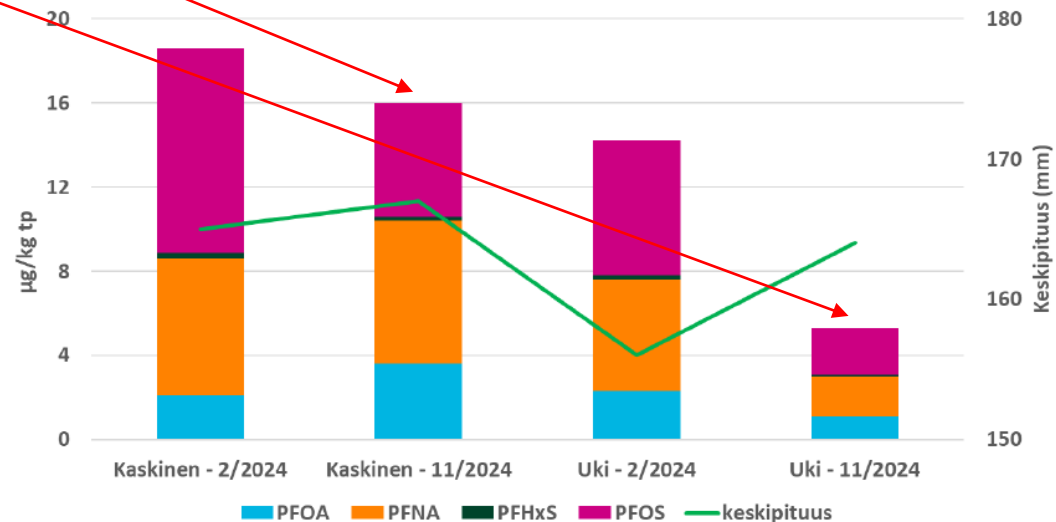
PFAS in Bothnian Sea herring - results

- Temporal and especially regional variation in unsorted small herring
- 11/2024 in the northern square 53H0 concentrations $8 \times 50G8$ (Sweden square)
- In size class II herrings, the differences are smaller, but still 53H0 = $3 \times 50G8$
- Not very large differences in the relative proportions of PFAS compounds
- For whole herring, the maximum amount does not apply directly to consumers

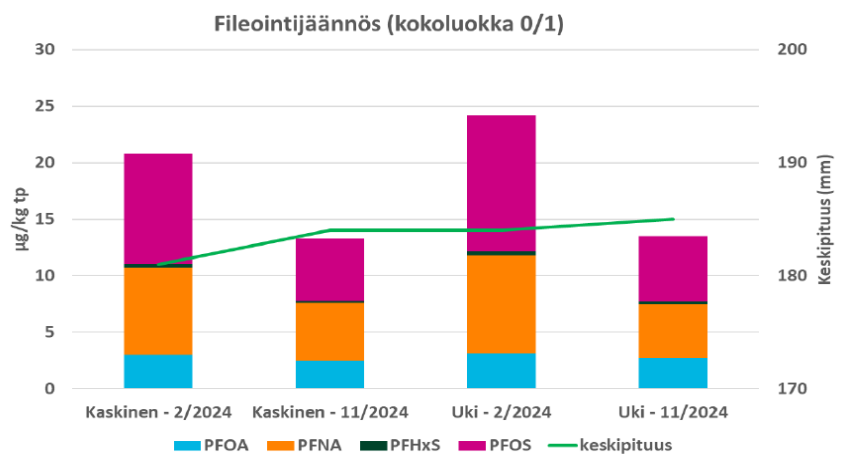
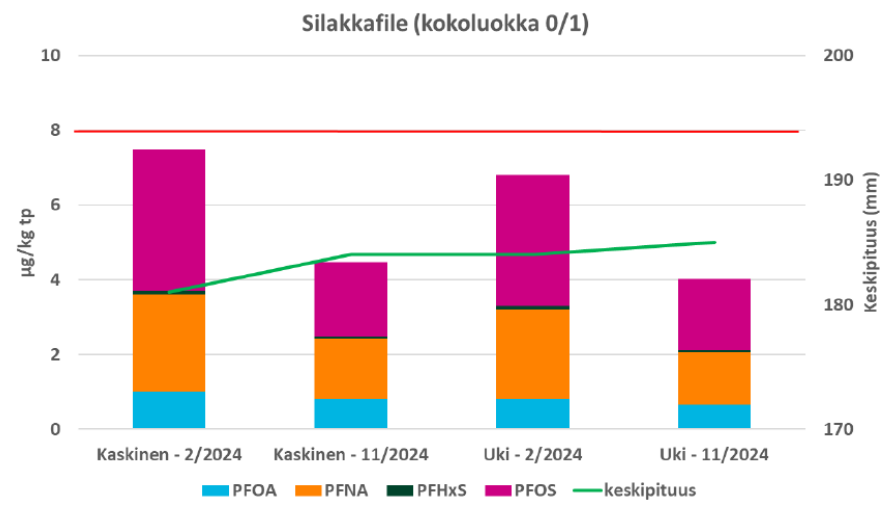
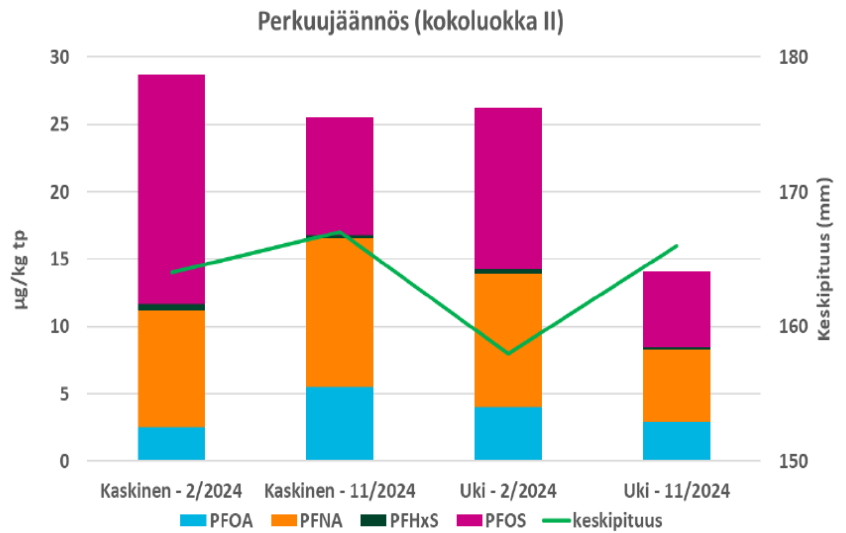
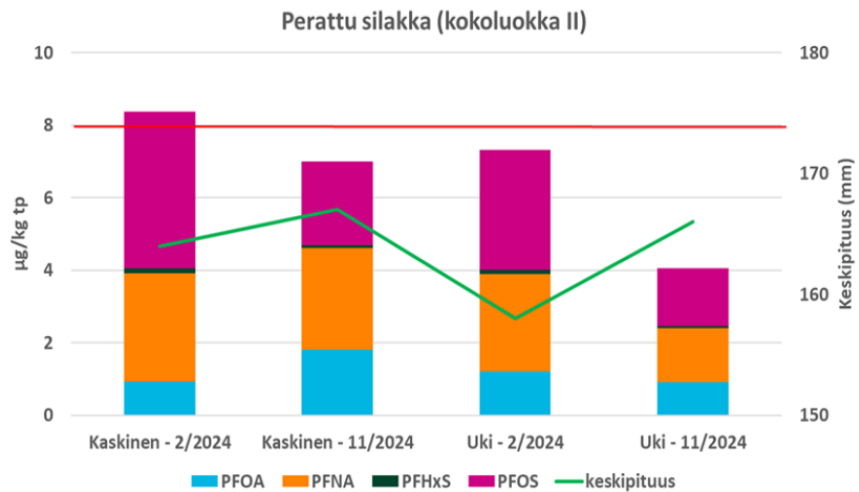
Lajittelematon kokonainen silakka



Lajiteltu kokonainen silakka (kokoluokka II)



PFAS in edible herring – results



- Differences between fishing times and squares decrease as herring size increases (max 2*)
- Concentrations in residues approximately 3*file concentrations
- Concentrations of Σ PFAS4 in edible herring meat ~below maximum limits
- Maximum limits of individual PFAS compounds were exceeded in some samples
- Reasons for concentrations of different sizes of herring in different areas unclear:
 - Diet at different ages?
 - Migration behavior?
 - Regional contamination?





Contents

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PFAS in farmed fish

Näyte	Otettu	PFOS	PFOA	PFNA	PFHxS	ΣPFAS4
Kirjolohifile	Joulukuu 2023	*	*	*	*	0,00
Siikafile	Joulukuu 2023	0,31	*	0,091	*	0,40
Kirjolohen mäti	Joulukuu 2023	0,49	*	*	*	0,49
Kirjolohifile	Kesäkuu 2024	0,07	*	*	*	0,07
Siikafile	Kesäkuu 2024	0,22	*	0,09	*	0,31

*Pitoisuus alle määrittämissärajat. Määrittämissärajat ylittävät pitoisuudet laskettu PFAS-yhdisteiden summapitoisuuteen nollana.

- PFAS concentrations ($\mu\text{g}/\text{kg}$) of rainbow trout file, whitefish file and rainbow trout roe purchased from retail stores were measured
- The limits of determination varied from sample to sample → direct comparison not always possible
- The concentrations were low, only PFNA and PFOS were detected, but even these were clearly below the maximum levels (only PFAS4 compounds in the table, others were hardly detected)





Contents

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Transfer of PFAS compounds from feed to farmed fish – experimental design

- Sea growth season 2023 normally with commercial feed in netpools
- 5/2024-11/2024 PFAS treatments for fish that were expected to produce eggs
- Fish were divided into three netpools, where the following feeds were fed based on the PFAS content of the fish meal:
 - **High-PFAS** feed: 30 m-% High-fish meal (=max PFAS in regular fish meal factory monitoring)
 - **Medium-PFAS** feed: 15 m-% High-fish meal + 15 m-% Low-fish meal
 - **Low-PFAS** feed: 30 m-% Low-fish meal
- Two pooled samples of three fish from each netpool: fillet, filleting residue and roe
- Total pooled samples 18 pcs: 2 replicates * 3 concentrations * 3 tissues



Transfer of PFAS compounds from feed to farmed fish – experimental design

- PFAS concentrations were also measured in:
 - High-PFAS, Medium-PFAS and Low-PFAS feeds
 - Low and High fishmeals used in feed production
- After 4 months of rearing, 20 fish reared on High-PFAS feed were transferred to a new tank and fed Low-PFAS feed for 2 months
 - Washout (WASHO) period, at the end of which pooled samples of fillet, filleting residue and roe were collected
 - The clearance of the fish was investigated compared to fish reared on the most contaminated feed until the end trial



PFAS in fish meal and feed – results

Näyte	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA	PFTTrA	PFHxS	PFHpS	PFOS	ΣPFAS4
Low PFAS jauho	<0.040	0,07	0,10	0,07	0,26	0,06	0,13	<0,050	<0,038	0,32	0,49
High PFAS jauho	0,79	9,5	24	3,6	3,0	0,45	0,96	1,1	0,35	33	67
Low PFAS rehu	<0.040	0,042	0,084	<0,040	0,069	<0,040	<0,040	<0,050	<0,038	0,23	0,36
Medium PFAS rehu	0,11	1,4	3,6	0,61	0,43	0,06	0,11	0,16	0,05	4,4	9,3
High PFAS rehu	0,18	2,2	5,8	0,96	0,64	0,09	0,15	0,25	0,07	7,4	15

- Low and High PFAS fishmeal ~140* difference in concentrations
 - LARGE natural variation in fish meal, i.e. between herring catches
- Low and High PFAS feeds ~40* difference in concentrations
 - High/Low ratios of feeds follow the High/Low proportion of meal → no other significant PFAS sources in feed

• Difficult to extract long-chain PFAS from feed → method development



Transfer from feed to fish – results

Näyte	SYÖTTÖ	PFOA	PFNA	PFHxS	PFOS	PFAS4
LOW FILE		*	*	*	*	*
MED FILE		*	0,08	*	0,20	0,28
HIGH FILE		*	0,12	*	0,28	0,40
LOW BY-PROD	6 kk High	*	0,00	*	0,09	0,09
MED BY-PROD		*	0,17	*	0,37	0,54
HIGH BY-PROD		*	0,38	*	0,82	1,2
LOW MÄTI		*	0,09	*	0,99	1,1
MED MÄTI		0,27	2,4	0,19	7,6	10
HIGH MÄTI		0,44	3,5	0,28	11	15

- PFAS concentrations in fillet << maximum levels of H-PFAS in feed too
 - Slightly more in by-products, but below maximum levels
 - No maximum levels in by-products unless used in the food industry
- Most Σ PFAS4 in roe: 1 $\mu\text{g}/\text{kg}$ (Low feed) – 15 $\mu\text{g}/\text{kg}$ (High feed)
 - Small amounts of roe used (low total exposure) and no maximum levels



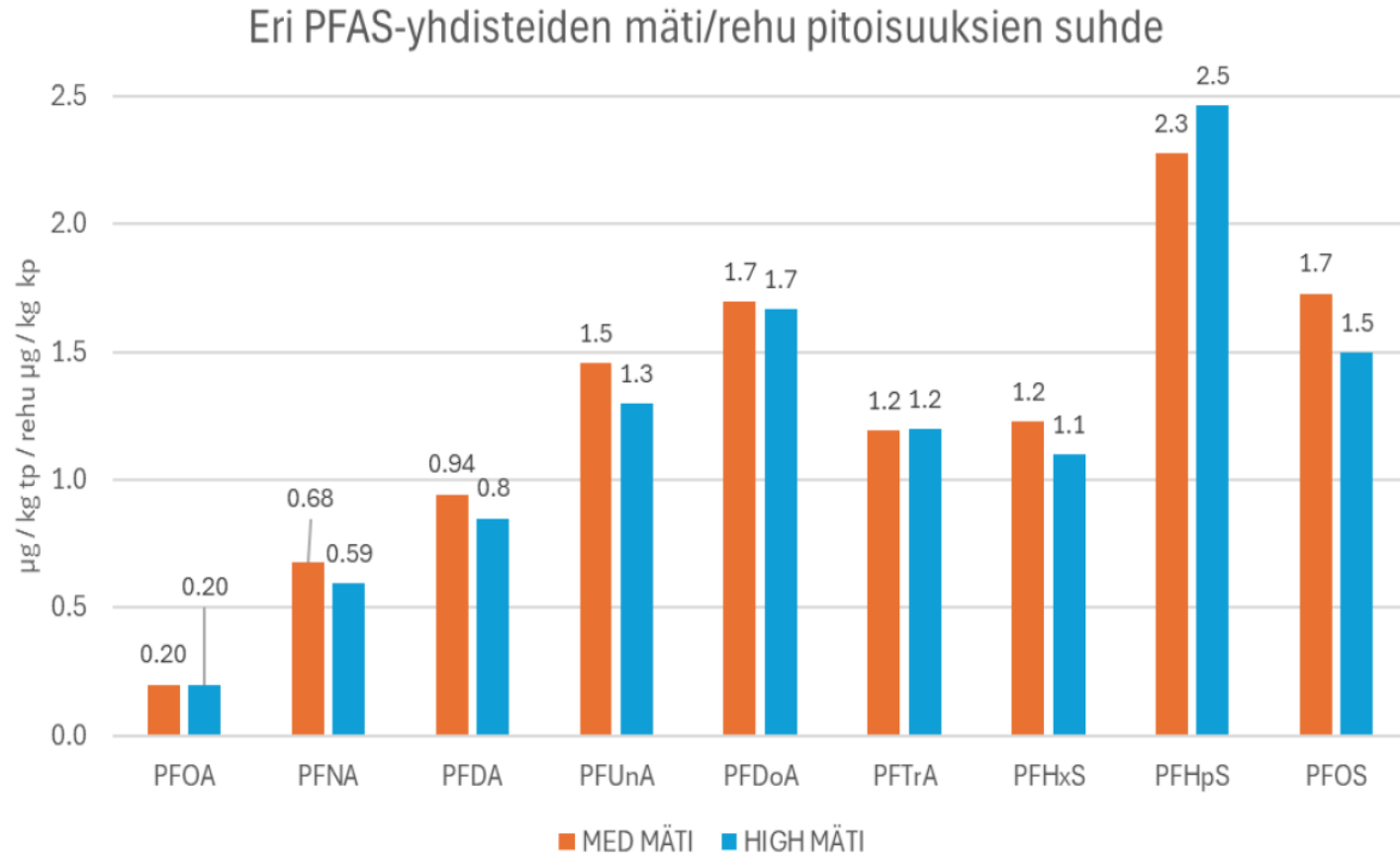
Clearance during WASHO period – results

Näyte	SYÖTTÖ	PFOA	PFNA	PFHxS	PFOS	PFAS4
HIGH FILE		*	0,12	*	0,28	0,40
HIGH BY-PROD	6 kk High	*	0,38	*	0,82	1,2
HIGH MÄTI		0,44	3,5	0,28	11	15
WASHO-0 FILE	4 kk High	*	0,18	*	0,47	0,65
WASHO FILE		*	0,04	*	0,14	0,18
WASHO BY-PROD	4 kk High + 2 kk Low	*	0,11	*	0,33	0,44
WASHO MÄTI		0,06	2,0	0,13	7,6	9,7

- Σ PFAS4 file 4 kk High (WASHO-0) > 6 kk High (growth dil., season?)
- Σ PFAS4 decrease during 2 kk WASHO: 4 kk High + 2 kk Low / 6 kk High:
 - File ~ 0,47
 - By-prod ~ 0,37
 - Roe ~ 0,61



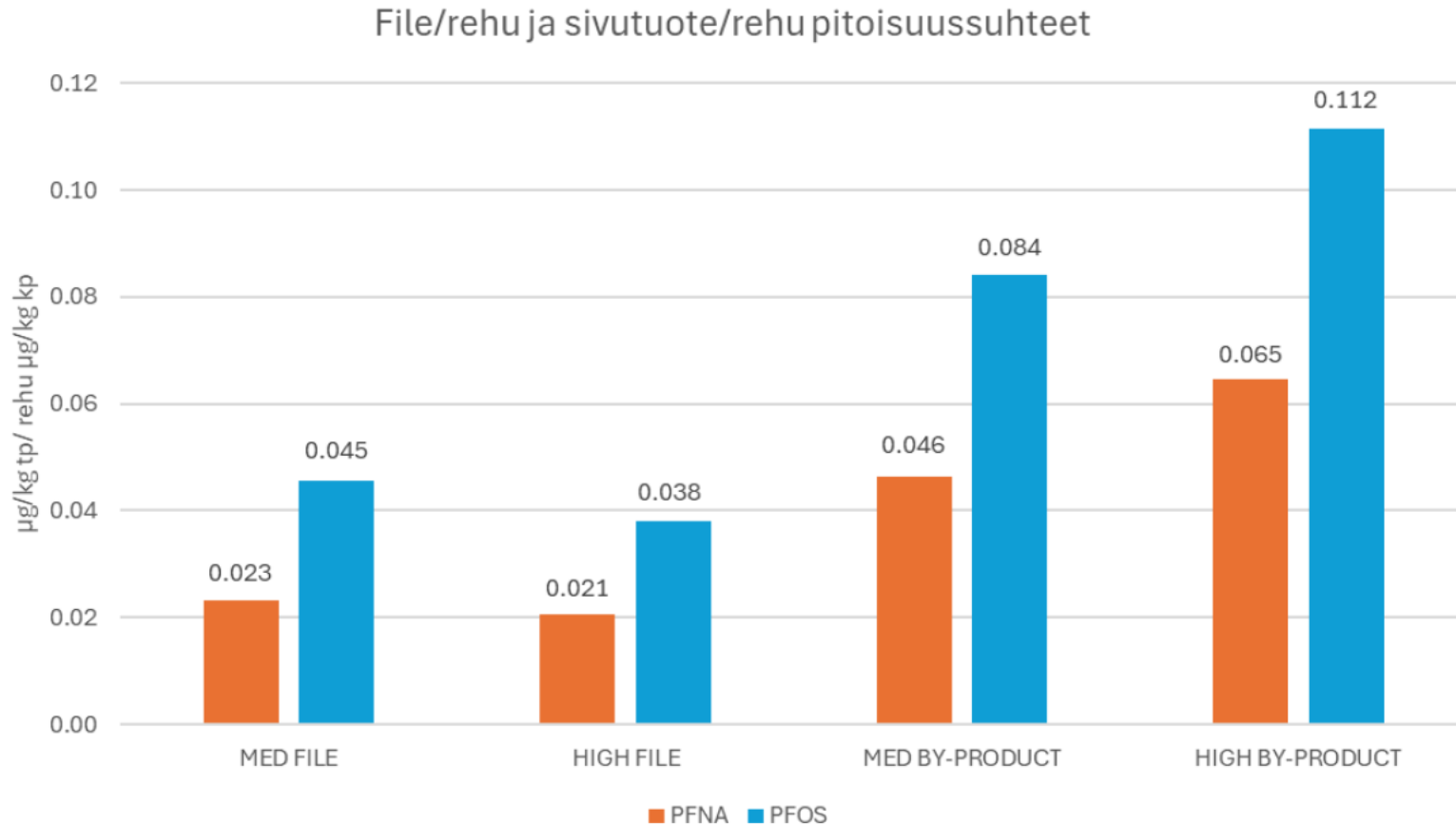
Roe/feed conc. ratios – results



- Accumulation in roe could be calculated for 9 PFAS - strongly depends on the compound
- $PFHpS = 12 * PFOA$
- Detailed determination of accumulation relationships was not the focus of the project



Accumulation in file and by-prod – results



- Only PFNA and PFOS were detected in the fillet and by-products
- PFAS concentration/ fresh weight in fillet = 0.02-0.05* PFAS concentration/dry weight in feed



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Conclusions-1

- ΣPFAS4 in edible parts of Bothnian Sea herring were 4–8 µg/kg tp
- Taking into account the measurement uncertainty, one of the herring meat PFOA > maximum limit
- Regional (east-west) and herring size-related variations in PFAS concentrations are large (especially in fishmeal) – reasons require more detailed studies
- PFAS in rainbow trout and whitefish fillets purchased from the market << maximum levels → No need to limit consumption



Conclusions-2

- Even in High-PFAS feed rainbow trout fillets PFAS concentrations << maximum levels
 - Large safety margin for PFAS accumulation in meat of farmed fish
 - Strict maximum levels for feed and feed ingredients should be avoided - could unnecessarily restrict the use of fish-derived ingredients in feed
- Roe concentrations can rise close to maximum levels of fish meat even with slightly contaminated Low-PFAS feed
 - Low consumption (i.e. total exposure) and roe does not yet reach maximum levels



Kiitos!

Link to final report

[Perfluoratut alkylyyhdisteet elintarviketeollisuuden käyttämässä silakassa ja kasvatetussa kalassa : Loppuraportti](#)