SUPPORTING INFORMATION

Influences of climate change on long-term time series of persistent organic pollutants (POPs) in Arctic and Antarctic biota

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Table S1: List of abbreviations used in this article

Abbreviation	**Full name**
AMAP	Arctic Monitoring and Assessment Programme
AO	Arctic Oscillation
C	Carbon
CBz	Chlorobenzene
CEAC	Chemical of emerging Arctic concern
CHL	Chlordane
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
ESB	Environmental Specimen Bank
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
N	Nitrogen
NAO	North Atlantic Oscillation
NIST	National Institute for Standards and Technology
OCS	Octachlorostyrene
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-*p*-dioxin
PCDF	Polychlorinated dibenzofuran
PDO	Pacific Decadal Oscillation
PFAS	Perfluoroalkyl substance
PFCA	Perfluorocarboxylic acid
PFOS	Perfluorooctane sulfonate
PFTrDA	Perfluorotridecanoic acid
PNA	Pacific/North American Pattern
POP	Persistent organic pollutant
STAMP	Seabird Tissue Archival and Monitoring Project
TMF	Trophic magnification factor

Table S2: Summary of the studies investigating temporal trends of persistent organic pollutants in Arctic and Antarctic biota in relation to climate parameters.

Species	Location	Years	Contaminants	Climate-related parameters	Associations	Reference
Freshwater biota						
Zooplankton, Arctic char	Canada	2008–2017	PCBs, CHLs, DDTs	Turbidity (proxy for permafrost slumps)	Higher concentrations of POPs in biota from lakes with higher carbon and particulate concentrations	Cabrerizo et al. (2019a; b)
Arctic char	Canada	1989–2015[a]	ΣPCBs, ΣDDTs, HCB, ΣHCHs, toxaphene	North Atlantic Oscillation (NAO) index, temperature (air), precipitation	Positive association between HCH and precipitation; positive associations between ΣPCBs, ΣDDTs, ΣHCHs and NAO in the preceding year	Cabrerizo et al. (2018)
Arctic char	Greenland	1999–2017	ΣPCBs, PCB-52, PCB-153, ΣDDTs, α-HCH, HCB	Biological variables ($\delta^{15}N$), Arctic Oscillation (AO) index, air temperature	Positive associations between ΣPCBs, α-HCH and air temperature	Rigét et al. (2020)
Arctic char	Norway (Bjørnøya)	1998–2017	ΣPCBs, HCB	Air temperature	Positive associations between HCB and air temperature, but indications of confounding factors	AMAP (2021)
Burbot	Canada	2000–2012	PCBs, DDTs	Air temperature	Positive associations between primary productivity and concentrations of ΣDDTs and PCB congeners, but not over the entire timespan	Carrie et al. (2010)
Terrestrial mammals						
Arctic fox	Norway (Svalbard)	1997–2013	PCBs, PBDEs, CHLs, *p,p'*-DDT, *p,p'*-DDE, β-HCH, HCB, mirex	Biological variables ($\delta^{13}C$, $\delta^{15}N$), sea-ice coverage (proxy for seal availability), reindeer mortality	Positive association between POPs and intake of marine diet; positive association between β-HCH and sea-ice cover; negative association between HCB and reindeer mortality	Andersen et al. (2015)
Arctic fox	Norway (Svalbard)	1997–2014	PFAS	Biological variables ($\delta^{13}C$, $\delta^{15}N$), sea-ice coverage (proxy for seal availability), reindeer mortality	Positive association between PFAS and intake of marine and high trophic level prey. Positive association between PFOS and sea-ice cover; negative association between PFCAs and reindeer mortality	Routti et al. (2017)
Marine fish						
Emerald rockcod	Antarctica	1981–2010[a]	PCBs, PBDEs, PCDD/Fs, CHLs, DDTs, HCHs, HCB	Iceberg calving event	Increase of concentrations of ΣPCBs, *p,p'*-DDE and ΣPBDEs after iceberg calving event	Cincinelli et al. (2016)
Seabirds						
Adélie penguins	Antarctica	1964–2005	DDTs	Glacier melt timing	Stable concentrations of ΣDDT (instead of expected decrease) related to release from glacier meltwater	Geisz et al. (2008)
Common murre	United States (Alaska)	1999-2010	ΣPCBs, *p,p'*-DDE, HCB, *α*-HCH, *cis*-nonachlor, dieldrin, heptachlor epoxide, oxychlordane, mirex	Pacific Decadal Oscillation (PDO) index	No association found between POP concentrations and PDO (different from results for thick-billed murres, see below)	Kalia et al. (2021)
Glaucous gull	Norway (Bjørnøya)	1997–2006	ΣPCBs, HCB, oxychlordane	AO index	Positive associations of ΣPCBs, HCB and oxychlordane with AO in preceding summer and winter; but negative associations with AO in the same year	Bustnes et al. (2010)
Northern fulmar	Canada	1975–2015[a]	PCBs, CHLs, CBz, DDTs,	AO and NAO indices,	Positive associations between chlorobenzenes, cis-/trans-	Foster et al. (2019)

			OCS, mirex, photomirex	precipitation, sea-ice extent, air and sea surface temperature	nonachlor, dieldrin, mirex, photomirex and NAO	
	Thick-billed murre	Canada	1975–2015[a]	PCBs, CHLs, CBz, DDTs, OCS, mirex, photomirex	AO and NAO indices, precipitation, sea-ice extent, air and sea surface temperature	Positive associations between some PCB cogneners, *p,p'*-DDE, chlorobenzenes, OCS, dieldrin and precipitation; negative associations between PCB-170, PCB-180, oxychlordane, cis-nonachlor, heptachlor epoxide and precipitation	Foster et al. (2019)
	Thick-billed murre	Canada	1975–2013[a]	ΣPCB, *p,p'*-DDE, HCB, oxychlordane, heptachlor epoxide, dieldrin	Biological variables ($\delta^{15}N$)	Positive association between trophic position and rate of POP decline	Braune et al. (2015)
	Thick-billed murre	Canada	1993–2015	PCB-153, PBDE-47, PFOS, *p,p'*-DDE, *α*-HCH	AO and NAO indices, precipitation, sea-ice coverage, sea level pressure[a], air and land surface temperature, wind speed	Positive associations between POP concentrations and AO or NAO indices (after a time-lag); positive associations of POPs with greater ice-coverage and earlier freeze-up of sea-ice; negative association between POP concentrations and temperature	AMAP (2021)
	Thick-billed murre	United States (Alaska)	1999–2010	ΣPCBs, *p,p'*-DDE, HCB, *α*-HCH, *cis*-nonachlor, dieldrin, heptachlor epoxide, oxychlordane, mirex	PDO index	POP concentrations were highest when PDO was near 0 and lowest during PDO extremes.	Kalia et al. (2021)
Marine mammals							
	Beluga	Canada	1989–2015	PCBs, CHLs, DDTs, HCHs, HCB, dieldrin, mirex	Biological variables ($\delta^{13}C$, $\delta^{15}N$)	Associations between ΣPCBs and $\delta^{13}C$; associations between dieldrin, mirex and both $\delta^{13}C$ and $\delta^{15}N$	Noël et al. (2018)
	Ringed seal	Canada (multiple locations)	1972–2016[a]	ΣPCBs, ΣCBz/HCB ΣCHLs, ΣDDTs, ΣHCHs, oxychlordane, trans-nonachlor[b]	AO and NAO indices; Pacific/North American (PNA) pattern; sea-ice coverage, air temperature	Positive associations between POPs and AO/NAO of preceding year, negative associations between POPs and AO/NAO of the year of sampling for most locations, but variations between locations; positive associations of ΣPCB and ΣCBz and sea-ice coverage	Houde et al. (2019)
	Ringed seal	Canada	1993–2008	PCBs, CHLs, DDTs, HCB, HCHs, dieldrin, mirex, toxaphene	Sea-ice (time of breakup)	Higher concentrations of some PCBs and *p,p'*-DDT in years with earlier sea ice break-up	Gaden et al. (2012)
	Ringed seal	Greenland (East)	1986–2017	ΣPCB, PCB-52, PCB-153, ΣDDT, *α*-HCH, HCB	Biological variables ($\delta^{15}N$), AO index, sea-ice coverage, seawater temperature	Positive association between all compounds and $\delta^{15}N$; positive association between HCB, *α*-HCH and AO; positive association between HCB and seawater temperature	Rigét et al. (2020)
	Ringed seal	Greenland (West)	1994–2017	ΣPCB, PCB-52, PCB-153, ΣDDT, *α*-HCH, HCB	Biological variables ($\delta^{15}N$), AO index, sea-ice coverage, seawater temperature	Positive association between PCB-52 and $\delta^{15}N$; negative association between AO and *α*-HCH; positive association between ΣPCB, PCB-52, PCB-153, ΣDDT and temperature; positive association between ΣPCB, ΣDDT and salinity; positive association between sea ice coverage and all compounds except α-HCH	Rigét et al. (2020)

Polar bear	Canada	1991–2007	ΣPCBs, ΣPBDEs, ΣCHLs, ΣDDTs, *α*-HCH, *β*-HCH	Biological variables ($\delta^{13}C$, $\delta^{15}N$, fatty acid signatures), sea-ice (time of breakup)	Associations between POP concentrations and diet composition; associations between time of sea-ice break-up and diet composition	McKinney et al. (2009)
Polar bear	Canada	WHB[c]: 1991–2015 SHB[d]: 2007 or 2008–2015	PCB-153, PBDE-47, PFOS, *p,p'*-DDE, *α*-HCH	AO and NAO indices, precipitation, sea-ice coverage, sea level pressure[a], air and land surface temperature, wind speed	Positive associations between POP concentrations and AO or NAO indices (after a time-lag); positive associations of POPs with later freeze-up of sea-ice; negative association between POP concentrations and temperature as well as precipitation	AMAP (2021)
Polar bear	Greenland	1984–2011	ΣPCBs, ΣPBDEs, PFAS, ΣCHLs, ΣDDTs, HCB, ΣHCHs, OCS, dieldrin, mirex, toxaphene	Biological variables ($\delta^{13}C$, $\delta^{15}N$, fatty acid signatures)	Associations between POP concentrations and diet composition	Dietz et al. (2021)
Polar bear	Norway (Svalbard)	2000–2014	PFAS	Biological variables ($\delta^{13}C$, $\delta^{15}N$), sea-ice (proxy for seal availability)	Positive associations of most PFAS with trophic level / intake of marine diet	Routti et al. (2017)
Polar bear	Norway (Svalbard)	1997–2017	ΣPCBs, ΣOH-PCBs, PBDE-47, PBDE-153, *p,p'*-DDE, HCB, *β*-HCH, oxychlordane	Biological variables ($\delta^{13}C$, $\delta^{15}N$)	Positive associations of POPs with trophic level / intake of marine diet	Lippold et al. (2019)

AO: Arctic Oscillation; CBz: chlorobenzene; CHL: chlordane; DDE: dichlorodiphenyldichloroethylene; DDT: dichlorodiphenyltrichloroethanes; HCB: hexachlorobenzene; HCH: hexachlorocyclohexane; NAO: North Atlantic Oscillation; OCS: octachlorostyrene OH-PCB: hydroxylated polychlorinated biphenyl; PBDE: polybrominated diphenyl ether; PCB: polychlorinated biphenyl; PCDD/F: polychlorinated dibenzo-*p*-dioxins and furan; PDO: Pacific Decadal Oscillation; PFAS: per- and polyfluoroalkyl substance; PFOS: perfluorooctane sulfonic acid; PNA: Pacific/North American Pattern; [a]Varying between locations and/or compound groups; [b]multiple other compounds analysed, but not included in analysis with climate parameters; [c]Western Hudson Bay; [d]Southern Hudson Bay

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