Arctic Seabirds Transport Marine-Derived Contaminants

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Transport of pollutants by migratory species, such as salmon, is known to affect contaminant distributions in Alaskan nursery lakes (*1*, *2*). Arctic seabirds may also be transporting industrial and agricultural contaminants from the ocean to land. Most of these seabirds are pelagic feeders with populations concentrated in very large breeding colonies of more than 20,000 individuals (*3*). Local nutrient enrichment from guano has been documented, but the possibility of contamination in areas near seabird nesting sites has been largely overlooked. In a recent study on Bear Island, the presence of seabird colonies adjacent to one lake coincided with elevated polychlorinated biphenyl concentrations in fish (*4*). Here we show that persistent organic pollutants and mercury concentrations in high arctic pond sediments are closely related to the varying influences of seabird populations in ponds on Devon Island, in the Canadian Arctic (Fig. 1A), and that the combined effects of biomagnification and biological transport of contaminants dwarf the amount transported from atmospheric pathways.

We studied contaminants in the surface sediments of high arctic ponds below the cliffs at Cape Vera (76°15′N, 89°15′W). The 245-m-high cliffs support a large colony (~10,000 breeding pairs) of northern fulmars (*Fulmarus glacialis*) (*3*), a medium-sized petrel that is found across the North Atlantic. During the breeding season, fulmars feed on zooplankton, squid, fish, and carrion (*5*). Fulmars from Cape Vera acquire most of their prey between Ellesmere Island and Greenland, 250 to 400 km from the colony.

We sampled 11 ponds; eight of these were located across a gradient of fulmar influence, and three ponds were outside the area influenced by seabird populations. The effect of birds on ponds was established by quantifying algal growth, water quality variables related to seabird guano inputs, and stable isotope ratios of nitrogen ($\delta^{15}N$) in pond sediment, which are enriched in guano relative to other N sources in the area. Because fulmars feed near the top of the marine food chain, $\delta^{15}N$ values in their tissues are elevated relative to atmospheric and terrestrial sources (*6*). $\delta^{15}N$ in sediment ranged from 0.74 to 18.4 per mil (‰), compared to 20.4‰ measured in guano (table S1).

Concentrations of dichlorodiphenyltrichloroethane (DDT), mercury, hexachlorobenzene (HCB), and other organochlorine compounds in the pond sediments showed strong correlations with both sedimentary $\delta^{15}N$ (Fig. 1) and nutrient concentrations in the water. Concentrations of HCB increased 10-fold over this impact range; mercury increased 25-fold; and DDT and its metabolites increased more than 60-fold, with the highest concentrations observed in the ponds that were most enriched by seabirds. Mercury concentrations in sediments of three ponds in the area most affected by seabirds approached or exceeded the Canadian environmental quality guidelines for protecting wildlife. Moreover, as animals convert DDT to its more persistent metabolite DDE, we might expect the relative proportions of DDT and its metabolites to be affected by the source of contamination. The ratio of DDE to DDT correlated significantly with $\delta^{15}N$; ratios in sediments reached 0.9, which are identical to values measured in guano. Thus, DDT in the more affected ponds was more "biologically processed," as we might expect of substances that have passed through the marine food web, which further corroborates their transport by biological vectors.

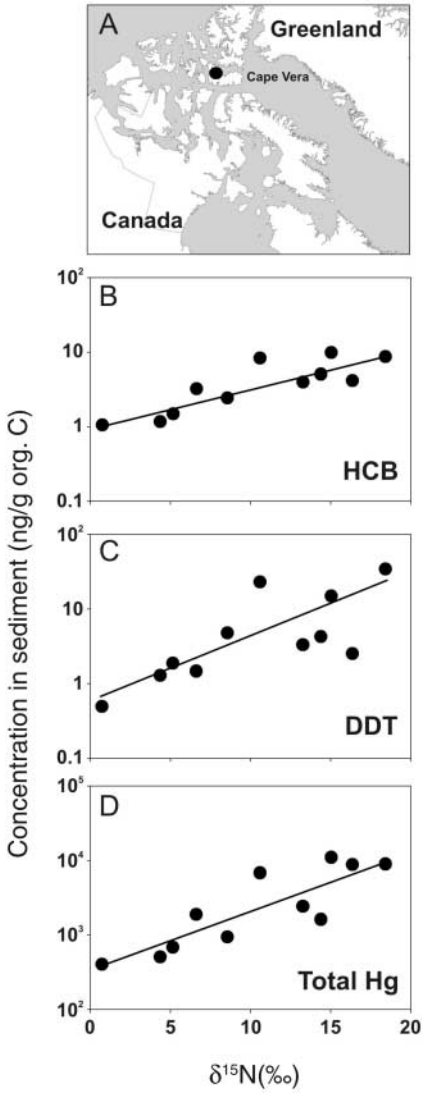

Fig. 1. (**A**) Sample sites. (**B** to **D**) Contaminant concentrations of (B) HCB, (C) DDT, and (D) total mercury (Hg) in surface sediments are plotted against $\delta^{15}N$. We use $\delta^{15}N$ as a proxy of seabird influence. However, when we expressed the contaminant data relative to other indicators of guano input [e.g., total P, total N, dissolved organic C (org. C), Cd], we found similar relationships. DDT values shown are the sum of DDT and its derivatives.

Contaminants in arctic wildlife are of particular concern both for ecosystem health and because traditional foods remain an important part of the diet of indigenous peoples. Although the biological pump mediated by seabirds provides a critical nutrient subsidy to terrestrial arctic ecosystems, seabirds are now also transporting and concentrating industrially produced contaminants to these remote environments.

References and Notes

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7. Supported by the Natural Sciences and Engineering Research Council of Canada, the EJLB Foundation, the Polar Continental Shelf Project, and the Northern Scientific Training Program.

Supporting Online Material
www.sciencemag.org/cgi/content/full/309/5733/445/DC1
Table S1

23 March 2005; accepted 22 April 2005
10.1126/science.1112658

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