

Long term trends of flame retardants & “Forever chemicals” in landlocked Arctic Char in the Canadian Arctic

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Key Messages

- Concentrations of brominated diphenyl ethers (PBDEs) have increased in landlocked Arctic char in Lake Hazen but have declined in Amituk and Resolute Lake since the mid-2000s
- Trends in concentrations of poly/perfluorinated alkyl substances (PFAS) in char were quite variable among lakes but generally showed increases for the period 2015 to 2019

Introduction

- Landlocked (LL) char are the only top predators in most Canadian high Arctic lakes and, therefore, can serve as a sentinel species for contaminants
- Four lakes near Resolute Bay along with Lake Hazen in Quttinirpaq National Park on Ellesmere Island have been included in contaminants studies funded by NCP
- All lakes have 13 or more years of sample collections.
- Organic contaminants like PFAS (aka “Forever chemicals”) are present in Arctic air and snow and enter the lakes during snow melt and precipitation
- Declining concentrations of PCBs and organochlorine pesticides have been found in LL char over the period 1990-2017 [1]
- There is evidence for continuing, and in some cases, increasing inputs of PBDEs and PFAS to Arctic ice caps [2],[3]

Monitoring and research questions

- What are the trends in concentrations of PFAS and PBDEs in LL char in the study lakes?
- Are national and international bans and phaseouts of PBDEs and PFAS being observed by our sentinels in high Arctic lakes?

Sample collection and chemical analyses

- Adult Arctic char** (200-1500 g) are collected annually by gillnetting – in late July and early August each year
- Fish sampling is led by Inuit Debbie Iqaluk from Resolute. In 2020 Debbie did all the fishing and processing of samples by herself
- All fish are dissected within 1 to 4 h after collection & subsamples of muscle+skin, liver, otoliths, GI tract are frozen (-20°C) for transport.
- Muscle is used for the analysis of PFASs and PBDEs
- Analysis of PBDEs and PFASs were done by GC-MS and LC-MS/MS, respectively, at the Canada Center for Inland Waters of ECCC
- Tri to hepta-bromo diphenyl ethers were summed to give $\Sigma 13$ PBDEs
- PFAS analysed included perfluoro-octane sulfonic acid (PFOS) and perfluorinated carboxylic acids with 7 to 11 carbon chains (Σ PFCA)



Results

PBDEs

- Geometric mean concentrations of $\Sigma 13$ PBDEs in the 4 lakes over a 20+ year period are plotted in Figure 1.
- $\Sigma 13$ PBDE significantly increased in Char Lake, Resolute Lake and Lake Hazen from the 1990s to 2017 (6.6 to 9.5%; Table 1).
- No significant trend of $\Sigma 13$ PBDEs was observed in char from Amituk Lake although concentrations increased over the period 2006 to 2017

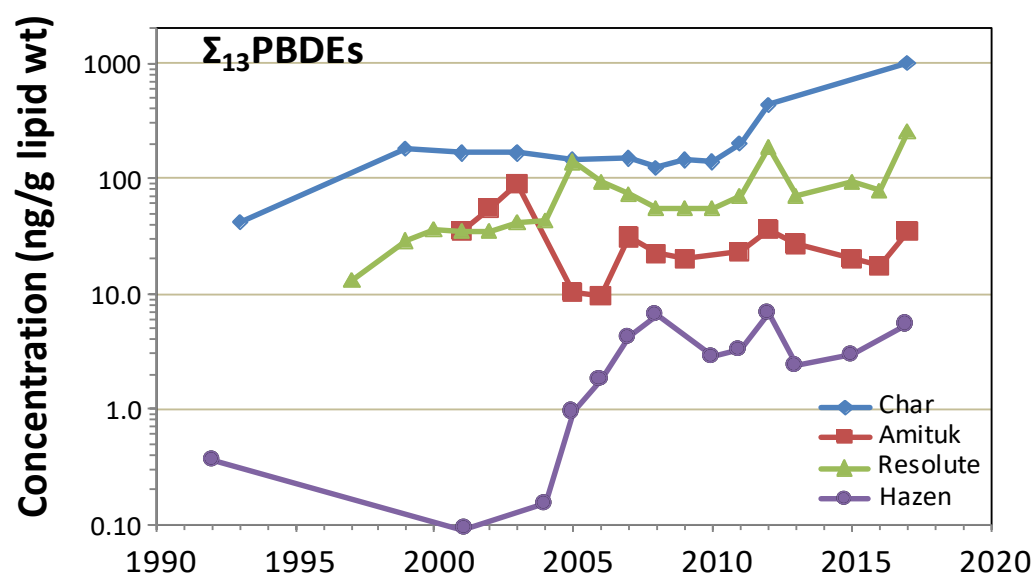


Figure 1. Trends in concentrations of $\Sigma 13$ PBDEs in muscle of landlocked char from Amituk, Char, Hazen and Resolute lakes from the 1990s to 2017. Symbols represent geometric means, ng/g (parts/billion) adjusted for lipid content of the muscle

PFAS

- PFOS in Amituk Lake char increased over the period 2009 – 2019 although the trend (6.4%/yr) was not statistically significant (Table 2).
- The increase was more rapid (40%/yr; $P=0.038$) from 2015 to 2019
- PFOS declined in Lake Hazen (2011-2019) and Char Lake (2008-2018) (Figure 2) although the trends were not significant (Table 2).
- Σ PFCA in LL char generally declined from 2007/08 to 2015 and then showed increasing concentrations in Hazen, Amituk, Char, and North Lake from 2015 to 2019 (Figure 2).
- Σ PFCA in Lake Hazen char increased from 2015 to 2019 (43%/yr) but the trend was not significant ($P=0.271$).
- Σ PFCA showed no significant trends in LL char from Char Lake and North Lake, however, data were more limited for these lakes.

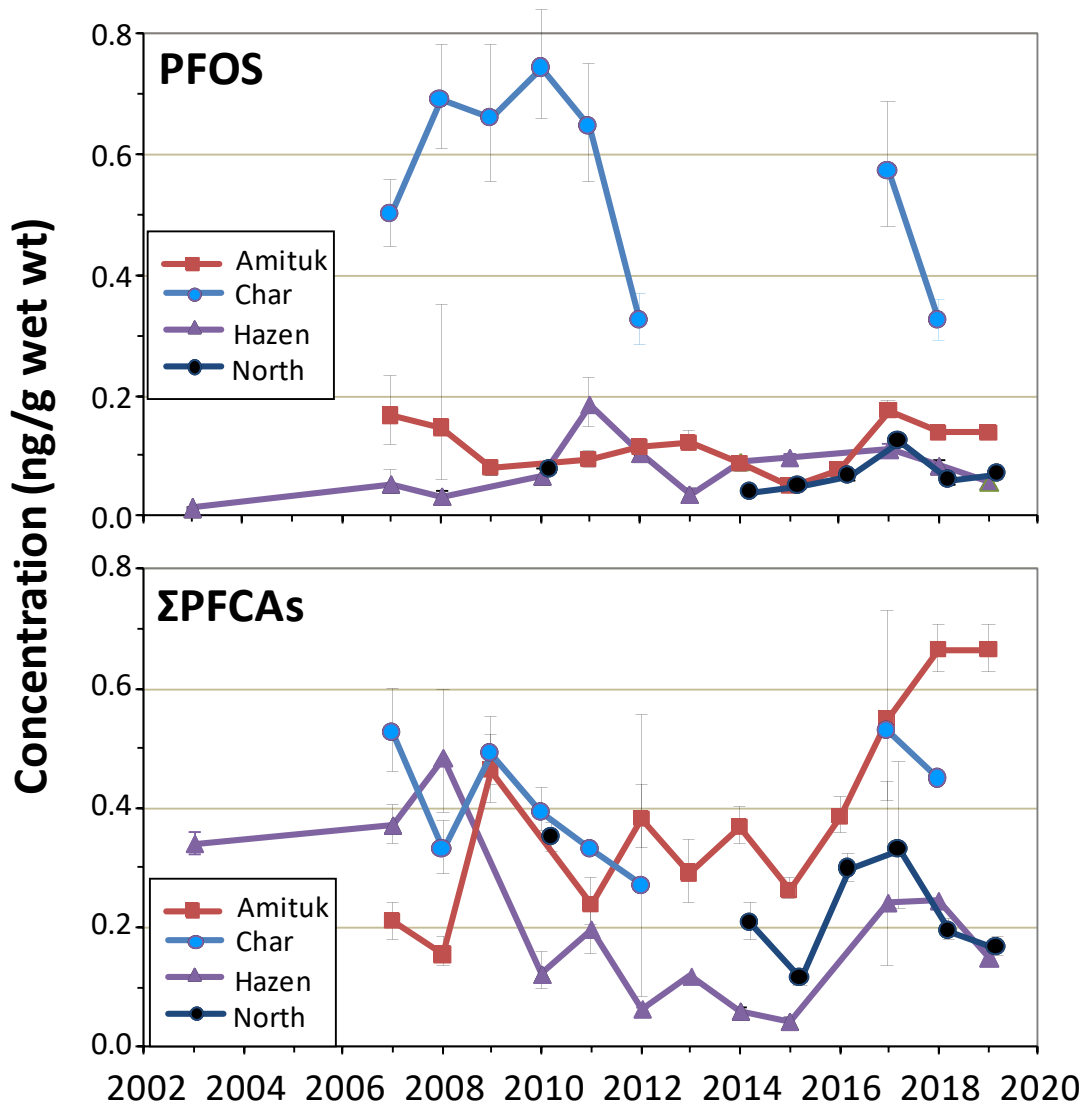


Figure 2. Trends in concentrations of PFOS and Σ PFCA in muscle of landlocked char from Amituk, Char, Hazen and North lakes from the early 2000s to 2019. Symbols represent geometric means, ng/g (parts/billion) based on fresh weight of the muscle. Vertical lines represent 95% confidence limits.

Table 1. Trends in $\Sigma 13$ PBDEs and HBCD concentrations in landlocked char from 4 high Arctic lakes*

Lake	Years	N	% change	95% Confidence intervals (%)	Statistically significant?	Lowest detectable change at power of 80%
Amituk	2001-2017	103	-2.6%	-9.2 – 4.4%	NS**	14%
Char	1993-2017	69	7.1%	2.3 – 13%	Yes, $P<0.009$	14%
Hazen	1992 -2017	141	6.6%	1.1 – 12%	Yes, $P<0.021$	13%
Resolute	1997-2017	174	9.5%	5.5 – 14%	Yes, $P<0.001$	5.7%

* % change and statistics calculated using the PIA program distributed by AMAP
 **NS = not statistically significant at $P=0.05$

Table 2. Trends (all data to 2019) of PFOS and (Σ PFCA) in landlocked char from high Arctic lakes

Lake	PFAS group	Years	N	% change	95% Confidence intervals (%)	Statistically significant?	Lowest detectable change at power of 80%
Amituk	PFOS	2009-19	91	6.4%	-3.0 – 17%	NS	13%
	PFOS	2015-19	30	40%	4.4 – 87%	Yes, $P=0.038$	60%
	Σ PFCA	2011-19	69	13%	5.5 – 20%	Yes, $P=0.004$	10%
Char	PFOS	2008-18	59	-5.2%	-13 – 3.0	NS	25%
	Σ PFCA	2007-18	66	1.0%	-4.9 – 7.3%	NS	16%
Hazen	PFOS	2011-19	80	-3.1%	-18 – 14%	NS	36%
	Σ PFCA	2008-19	99	-2.6%	-18 – 16%	NS	38%
	Σ PFCA	2015-19	50	43%	-48 - 295	NS	>99%

Discussion and Conclusions

- Increasing trends of $\Sigma 13$ PBDEs, Σ PFCA and PFOS in landlocked char from the most remote lakes, Amituk and Hazen, were surprising given the phase-outs of these substances.
- Results agree with trends of PFOS to the Devon Ice cap [2] and with air measurements at Alert that also showed an increase of PFOS from 2006 to 2013 [5].
- The increasing concentrations of PBDEs in Char and Resolute Lakes could also reflect remobilization of local contaminants in the Resolute Bay airport and hamlet area, due to greater summer precipitation and warming of the past 15 years
- Char from Resolute Lake were not analysed for PFAS because they have relatively high PFOS (mean 28 ng/g ww; range 13 – 122 ng/g) based on previous studies [4].
- Soils around the airport and within the catchments of nearby lakes showed higher concentrations of PFOS than sites that were further away (North Lake and Amituk Lake) probably due to past contamination due to use of PFOS was used in fire-fighting foams [6].

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