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Insights into year-round mercury levels in Antarctic krill and its relationship with environmental and biological factors

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Project background and aims

The chemistry of mercury (Hg) in the oceans is more complex than that of any other trace elements, with many chemical reactions occurring between the atmospheric deposition of Hg on surface waters and its burial in the sediment and/or bioaccumulation in the food chain (Cossa et al., 2011). Long-range atmospheric transport and deposition processes have resulted in Hg being widely available in the oceans (Cossa et al., 2011), even in areas away from major urban developments, such as Antarctica (Dommergue et al., 2010). Inorganic Hg and organic monomethylmercury (MeHg), which is a neurotoxic Hg species that biomagnifies in food webs, are passively assimilated by phytoplankton from the surrounding water. Consumers feeding on phytoplankton assimilate and retain Hg and MeHg from their food with varying efficiencies, and become themselves a source of (Me)Hg to higher trophic levels. Given the key role played by Antarctic krill (*Euphausia superba*) in the Southern Ocean food webs, including to megafauna who may feed exclusively on them, it is important that we understand Hg dynamics in this species. A baseline of Hg concentrations in Antarctic krill from different locations and covering several years can better enable society to understand, predict, and adapt (where possible) to any potential future ecosystem changes.

This project aimed to provide a baseline of Hg concentrations (total Hg and MeHg) in juvenile and adult krill individuals, which were collected by the industrial fishing vessel *FV Saga Sea* (Aker BioMarine, Norway) from South Georgia, the South Orkney Islands, and the West Antarctic Peninsula on an almost fortnightly basis between December 2013 and August 2019 (except for October and November months). We also analysed the baseline data to understand the potential influence of biological (krill size, sex, and life stage) and environmental (location and sampling time) parameters on krill Hg concentrations.

Methods

A total of 451 krill individuals were sexed, measured (as per Kirkwood, 1982)), freeze-dried for 24h (Fig. 1), weighed (dry mass, dm), and homogenised to a fine powder (20 -100 µm, IKA A11 Analytical micromill, MEDOS, Australia). Samples were then analysed for Hg and trace metal with a Milestone Direct Mercury Analyzer (DMA-80 Tri-Cell; Milestone, Bergamo, Italy) using the USEPA method 7473 (U.S. EPA, 1998). Analyses costs were paid for with the Antarctic Science International Bursary. Various statistical analyses (generalised linear models compared with Akaike Information Criterion, analyses of variance, Wald tests, pairwise comparisons, gaussian linear models, linear regressions, and vector autoregressive modelling) were applied to the data to understand variability in Hg concentrations in krill.

Figure 1. Krill individuals after being freeze-dried for 24h.

Results and discussion

Several studies have investigated krill Hg concentration over the past three decades and, when results are compared, values seem to be relatively stable despite increasing human presence (i.e., potential Hg sources) in Antarctica. Of these (Bargagli et al., 1998; Brault, 2012; Caroli et al., 1998; Cipro et al., 2017; dos Santos et al., 2006; Korejwo et al., 2023; Locarnini & Presley, 1995; Mirzoeva et al., 2022; Nash et al., 2021; Polito et al., 2016; Seco, Aparício, et al., 2021; Seco et al., 2019; Seco, Freitas, et al., 2021; Sontag et al., 2019), we report some of the lowest values (Fig. 2).

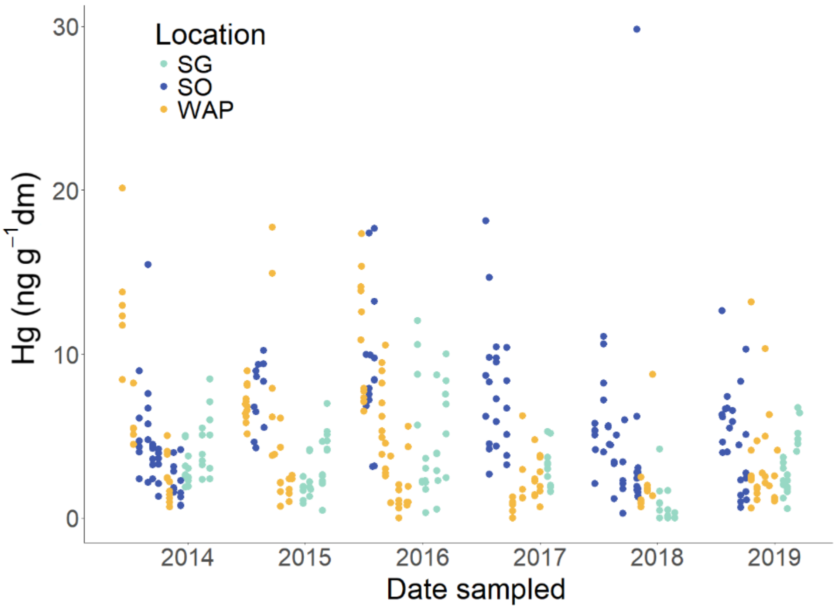

Figure 2. Total mercury (Hg) concentrations (ng g^{-1} dry mass, dm) of krill sampled from South Georgia (SG, green dots), the South Orkney Islands (SO, blue dots), and the West Antarctic Peninsula (WAP, yellow dots) between December 2013 and September 2019.

Individual size had a statistically significant, though minor, negative relationships with krill Hg concentrations, with dry mass having a greater predicting power than length. Unlike reported in other published studies (e.g., Seco et al., 2019), neither sex or life stage seemed to influence Hg variability in our krill, though I should note that we did not have enough juvenile samples to accurately predict the effect of multiple life (adult, subadult, and juvenile) and maturity stages on krill Hg levels. We propose that krill undergo three major changes in Hg concentration during the juvenile-to-adult transition: a decrease from the juvenile to the subadult stage accompanying changes in feeding frequency and environment (Korejwo et al., 2023); a gradual increase as subadults grown into adults; and a second decrease as gravid females spawn and males release spermatophores (as suggested by Seco et al., 2019).

Many factors are believed to contribute to spatially distinct patterns in Hg distribution in Antarctic waters and, thus, its concentration in lower trophic levels. While statistical analyses revealed significant differences between the three sampling sites, location lacked statistical power as a predictor variable and we were unable to elaborate on what could have caused these differences. This is because sampling was conducted one location at a time and generally during location-specific seasons, such that we never had data for more than two locations in any given month (i.e., we had an unbalanced dataset). Where comparisons between locations could be made for a given month, values did not seem too different.

Timing of sampling was the parameter with best predicting power for krill Hg concentrations, which exhibited a yearly cycle peaking in early austral summer (in the absence of mid-to-late spring data) and bottoming out in winter before rising again in early spring. We had expected that this annual cycle would resemble that reported for fatty acids (e.g., Ericson et al., 2018; Hellessey et al., 2018), which have often been linked to organic contaminants, but instead it appeared related to variations in chlorophyll a concentration (i.e., phytoplankton availability) and seasonal krill feeding regime.

Next steps

Total Hg results have been reported in a manuscript recently submitted to a special issue (entitled “Mercury in the environment”) to be published by the journal Environmental Chemistry. Results for other trace metals will soon be analysed and written up into a manuscript. We have been unable to analyse samples for MeHg, but have plans to do so in the near future.

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