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Organochlorine and Mercury Residues in Snakes from Pilot and Spider Islands, Lake Michigan—1978

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Little is known about the chronic effects of environmental pollutants on snakes (HALL 1980), but some investigators have suggested that snakes make good biological indicators of environmental contamination (FLEET and PLAPP 1978, BRISBIN et al. 1974, BAUERLE et al. 1975, JANSSEN et al. 1976, STAFFORD et al. 1976). Being carnivorous, snakes would be expected to carry fairly high contaminant loads as a result of food chain concentration. They are also generally more sedentary than many other vertebrates and should, therefore, be good indicators of pollutants in the area where they are collected. During the course of a contaminant study with waterfowl on several islands in Lake Michigan, we collected snakes in order to measure their organochlorine and mercury levels.

METHODS

On 3 June 1978, we collected one northern water snake (Nerodia sipedon) on Pilot Island, and between 17 June and 20 July 1978, we collected six common garter snakes (Thamnophis sirtalis) on Spider Island. Both islands are located in Lake Michigan, off the northern tip of the Door County peninsula, Wisconsin. Pilot Island is about 1.7 km from another island, Detroit Island, and about 3.9 km from the Door County peninsula. Spider Island is about 0.9 km from the peninsula. We have found birds from this area of Lake Michigan to be highly contaminated with organochlorines and mercury (unpublished data).

We froze the snakes, and at a later date they were thawed, measured, sexed, and the stomach contents identified and separated from the remainder of the carcass. Samples were then kept frozen until chemical analyses were performed. Ova from the watersnake and embryos from the female garter snakes were included with the carcasses for residue analyses.

The procedures used to prepare the carcasses and stomach contents and those used in solvent extractions, lipid removal, and organochlorine pesticide separation were described by CROMARTIE et al. (1975). Samples were separated into four fractions to insure the isolation of dieldrin and endrin. Quantitation of organochlorines in these fractions was performed using a gas-liquid chromatograph equipped with an electron-capture detector, automatic sampler, digital processor, and a 1.5% OV-17/1.95% QF-1 column (KAISER et al. 1980). The analytical method for toxaphene followed PROUTY et

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al. (1977). Other pesticides and PCBs were quantified as described by CROMARTIE et al. (1975). PCBs were quantified on the basis of Aroclor 1260.

Average recoveries of organochlorine pesticides and PCBs from spiked bird tissues ranged from 80-104%. Residue levels were not corrected for percentage recovery. The lower limits of quantification on a wet-weight basis were 0.5 ppm for PCBs, 0.05 ppm for endrin, and 0.1 ppm for all other organochlorine pesticides.

Mercury determinations were made by the Environmental Trace Substances Research Center, Columbia, Missouri. Samples of snakes or stomach contents were first digested with nitric acid. Stannous chloride was added to reduce ionic mercury to elemental mercury, which was measured photometrically in the vapor phase by atomic absorption. The lower limit of quantification was 0.001 ppm, wet weight.

RESULTS AND DISCUSSION

Residues of organochlorines and mercury are shown in Table 1. None of the samples contained measurable levels of p,p'-DDD, p,p'-DDT, heptachlor epoxide, oxychlordane, cis-chlordane, cis-nonachlor, toxaphene, mirex, or HCB. Although sample sizes were small, there were no obvious differences in residues between the sexes. Residues in the watersnake appear comparable to those in the garter snakes.

Do our results show snakes to be good biological indicators of organochlorine and mercury pollution? We need to look at this in two ways. First, a good biological indicator should concentrate most of the environmental contaminants in the ecosystem to detectable levels in its tissues, and second, the indicator species should reflect the levels of contaminants in the area of interest and not from some distant place. The first requirement is not met especially well by the snakes in our sample. Fish-eating birds appear to do a better job of concentrating the major contaminants than do the snakes. For example, the carcasses of red-breasted mergansers (Mergus serrator), a fish-eating duck, shot near Spider Island contained as much as 14 ppm DDE, 1.5 ppm dieldrin, 0.48 ppm trans-nonachlor, 47 ppm PCBs, and 1.5 ppm mercury (unpublished data). In addition, the mergansers contained the following residues which were not detected in the snakes: p,p'-DDD, p,p'-DDT, heptachlor epoxide, oxychlordane, cis-nonachlor, toxaphene, mirex, and endrin. We do not know why the snakes were less contaminated than the mergansers. They may rid themselves of organochlorines and mercury more readily or they may not be ingesting as many contaminants. It is also possible that the mergansers picked up some contamination far from the islands where the snakes were collected.

In spite of their fewer and lower residues compared to a fish-eating bird, snakes do meet the second requirement of a biological indicator; they are more sedentary than birds and, therefore, may be more accurate indicators of contaminants in a small area. CARPENTER

TABLE 1

Residues of organochlorines and mercury in snakes and stomach contents of snakes from Pilot and Spider Islands in Lake Michigan.

Material	Sample Number	Sex	Snout-vent length (mm)	Lipid (%)	Contaminant levels (ppm wet-weight) p,p'-DDE	Dieldrin	Endrin	trans-Nonachlor	PCBs	Mercury
Water snake	1	F	855	6.2	1.6	ND	ND	0.25	4.3	0.45
Garter snake	1	F	670	9.0	0.78	0.19	ND	0.33	5.8	0.27
Garter snake	2	M	700	8.6	0.22	ND	ND	0.10	1.3	0.30
Garter snake	3	F	646	4.4	0.24	ND	ND	0.13	1.7	0.14
Garter snake	4	M	680	8.1	0.60	0.11	ND	0.21	3.5	0.40
Garter snake	5	F	752	3.2	0.58	0.11	ND	0.18	3.3	0.41
Garter snake	6	F	701	4.6	0.40	0.10	ND	0.12	1.8	0.30
Nestling bird	1[a]			--[b]	0.22	ND	0.45	ND	0.85	--
Earthworms	2			1.8	ND[c]	ND	ND	ND	ND	0.06
Nestling bird	3			1.5	0.23	ND	ND	ND	1.0	0.17
Earthworms	4			--	ND	ND	ND	ND	ND	0.08
Nestling birds (2)	5			1.1	0.45	ND	ND	ND	1.3	0.16

[a]The sample numbers for stomach contents (nestling birds or earthworms) correspond to the garter snake of the same number.

[b]No analysis was run.

[c]No residues were detected at the quantifiable level.

(1952) calculated the average "activity range" of garter snakes to be only 2.07 acres. FITCH (1965), however, estimated a home range of 35.0 acres for male garter snakes and 22.7 acres for females, a difference from the previous study he attributed primarily to different field techniques and interpretation of results. Water snakes on islands in Lake Erie have evolved into a separate subspecies, although there is some movement of snakes among the islands and mainland (CAMIN and EHRLICH 1958).

We have no information on the movements of snakes onto or off of our study islands, but we believe the garter snakes, at least, are largely sedentary. Residues in snakes on Spider and Pilot Islands could be measured in the future to determine any changes in contaminant levels on or near these islands. However, it is important to recognize that although the snakes may stay on the islands, certain of their food items such as fish and nestling birds may have acquired their residues from some distance away. Nevertheless, snakes probably would be a better indication of local contamination than birds.

Furthermore, both N. sipedon and T. sirtalis are abundant over wide areas of North America. The common garter snake has the largest geographic range of any North American snake and occurs over wide areas where there are no other snakes (FITCH 1965). Therefore, residues in these two species may be compared from one area to another. For example, MEEKS (1968) reported less than 0.1 to 0.9 ppm DDT and metabolites in body cross-sections of northern water snakes from a marsh at the southwestern edge of Lake Erie treated with 0.2 pounds of DDT per acre. Garter snakes collected in areas of Maine sprayed for several years with 1 pound of DDT per acre contained from 3.20 ppm DDT and metabolites in the year following application to 0.06 ppm 10 years after the last spraying (DIMOND et al. 1975). By comparison, our DDE levels in snakes are high, especially in light of the fact that our samples were collected six years after the ban on DDT use.

We have included percentage lipid values in Table 1 because some authors (FLEET et al. 1978, JANSSEN et al. 1976, STAFFORD et al. 1976) analyzed only fat bodies, making whole body comparisons of residues impossible. Using the percentage lipid values in Table 1, one can convert our results to those on a lipid weight basis if comparisons with other studies are desired. The use of the lipid-weight basis greatly exaggerates body burdens of contaminants. Lipid levels are also highly variable and can be expected to change with nutritional and reproductive changes. The expression of residues on a whole body wet-weight basis is probably the most useful way to express results, especially when percentage lipid values are also stated.

Five of the garter snake stomachs contained recognizable food items. Snakes 1, 3, and 5 contained nestling birds and snakes 2 and 4 contained earthworms. Although we could not identify the species of birds found in the stomachs, both red-winged blackbirds (Agelaius phoeniceus) and grackles (Quiscalus quiscula) were common

nesters on the islands. On one occasion we observed a garter snake trying to swallow a nestling bird, and on another occasion a garter snake was seen trying to swallow a small alewife (Alosa pseudoharengus).

The lack of contaminants in earthworms was surprising because the ground on these islands was liberally dotted with herring gull (Larus argentatus) droppings, dead fish, rotting gull eggs, and dead birds, all of which likely contain several contaminants. For example, herring gull eggs collected in 1978 on a nearby island contained as much as 70 ppm DDE, 160 ppm PCBs, and 0.37 ppm mercury (unpublished data). One would expect that as material on the ground decomposed, contaminants would enter the soil. We did not analyze any soil samples for organochlorines and mercury, but apparently the earthworms were not exposed to high levels in the soil. Because the islands are limestone outcrops, their soils are likely alkaline. Pesticides have been reported to be less adsorbed and more rapidly broken down in alkaline soils than in acid soils, although many other soil and climatic factors influence rate of degredation (EDWARDS 1975, GORING et al. 1975). The birds found in the stomachs of three snakes were considerably more contaminated than the earthworms. One of these nestlings contained the only endrin found.

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