Effects of Persistent Organic Pollutants (POPs) in Arctic Wildlife

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Introduction

Arctic biota contain a range of persistent organic pollutants (POPs), particularly organochlorines (OCs). In some Arctic species, concentrations of some POPs are as high as those seen to cause effects in other highly contaminated biota from more southerly latitudes. Two Arctic Monitoring and Assessment Programme (AMAP) Assessments[1,2], as well as some new studies[3-9] confirm that effects are occurring in the Arctic and these are reviewed here. Species that might be at risk for specific types of effects based on their tissue concentrations and dietary intakes of certain POPs are also identified.

Methods

There are three general strategies for assessing the potential effects of contaminants on living organisms. These are: 1) measuring subtle indicators of biological responses (biomarkers) to contaminants and correlating these to tissue concentrations of specific OCs; 2) using field experiments and laboratory studies with Arctic species, to better build the case that specific POPs are the cause of the effects being seen; and 3) comparing levels of OCs in Arctic species to known detrimental levels such as no-adverse-effect-levels (NOAEL/NOEL) and lowest-adverse-effect-levels (LOAEL/LOEL) derived from laboratory tests or from observations on affected animals in the wild. In this assessment, comparisons were also made between OC levels in the diet of selected Arctic biota and known dietary no-adverse-effect-concentrations (NOAEC), lowest-adverse-effect-concentrations (LOAEC) in food or to environmental quality criteria/guideline values for protecting wildlife that consume aquatic biota.

Results and Discussion

Current concentrations of some OCs in several Arctic species are correlated to various types of biological effects or are at or above the known threshold levels associated with effects that have been seen in other species studied either in the laboratory or in the field. Based on these results the following conclusions can be drawn.

Reproduction and development: Negative effects on reproduction and development have been seen and are correlated to increased levels of various POPs (primarily DDE, PCB and dioxin-like compounds) in Alaskan peregrine falcons, bald eagles from the Aleutian Islands, glaucous gulls from Bjørnøya (Norway), great black-backed gulls from northern Norway[4] and Svalbard and Hudson Bay polar bears. In female polar bears from Svalbard, increasing plasma progesterone levels were correlated with higher PCB concentrations, indicating possible inhibition of enzymes that convert progesterone to estrogen[5]. Bone mineral density in Greenland polar bears was negatively correlated to higher OC levels[6].

Cytochrome P450: Increased cytochrome P4501A (CYP1A) enzyme activities (often measured as EROD) are correlated to increased PCB levels in Arctic char from two lakes (with high or low POP levels) on Bjørnøya, in glaucous gulls at Bjørnøya, in black guillemot from Saglek Bay, Canada, and in Svalbard ringed seals and polar bears. Increased testosterone 6-b hydroxylation (CYP3A) is correlated to increased toxaphene levels in Svalbard harp seals. Laboratory studies with wild Arctic char show increased EROD activity correlated to PCB treatment, with stronger effects in fasted versus fed fish.

Hormones: Decreased retinol levels are correlated to increased levels of PCBs in black guillemots at Saglek Bay, Canada, PCBs and/or TEQs from dioxin-like compounds in northern fur seal pups from the Aleutian Islands and PCB, HCB and HCH levels in Svalbard polar bears. In a comparison of polar bears from Svalbard (higher PCB levels) and

Resolute, Canada (lower PCB levels), retinol levels were negatively correlated with persistent PCBs and positively correlated with OH-PCBs, suggesting that PCB affects retinol metabolism and storage in the liver. Decreased thyroid hormone levels (particularly T4) are correlated to increased levels of HCB, DDE, PCB and oxychlordane in male glaucous gulls from Bjørnøya[7], increased PCB and TEQs in northern fur seal pups, and increased PCB levels in polar bear from the Svalbard/Resolute study.

Immune response: In laboratory studies, basal cortisol levels were suppressed by PCBs in starved Arctic char after handling. Disease susceptibility was highest in the fed char with no difference due to PCB exposure, while disease susceptibility increased with PCB exposure in the starved group. This indicates that PCBs compromise stress responses and reduce immunocompetence, and the effect of fasting makes char more sensitive to the effects of PCBs. In northern fur seal and Steller sea lion pups, various measures of normal immune function were negatively correlated to increasing PCB levels. Decreased antibody production after vaccination was also correlated to increased PCBs in northern fur seals. In Svalbard polar bears, a significant decrease in antibodies with increased PCB levels was found. In mothers and cubs, a similar negative correlation was found for IgG levels in cubs. In the Svalbard/Resolute study, polar bears with high PCB levels were found to exhibit immunosuppression expressed as reduced IgG production and lowered lymphocyte responses after vaccination. Reduced cortisol levels were correlated to high OC levels in Svalbard polar bears[8]. The intensity of nematodes was positively correlated with concentrations of DDT, mirex and PCB in glaucous gulls from Bjørnøya. Laboratory studies of glaucous gull chicks with high dietary PCB exposure show an impaired ability to produce antibodies (IgG and IgM). In a field vaccination experiment with wild glaucous gulls from Bjørnøya, correlations were seen between reduced lymphocytes and reduced vaccination response and high OC levels, indicating increased disease susceptibility[9].

Comparison to thresholds: Based on known thresholds for effects, several Arctic species may be at risk for reproductive and/or immunosuppressive effects from current levels of SDDT, SPCB, and/or dioxin-like substances. Those at greatest risk include peregrine falcons, bald eagles, white-tailed sea eagles, glaucous and great black-backed gulls, great skuas, some alcids, harbor porpoises, seals, northern fur seals, Steller sea lions, belugas, long-finned pilot whales, narwhal, minke whales, killer whales, sea otters, polar bears, and Arctic fox. If the risk for subtle neurobehavioral effects from SPCB in exposed offspring of mammals is included, then some reindeer and mountain hares, wolverines, walrus and gray whales are also potentially at risk. Burbot from some sites have toxaphene levels high enough to affect fry bone development and burbot, land-locked char (Bjørnøya), Greenland shark and Greenland halibut have SPCB levels associated with increased liver enzyme production in Arctic char.

Dietary intake: An assessment of risks from dietary intake was attempted, based on results from laboratory feeding experiments, POP levels in prey items, and information on different species' food preferences. Reproduction in piscivorous marine mammals such as minke whale, beluga, narwhal, long-finned pilot whale, harbor porpoise, and seals may be affected by dietary levels of SPCB in marine fish. Killer whales, walrus, polar bear, and Arctic fox that prey on seals have dietary intakes of SPCB that may cause reproductive effects. Using environmental quality guidelines for protecting aquatic wildlife, dietary intakes of SDDT, SPCB, toxaphene and dioxin-like substances are problematic for many marine and freshwater piscivorous species and in some cases for molluscivores. The same is true for predatory seabirds feeding on seabird eggs and chicks and for killer whale, walrus, polar bear, and Arctic fox that consume marine mammals.

Conclusions

Studies in Arctic biota have found associations between several biomarkers and concentrations of some POPs. Biomarkers for POP effects measure changes at the cellular or individual level and are warning signals. These studies have included both field experiments and laboratory studies, which gives added weight to the possible link between some POPs and. Of particular biological significance are those biomarkers relates to affects on resistance to infection, reproduction and behavior. Negative effects on these reduce the margin of safety for the affected species, putting them at higher risk. Levels of POPs in some arctic biota are above levels associated with threshold effects in the biota or for biota that consume them. Therefore, based on the present evidence, it is believed that effects of biological significance are occurring in some Arctic species related to POPs exposure.

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