Organochlorines and Trophic Positions in a Marine Pelagic Food Chain Leading to Seabirds in the Norwegian Arctic

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Introduction

The lipophilic and hydrophobic organochlorines are persistent in the environment and tend to bioaccumulate in the body lipids of organisms. Organisms in polar regions are particularly vulnerable to bioaccumulation because of their high content of lipids for energy storage (1,2). In the Arctic, transfer through the diet (biomagnification) has resulted in high concentrations of some organochlorines in top predators such as the polar bear (*Ursus maritimus*) (3-5) and the glaucous gull (*Larus hyperboreus*) (6).

Studies of the fate of organochlorines in organisms in marine food chains leading to top predators have been carried out in the Canadian Arctic (7,8). However, there are few data available on the organochlorine burden in organisms others than the top predators in the Norwegian Arctic.

To study the bioaccumulation of organochlorines in food chains leading to glaucous gull, the following animals were chosen for organochlorine analysis; copepods (*Calanus* spp.), euphausiids (*Thysanoessa* spp.), amphipods (*Parathemisto libellula*), polar cod (*Boreogadus saida*), Atlantic cod (*Gadus morhua*), black-legged kittiwake (*Rissa tridactyla*) and glaucous gull. Spider crab (*Hyas araneus*) was also included in this study since it has been found to be eaten by the glaucous gull (9).

The trophic relationships among the organisms included in the present study have been described based on stomach analysis (10,11). However, trophic models based on stomach analysis only give an idea of the trophic position of an organism with respect to momentary ingestion. Stomach analysis do not reveal the influence of assimilation ability and temporal or spatial variations in diet on trophic position of an organism (12). Another approach to determine the trophic position of an organism is to determine the enrichment of naturally occurring stabile isotopes of nitrogen in the organisms (12,13). The $\delta^{14}N$ is excreted by the organisms whereas the heavy isotope of nitrogen ($\delta^{15}N$) is not. Thus, nitrogen isotope ratios were included to determine the relationship between the burden of organochlorines and the trophic position of the organisms.

Materials and Methods

The animals for organochlorine analysis were collected in June 1995 from the vicinity of Bjørnøya, Svalbard (74°23'N, 19°10'E), during the ICE-BAR 1995 cruise organised by the Norwegian Polar Institute (14). Crustaceans and fishes were collected by trawling, except crabs which were collected by divers at 15 meter depth on the south coast of Bjørnøya. The seabirds were shot. Polar cod were caught by a fishing boat in the vicinity of Bjørnøya in May, when the area was still influenced by ice.

The concentrations of HCHs (the sum of α-, β- and γ-HCH), HCB, chlordanes (the sum of *cis*-chlordane, oxychlordane and *trans*-nonachlor), DDTs (the sum of *p,p'*-DDE, *p,p'*-DDD, and *p,p'*-DDT), PCBs (the sum of congeners PCB-28, -31, -52, -47, -66, -101, -99, -110, -151, -149, -118, -153, -105, -141, -137, -138, -187, -128, -156, -157, -180, -170, -199, -196, -189, -194, -206, -209) were quantified by GC-ECD in the whole body of zooplankton (two pooled samples from each species), polar cod (n=14) and Atlantic cod (n=15), in the hepatopancreas of spider crabs (two pooled samples) and in the livers of kittiwake (n=11) and glaucous gull (n=15). The analysis where carried out at the accredited Environmental Toxicology Laboratory at the Norwegian College of Veterinary Medicine, Oslo, Norway (5,15).

Zooplankton and polar cod for stable nitrogen isotope analysis were collected by WP-3 net (1000 μm mesh size), Tucker trawl and SCUBA diving in the marginal ice zone of the Barents Sea during the cruise (14). Spider crabs, Atlantic cod and seabirds for stable nitrogen isotope analysis were collected close to Bjørnøya during the same cruise (14). The analysis of stable nitrogen isotopes were carried out at The Institute for Energy Technology, Kjeller, Norway, using the standard methods as described by Hobson & Welch (13). The enrichment of $\delta^{15}N$ in the whole body of the crustaceans and in the muscle of the fishes and the seabirds is expressed as $\delta^{15}N$-values: $\delta^{15}N=((\delta^{15}N/\delta^{14}N)_{sample}-(\delta^{15}N/\delta^{14}N)_{air})*1000$ (12,13). The $\delta^{15}N$-value usually increases stepwise by 3-5 ‰ per trophic transfer, which can be used to assign a trophic level to the organism (12,13).

Results and Discussion

The concentrations and relative patterns of the different organochlorines in the organisms have been described elsewhere (15).

Here, we focus on the bioaccumulation of organochlorines with respect to trophic position of the organism, and the biomagnification potentials of the various organochlorine groups with respect to their physicochemical properties.

The $\delta^{15}N$-values increased from 9.38 ‰ in copepods to 15.8 ‰ in seabirds (Table 1). A stepwise enrichment of 3.8 ‰ was used to assign a trophic level to organisms lower in the food chain (copepods to fishes) (12,13). Due to a different catabolism, a stepwise enrichment of 2.4 ‰ was used to assign a trophic level to the seabirds (12,13).

The relationships between the log-transformed mean concentrations in $ng \cdot g^{-1}$ lipid weight of the organochlorines (HCHs, HCB, chlordanes, DDTs and PCBs) and the mean levels of $\delta^{15}N$-values are shown in Figure 1. In the lower end of the food chain (copepods to fish) the mean concentrations of the different organochlorine groups were low (10.1–85.8 $ng \cdot g^{-1}$ lipid weight) and did not increase with the organisms' trophic position. In the upper end of the food chain (seabirds) the concentrations of organochlorines were one to three orders of magnitude higher than in crustaceans and fish, depending on the organochlorine group (Figure 1) (15).

Table 1. Relationship between mean stable nitrogen isotope values; $\delta^{15}N$ (SD) (14), and trophic position of the organisms (13).

Organisms	n	$\delta^{15}N$	Trophic position
Copepods	5	9.38 (0.43)	2.05*
Euphausiids	4	10.48 (0.71)	2.34*
P.libellula	1	11.85 (-)	2.70*
Spider crab	2	12.30 (0.20)	2.82*
Polar cod	4	13.75 (0.34)	3.20*
Atlantic cod	4	14.23 (0.64)	3.32*
Kittiwake	3	14.43 (0.87)	4.76**(3.38*)
Glaucous gull	4	15.80 (0.23)	5.33**(3.74*)

*Trophic position calculated as $TL=1+(\delta^{15}N-5.4)/3.8$ (13).

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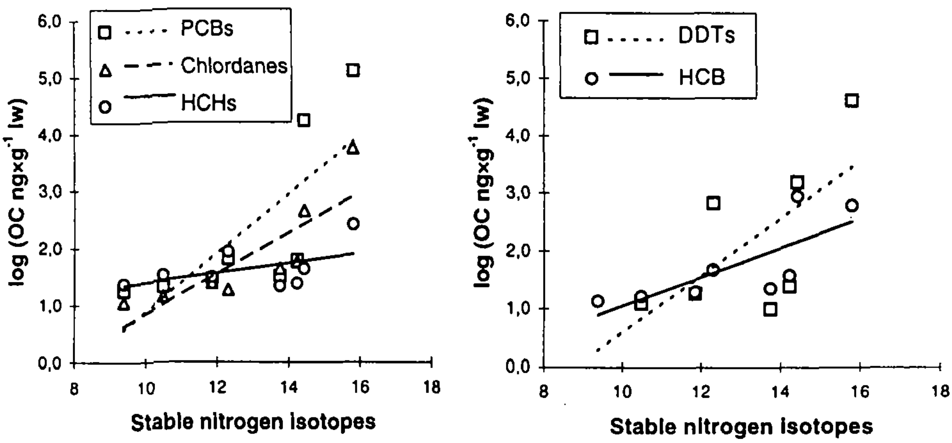

Figure 1. Relationships between log-transformed mean concentrations ($ng \cdot g^{-1}$ lipid weight) of the different organochlorines (OC) and mean stable nitrogen isotope values ($\delta^{15}N$) in the marine pelagic food chain leading to seabirds from the Barents Sea area. Linear trend lines illustrate the biomagnification potential of the different organochlorines from the lower to the upper end of the food chain.

The mode of bioaccumulation of the various organochlorines depends on the physicochemical properties of the compounds such as their hydrophobicity and lipophilicity (17). These properties are often described by octanol-water-partitioning-coefficients (K_{ow}s). The K_{ow}s increase with increasing lipophilicity and hydrophobicity of the substance (16). Organisms show increased bioaccumulation and decreased elimination of organochlorines with log K_{ow} greater than 5, whereas organochlorines with lower log K_{ow}s are more readily metabolised and excreted (17).

The overall increase in organochlorine concentrations with the organisms trophic position in the marine food chain was least for HCHs, followed by HCB, intermediate for chlordanes, followed by DDTs and highest for PCBs (Figure 1). This is consistent with the physicochemical properties of these compounds in which HCHs, HCB, chlordanes and DDT have log K_{ow}s of about 4, 6, 6 and 7, respectively (16-18), whereas the log K_{ow}s PCBs increase from 5 to 8, depending on the degree of chlorination (17).

Thus, the biomagnification of the different organochlorines in the present marine food chain are generally consistent with the physicochemical properties of the compounds.

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