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Seasonal variation in accumulation of persistent organic pollutants in an Arctic marine benthic food web

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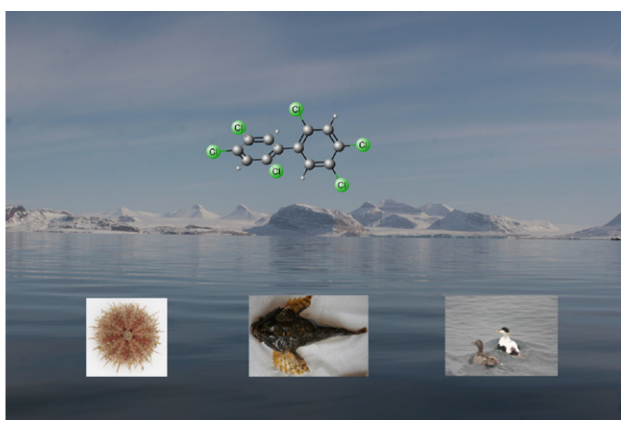
HIGHLIGHTS

- Seasonal variation in POP biomagnification was investigated in a benthic food web.
- Levels of POPs are generally low in benthic species from Kongsfjorden, Svalbard.
- POP-concentrations varied with season, but direction of change varied among taxa.
- No POP-biomagnification, except for cis-nonachlor, was detected in this study.
- δ^{15}N-values does not seem to be a good proxy for trophic level in macrozoobenthos.

GRAPHICAL ABSTRACT



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ABSTRACT

The aim of the present study was to investigate seasonal variation in persistent organic pollutant (POP) concentrations, as well as food-web biomagnification, in an Arctic, benthic marine community. Macrozoobenthos, demersal fish and common eiders were collected both inside and outside of Kongsfjorden, Svalbard, during May, July and October 2007. The samples were analysed for a selection of legacy chlorinated POPs. Overall, low levels of POPs were measured in all samples. Although POP levels and accumulation patterns showed some seasonal variation, the magnitude and direction of change was not consistent among species. Overall, seasonality in bioaccumulation in benthic biota was less pronounced than in the pelagic system in Kongsfjorden. In addition, the results indicate that δ^{15}N is not a good predictor for POP-levels in benthic food chains. Other factors, such as feeding strategy (omnivory, necrophagy versus herbivory), degree of contact with the sediment, and a high dependence on particulate organic matter (POM), with low POP-levels and high δ^{15}N-values (due to bacterial

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isotope enrichment), seem to govern the uptake of the different POPs and result in loads deviating from what would be expected consulting the trophic position alone.

1. Introduction

Global climate change may remobilize environmental contaminants and alter contaminant transport pathways, fate, and routes of exposure for Arctic organisms (Armitage et al., 2011; UNEP/AMAP, 2011). The Arctic is particularly sensitive to climate change and already exhibits clear impacts (Wassmann et al., 2011). Ongoing changes in contaminant exposure, from primary to secondary sources, changes in primary production, food-web characteristics or life-history strategy may alter bioaccumulation of Persistent Organic Pollutants (POPs) (UNEP/AMAP, 2011). A major challenge in studying the effects of climate change on contaminant behaviour in the Arctic is the lack of good baseline data on contaminant levels, bioaccumulation processes (UNEP/AMAP, 2011) and food-web structure (Wassmann et al., 2011). Without knowledge of natural variability ranges (e.g. spatial, seasonal, and inter-annual) it will be impossible to predict and interpret how climate change affects contaminant concentrations and fluxes in Arctic food webs.

Several assessments of levels and effects of POPs in Arctic biota, produced during the last decades (AMAP, 2004; Letcher et al., 2010), have focused on higher trophic level organisms (fish, seabirds and mammals). Only few studies have also included lower trophic levels species, but the main emphasis has been on species from the pelagic environment (e.g. Borgå et al., 2001; Fisk et al., 2001a,b; Hallanger et al., 2011a,b; Hargrave et al., 2000). Knowledge concerning levels of POPs in benthic food webs from Arctic seas is very sparse (Fisk et al., 2003), but some data from Svalbard (Hop et al., 2001, 2002; Svendsen et al., 2007), the Barents Sea (e.g. Boitsov et al., 2011), and the Canadian Arctic (Fisk et al., 2003; Hargrave et al., 1992) are available. Given the importance of benthic species in the diets of some seabirds (e.g. eiders (*Somateria mollissima*)), marine mammals (e.g. bearded seals (*Erignathus barbatus*) walrus (*Odobenus rosmarus*)), and commercial fish (e.g. cod (*Gadus morhua*)), baseline contaminant-data for Arctic benthos is critically needed.

Pollutants within the water column can be transported to benthic communities through adsorption to suspended particulate matter, followed by sedimentation (Wania and Daly, 2002). Bioturbation of sediment by invertebrates allows pollutants to remain in the surface sediment (Josefsson et al., 2010) and maintain contact with benthic populations over extended time periods, allowing for long-term bioaccumulation and biomagnification (Alexander, 1995). Since marine sediments are sinks for many POPs (Lebeuf and Nunes, 2005; O'Driscoll et al., 2013), knowledge about uptake and transport of POPs through benthic food webs is essential in order to predict the fate and effects of currently released and remobilized compounds.

Benthic invertebrates have a larger range of sizes, feeding ecology, and ecological niches than pelagic invertebrates, and therefore a greater potential range for accumulation of POPs (Fisk et al., 2003). High trophic diversity, and generally sedentary lifestyles allow benthic systems to integrate contamination signals over months to decades. This makes some benthic species well suited for studies of spatial and temporal variability in bioaccumulation of contaminants.

The Arctic environment is characterized by high seasonality in light intensity, primary production, food availability, lipid accumulation, and ice cover. These factors have been shown to influence the seasonal availability and uptake of POPs in organisms and food webs (Borgå et al., 2004; Fisk et al., 2001b). Seasonal variation in uptake and transport of POPs has been reported in Arctic pelagic food webs (Fisk et al., 2001a, b; Hallanger et al., 2011a,b; Hargrave et al., 2000), as well as in benthic species from temperate regions (Hummel et al., 1990; Knickmeyer and Steinhart, 1988). However, studies on seasonality in contaminant accumulation in Arctic benthic communities are lacking.

The aim of the present study was to investigate seasonal variation (from May to October) in POP concentrations, as well as food-web biomagnification, in an Arctic, benthic marine community in Kongsfjorden, Svalbard.

2. Materials and methods

2.1. Study site

Kongsfjorden (79°N, 12°E) is an open fjord system on the northwest coast of Svalbard (Fig. 1). Due to the lack of a shallow sill, free exchange of Atlantic and Arctic water masses across the shelf-fjord boundary has a large impact on the fjord's physical and biological environment (Cottier et al., 2005). In the year of sampling (2007), temperature and salinity profiles (data not shown; conductivity, temperature and density (CTD), 911 *plus*, Sea-Bird; Washington, USA) indicated that Kongsfjorden was dominated by Atlantic water masses during all sampling periods. In winter 2006–2007, Kongsfjorden was not covered by sea ice (Gerland et al., 2007).

2.2. Field sampling

Benthic invertebrates, demersal fish and common eiders were collected during three cruises with R/V Lance or R/V Jan. Mayen (May 12–18, “spring”; July 26–29, “summer”; and October 1–10, “autumn”). Macrozoobenthos was collected at two stations, one in the middle of Kongsfjorden (inner station; 78°96′ N, 11°94′ E, 329 m depth) and one on the shelf outside Kongsfjorden (outer station; 78°94′ N, 8°54′ E, 291 m depth) (Fig. 1), using a Rothlisberg–Pearcy epibenthic sledge and a van Veen grab (0.1 m^2). Sledge haul times ranged from 15 to 25 min at a speed of one knot. Material collected was washed through a 1 mm round-mesh sieve. Remaining animals were sorted to phylum and transferred to holding chambers for depuration for 12–24 h at approximately 4–6 °C (in situ temperature). After depuration, animals were identified to species or genus level and frozen whole (shells from molluscs were removed) at −20 °C. Sub-samples were analysed for POPs and stable isotopes of carbon and nitrogen (data published by Renaud et al., 2011).

Three species of fish; shorthorn sculpin (*Myoxocephalus scorpius*), staghorn sculpin (*Gymnocanthus tricuspis*) and Atlantic cod (*Gadus morhua*), were caught using multi-panel gillnets placed near the inner benthos station (78°55.79′N 11° 54.80′E) (Fig. 1), at depths ranging from 10 to 25 m. Length and weight of fish was measured prior to dissection, shortly after collection (Table S1). A sub-sample of the dorso-lateral muscle was dissected from each fish for isotope-analyses, while the remainder of the fish was wrapped in aluminium foil and frozen (−20 °C) for POP-analyses.

Female common eiders (all adults) were sampled in the mid part of Kongsfjorden, using a shotgun. Biometric data (Table S1) were recorded prior to dissection. Pectoral muscle was used for analyses of POPs and stable isotopes. All samples were frozen at −20 °C until analyses. Permission for sampling was granted by the Governor of Svalbard.