Environmental pollutants in top predators from the Norwegian coast and Arctic - occurence, levels and effects

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Introduction

The persistent, lipophilic and toxic organochlorines (OCs), like the pesticides DDT and the industrial chemicals polychlorinated biphenyls (PCBs), have for many years been of great concern as environmental pollutants in the marine ecosystems. Such compounds are stored in body fats and increasingly concentrated along food webs. OCs are transferred to the Arctic by air and water currents (1,2) and surprisingly high OC levels, especially PCBs and certain chlordane metabolites are found in marine mammals constituting ends of marine food chains and in top predator seabirds in the Arctic (3-10). Toxic effects related to exposure to such levels have been reported in marine mammals living in particularly polluted waters (11-13) and from various experimental studies it is well known that OCs may generate adverse effects after chronic administration and both the pesticides and the PCBs may produce a range of effects including neuro, reproductional and immunotoxicities (14-18). The Norwegian Polar Institute, the Universities of Oslo, Bergen and Trondheim, the Norwegian College of Veterinary Medicine and the National Veterinary Institute have since 1987 collaborated with the aims to provide comprehensive baseline data on important OC contaminants, to assess factors influencing the levels and to elucidate possible biological/toxic effects of particularly the very high PCB exposure in marine mammals and seabirds (particularly the avian top predator glaucous gull) from the Norwegian coast and Arctic. Thus, the occurence and levels of selected OCs (22-42 individual PCB congeners, DDTs, chlordanes, HCB and HCHs) were studied in harbour seals (*Phoca vitulina*) (19, 20), grey seals (*Halichoerus grypus*) (21,22), harbour porpoises (*Phocoena phocoena*) (22) and minke whale (*Balaenoptera acutorostrata*) (24) caught along the coast of Norway, ringed seals (*Phoca hispida*) (25), harp seals (*Phoca groenlandica*) (24,26-28), hooded seals (*Cystophora cristata*) (28) in the Barents Sea area, polar fox (*Alopex lagopus*) at Svalbard (29), glaucous gulls (*Larus hyperboreus*) at Svalbard and Bjørnøya (4,5) and polar bears (*Ursus maritimus*) in the Svalbard area and in the Russian Arctic (7,8,30,31). Studies of the possible toxic effects, particularly on the immunosystem and reproduction, of the very high PCB levels in glaucous gull and polar bear are on-going. Data obtained in the field (f.i. reproductive success and cub survival in polar bears and intestinal nematodes in glaucous gulls), levels of various biochemical and physiological parameters (f.i. thyroid hormones and retinol, EROD activity, IgG, IgM, IgA) have been coupled with PCB levels (5-7, 30-32). In addition, immunization studies are in progress to reveal possible effects of PCBs on the immune system (disease

resistance) as measured by specific antibody response, immunoglobulin concentrations and occurence of natural antibodies in polar bear and glaucous gull from area with high and low PCB exposure. Highlights from these collaborative studies will be presented.

Materials and methods

Sampling procedures

Samples of more than 1000 individuals were obtained from live animals (blood and adipose tissue) and animals killed for scientific purposes (blood and various tissue samples).
Sampling of polar bears was done during March and April each year from 1990 to 1998 on land-fast ice. Most captures took place in the southern and south-eastern parts of Svalbard, with a few bears captured in the northern parts of the archipelago. Blood samples were also collected from polar bears from the Russian Arctic in cooperation with G. Garner and S. Belikov from Alaska and Moskow, respectively. Bears were anesthetized by using remote intramuscular injection of Zoletil(R) from a helicopter (33). Anesthetized bears were measured and their physical condition assessed. A vestigal tooth was extracted for age determination by cementum annuli (34). Details on sampling procedures for all species are presented in the specific papers (3-8, 19-33). Samples were stored in polypropylene containers (-20^{0}C).

Field studies

Most adult female polar bears were equipped with satellite transmitters (Telonics Inc., Mesa, Arizona, USA) (33). The transmitters were programmed to send information during six hour intervals every six days for about two years. Information on the location of the transmitter as well as sensor data on internal transmitter temperature and short- and long-term bear activity were recorded. Female polar bears normally have a three year reproductive cycle and mate during spring. Only pregnant bears are denning. Reproductive rates can be estimated from satellite data.

A total of 40 adult glaucous gulls were sampled at Bjørnøya in July 1996. The intestine of each gull was examined for macro-parasites (32)

Analyses of organochlorines

All samples were analyzed by the same methods in the same laboratory, Miljøtokslaboratoriet, at the Norwegian College of Veterinary Medicine, which is accredited as a testing laboratory according to the requirements of NS-En 45001 and ISO/IEC Guide 25 for these analyses. Details of the analytical method used and the analytical quality are described in (7) and species/sample dependent modifications are given in the respective papers (3-8, 19-33).

Analyses of vitamin A

Total retinol (i.e. retinol plus retinyl esters) in polar bear plasma was determined at the university of Oslo by HPLC after hydrolysis with potassium hydroxide (10%) in ethanol and extraction into hexane as described in (35). The method for vitamin A determination in glaucous gull and grey seal is described in (5,21).

Analyses of thyroid hormones

Determination of the concentration of free thyroxin (FT4) and total thyroxin (TT4) in polar bear plasma was done by fluoroimmunoanalyses (Delfia kit, Wallac, Turku, Finland) at Hormonlaboratoriet, Aker sykehus, Oslo, Norway. The method for thyroid hormone determination in grey seal is described in (21).

Analyses of IgG

Serum IgG concentration was measured using a conventional single radial immunodiffusion test (36). Antiserum against purified polarbear IgG was produced in rabbits. The diameters of the precipitation zones were measured and the IgG concentrations were calculated from a standard curve derived from five dilutions of purified IgG on each plate.

Activities of EROD

The method for determination of activities of hepatic EROD in glaucous gull is described in (5)

Results and discussion

Many factors like age, sex, season (nutritional- and reproductive status, feeding habits) are known to influence the levels and pattern of OCs. Comparison of OC levels between species and groups of individuals should always be done with this knowledge in mind. The major contaminants found were PCBs. Alarmingly high PCB levels were found in polar bear at Svalbard (mean 25 ppm in fat), harbour porpoise along the Norwegian coast (mean 20 ppm in blubber) and glaucous gull at Bjørnøya (mean 16 ppm hepatic tissue fw) (3-7,37). Polar foxes from Svalbard also contained high levels of PCBs (mean 8 ppm in fat) as compared to corresponding levels in foxes on the Norwegian mainland (29). Relatively low PCB levels were found in the different seal species and minke whale, though the individual differences were large and differences between populations of the same species varied also (23,24-28,37). Differences in food preferences explain most of the variation in pollutant levels between species and it may also contribute to variation between populations of the same species or even between individuals of the same populations when diet is subject to age-related or sex-related variations. Differences in xenobiotic metabolizing capacity between species also play an important role, and by comparing the detailed pollutant pattern between species indirect information about the metabolizing capacity is demonstrated (3,6,7,38). Variable proportions of most OCs are transferred to marine mammal offspring during gestation and particularly during lactation. The total amount of OCs transferred during a complete reproductive cycle is estimated to range 7-100%, depending on the species and compound. This result in a decrease or a stabilization of tissue concentrations in mature female marine mammals, thus producing lower residue levels in adult females as compared to adult males. Accumulation of PCBs with age was found in male harbour porpoises and in male polar bears, and significantly higher levels of PCBs were found in adult harbour seals at the southern coast of Norway and in adult male polar bears than in their corresponding females (7,19,23). However, since all compounds are not transferred at the same rate, their relative abundance varies with age and sex. Different seal species undergo a yearly cycle of reproduction in the winter and moulting in early spring with low blubber layer and relatively high blubber levels of OCs as demonstrated in harp seals sampled at different times during their reproductive cycle (24,26). Also in glaucous gull the effect of changes in the nutritional condition on OC levels have been demonstrated (6). The importance of differential transfer of the different OCs from mother to offspring via milk has been demonstrated in polar bear, harp seal and hooded seal (7,23). F.i. the levels of most PCBs were higher in depot lipid of polar bear yearlings than in depot lipid in their mothers. This means that young cubs are exposed to PCBs at a period of growth and development when they are most sensitive. Geographical differences in OC levels were observed between comparable groups of animals. Thus, a decreasing OC level from south to north along the coast of Norway was found in harbour porpoises and harbour seal (3,19,26) and an increasing PCB level was found in harp seal from the the West Ice area to the East Ice area (23). Also in polar bear where the PCB levels at

Svalbard are about 6 and 3 times higher than the corresponding levels in Alaska and in Canada respectively (9), the levels are increasing further reaching a maximum around Franz Josephs land and the Kara Sea area. Further east PCB levels are declining towards Alaskian level (39). Studies on the possible toxic effects on polar bears and glaucous gulls of the very high PCB levels are on-going. Field studies on reproduction success of female bears did not reveal any connection with PCB levels, the sample sizes are, however still small (7). The cub survival of polar bears at Svalbard is, however lower than in most other polar bear populations (40). The reason for this low survival is not clear but the high pre- and postnatal intake of PCBs at a crucial period could adversely influence the early development of cubs and lead to higher mortality. In glaucous gull at Svalbard a significant positive association was found between helminth nematode infection intensities and PCB level (32). Normal regulations of vitamin A and thyroid hormones are important for a wide range of biological functions such as growth, cell differentiation, reproduction, behaviour and function of the immune system. PCBs have been found to disturb the functions of these parameters both in experimental species and marine mammals (41). Our polar bear studies have revealed a significant negative correlation between PCBs and retinol and thyroid hormones respectively in plasma (30), while in glaucous gull the very high PCB levels found in the liver did not significantly correlate with plasma retinol levels. However, in glaucous gull a significant positive correlation was found between retinol plasma level and hepatic EROD activity, which was negatively correlated with some of the PCB congeners (5). The significance for the individual polar bear and glaucous gull of these findings, indicating effects of PCBs on the molecular level, is however difficult to interpret. Studies on a possible effects of the very high PCB levels on the immune system are in progress and preliminary results indicate immune suppression since a negative correlation between IgG and sum PCB in plasma has been found (31). In conclusion, the biological effect studies on polar bear at Svalbard and glaucous gull at Bjørnøya show some responses that may be related to current levels of PCBs. Thus, in polar bear there is some evidence of reduced cub survival, disturbed immune function and disturbance of the thyroid hormone and retinol balances. The significance of these findings on individual and population levels has to be further elucidated and studies are in progress focusing on immunotoxicology in particular.

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