The role of bird species in biological focussing of Persistent Organic Pollutants and as vectors for the long-range environmental transport of pollutants to the Antarctic

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1. Introduction

Persistent organic pollutants (POPs) are anthropogenic and ubiquitous contaminants.[1] Long range environmental transport (LRET), particularly atmospheric, has facilitated the redistribution of the world's semi-volatile POP burden, with a proportion reaching and persisting at high latitudes. Atmospheric LRET is however not the only transport mechanism by which POPs may reach the Polar regions. Alternate pathways such as ocean transport, local anthropogenic activities, and migratory biota must increasingly be considered.

The latter pathway in particular may become of increasing importance in a global warming context as species boundaries are altered. POPs are known to bioaccumulate within organisms, and may be transported regionally and globally via migratory species. Many species exploit the seasonal productivity of Polar regions, yet overwinter at lower latitudes. It is thus possible for these migratory species to accumulate pollutants at lower, more contaminated, latitudes and act as a vector of these pollutants to Polar regions through their excrement, predation or carcases.[2] Antarctic migratory biota, particularly bird species have been shown to possess much higher POP burdens than species with life histories restricted to the region.[3]

Since biotic LRET implies a different transport mechanism than LRET via ocean and atmospheric currents, the transported pollutant profiles are likely to be different, reflecting pollutants commonly present in lower latitude migratory destinations. Accumulated chemicals are also likely to undergo biological transformation, rather than environmental weathering, increasing the likelihood of profiles differing from ambient pollutant profiles. The pollutant burdens of migratory biota can therefore be expected to reflect the combination of Antarctic profiles together with the pollutant profiles of their non-Antarctic feeding grounds.

In this study we targeted a model Antarctic migratory bird species, south polar skua, and an endemic Antarctic bird species restricted to the region, Adélie penguins. Tissues and guano of migratory and non-migratory birds were analysed for a suite of compounds reflecting historical and recent/current usage chemicals. Their profiles are compared to evaluate differences in contaminant burdens and profiles and thus discern migratory biota as a potential source of chemicals to the Antarctic region. The "biological focusing" of pollutant hotspots by both migratory and non-migratory species is also investigated.

2. Materials and methods

South polar skuas (*Stercorarius maccormicki*) and Adélie penguins (*Pygoscelis adeliae*) were the targeted study species in the present study, alongside the opportunistically sampled snow petrel (*Pagodroma nivea*). The skua overwinters in the Northern Pacific, Indian and Atlantic Oceans, while Adélie penguins, found along the entire Antarctic coast, overwinter on the sea-ice edge and are non-migratory. Snow petrels are also restricted to Antarctic waters. These Antarctic species occupy a similar trophic level, often foraging primarily on Antarctic krill, whilst skuas are also known to be opportunistic scavengers.

Penguin and skua guano were collected from areas near penguin breeding colonies in Australia's Antarctic territory during the 2012/13 and 2013/14 summers. Tissues samples of chest muscle from skua and penguin carcases were also collected from these locations. Opportunistic snow petrel guano was also collected.

Samples were analysed for a wide range of POPs including polychlorinated biphenyl congeners (PCBs), the organochlorine pesticides (OCPs) *α*-, *β*- and *γ*-hexachlorohexane (HCH), *oxy*chlordane, *trans*- and *cis*-nonachlor, *trans*- and *cis*-chlordane, hexachlorobenzene (HCB), and *p,p'*-DDT and its metabolites (*p,p'*-DDD and *p,p'*-DDE), and the brominated flame retardants (BFRs) polybrominated diphenyl ethers (PBDEs), *α*-, *β*- and *γ*-hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA). Following hot Soxhlet extraction and SPE fractionation, the above targeted analytes were quantified using GC-MS and LC-MS/MS.

3. Results and discussion

The majority of the targeted analytes was detected in the muscle and guano of all 3 bird species, except for some smaller PCB congeners that were only found in skua muscle and guano. All bird species samples were dominated by the OCPs *p,p'*-DDE and HCB. These two compounds have repeatedly been found to dominate Antarctic profiles suggesting that the principal source of contamination, even for migratory biota, is in their Antarctic feeding ground. The larger congeners were the most abundant PCBs in all species, reflecting their resistance to biological breakdown. Although at much lower concentrations than other pollutants, *α*-HBCD and BDE-47 were the highest concentration BFRs found in skua and Adélie muscle and guano. Only *α*-, *β*-, and *γ*-HBCD were detectable in snow petrel guano.

The greatest differences between migratory and non-migratory species were observed for PCBs, the historical usage of which has been limited in the southern hemisphere. The concentrations of OCPs, BFRs and PCBs in skua tissue samples were up to 1, 1 and 2 orders of magnitude respectively higher than those in penguin samples. The difference in guano concentrations was much less among the different species. Levels of PCBs and OCPs in skua guano were only 1 order of magnitude higher than those in penguins and less than an order of magnitude higher than those in petrels. In contrast to muscle samples, BFR concentrations tended to be higher in the resident penguin and petrel guano than those in the migratory skua potentially reflecting a local Antarctic source as all colonies sampled were within 30 km of research stations.

PCB burdens in skua and penguin muscle exhibited similar profiles, dominated by CB-180 and -153. These congeners together made up more than 40% of the PCB burden in both species. Skua tissue, however, contained a number of the smaller PCB congeners including CB-28, -74, -101, -110, -149 and -151 that were not found in the penguin samples. This may be a result of the different trophic levels and feeding locations of the species.[4] Profiles seen in guano samples were similar to those seen in tissue of the same species.

A similar OCP profile was seen in skua and penguin tissue. In both cases, *α*-HCH was not detectable whereas both *β*- and *γ*-HCH were, with the latter being found in higher concentrations in penguins. For the guano samples, each species exhibited more distinctive profiles than those from tissue comparison. In many cases however, compounds that were detectable in tissue were not detectable in guano of that species.

BFRs were chosen as a group of compounds to discern differences in regional contamination between the migratory and non-migratory species as their contamination levels in Antarctica are limited in many cases and are still being used/released from lower latitudes. Levels of BFRs were much lower than those of the other POP groups investigated. The profiles of BFRs in the muscle and guano of skua and penguins and guano of petrels were more dissimilar to each other than any other group of POPs. Skua muscle was dominated by *α*-HBCD and BDE-154 with the latter not being detectable in the penguin muscle. Penguin muscle was dominated by *γ*-HBCD and BDE-47. The profiles of BFRs in guano were even more dissimilar than tissue, with in most cases, skua samples having the lowest pollutant burden of the three species. For both skua and snow petrels, *α*- and *γ*-HBCD respectively were the BFRs in highest concentration. However, skua tissue also had high concentrations of some PBDEs not detected in snow petrel samples. Penguin guano samples were dominated by BDE 47 and 99, unlike those from the other species. They were in fact the only two BFRs detected in penguin guano other than the three HBCD isomers.

4. Conclusions

This study found distinct POP profiles and levels between migratory and non-migratory bird species with skuas potentially acting as vectors for chemicals not currently widespread within the Antarctic. Both migratory and non-migratory species may be contributing to "biological focusing" creating hotspots within Antarctic colonies, potentially carrying direct effects to ecologically significant areas. Long term chemical surveillance of migratory biota enables a more quantitative evaluation of the magnitude of this chemical pathway.

5. References

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