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PESTICIDE AND HEAVY METAL LEVELS OF WATERBIRDS IN THE EVERGLADES AGRICULTURAL AREA OF SOUTH FLORIDA

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Abstract.—Egg and liver tissues from eight species of waterbirds collected in the Everglades Agricultural Area (EAA), Lake Okeechobee, and Lake Kissimmee were analyzed for mercury (Hg), lead, DDT, DDE, DDD, dieldrin, heptachlor, *trans*-nonachlor, chlordane, endrin, toxophene, and PCBs. Most tissues exhibited low concentrations of most of the biocides, except for elevated levels of Hg and DDE at the EAA and Lake Okeechobee. Although concentrations generally were below levels currently thought to have a significant biological effect on birds, a few birds had concentrations that were at levels that could be detrimental.

Organochlorine and heavy metal contaminants have been studied in many species of waterbirds (Faber et al. 1972, Biskup et al. 1978, Ohlendorf et al. 1978, Hoffman and Curnov 1979, Blus et al. 1980, Cheney et al. 1981, Custer et al. 1983, Fleming et al. 1984a, Henny et al. 1984, Ohlendorf et al. 1988). Most of these studies have investigated the effects of bioaccumulation of pesticide residues, but some researchers also have studied the direct poisoning of waterbirds (cf. Stickel et al. 1979, Zinkl et al. 1981). Despite having large populations of waterbirds (Ogden 1978), only a few studies have investigated pesticide and heavy metal contamination in Florida (e.g., Ohlendorf et al. 1978, Fleming et al. 1984b).

The Everglades Agricultural Area (EAA) occupies portions of Palm Beach, Hendry, and Broward counties that once constituted the Everglades slough habitat that extended from southern Lake Okeechobee to Florida Bay. Much of this area now is intensively used for growing sugar cane, sweet corn, sod, rice, and various winter vegetable crops. Many types of pesticides are used to control pests and diseases on these agricultural products in the EAA (Florida Department Agricul-

ture 1987, IFAS 1987, Johnson 1987, Kucharek et al. 1988). Currently, there are 10 species of waterbirds with an estimated 12,000-15,000 nesting pairs that breed or forage in the EAA and adjacent wetlands (Runde et al. 1991). There is the potential for pesticide contamination to have an impact on the regional waterbird population. No data on pesticide or heavy metal contamination in waterbirds from the EAA or nearby wetlands are available. A study of pesticide levels for Fulvous Whistling-Ducks (*Dendrocyona bicolor*) in the EAA found a wide array of residues, including the banned pesticide aldrin (Florida Game and Fresh Water Fish Commission, unpubl. data). The dearth of available data precludes the development of recommendations to protect avian species in the EAA from exposure to pesticides. The objective of this study was to establish a contamination data base and allow detection of possible hazardous contaminant levels in selected species of waterbirds in and around the EAA.

METHODS

The initial study design called for collecting eggs and nestlings of waterbirds from one or more breeding sites in the EAA and Lake Okeechobee (see Nesbitt et al. 1982, Runde et al. 1991). However, I was not able to gain access to most private properties with colonies in the EAA region because the landowners did not want to cooperate with a pesticide study. Prolonged drought conditions further reduced the number and location of breeding waterbirds in the EAA in 1991, 1992, and 1993. Therefore, I also decided to collect waterbirds as they foraged in the EAA during the months of May through July as an indication of pesticide and heavy metal contamination of resident birds. A single egg was removed from nests of Great Egrets (*Ardea alba*) and Little Blue Herons (*Egretta caerulea*) at a small colony of waterbirds in the EAA during 1993. Addled eggs of Snail Kites (*Rostrhamus sociabilis*) were collected from nests along the southern edge of Lake Okeechobee in 1992 and 1993. As a control to compare contaminant concentrations elsewhere in Florida, a single egg was collected from waterbird nests at a colony on Bird Island, Lake Kissimmee. Whereas, Lake Kissimmee potentially receives agricultural runoff, I deemed the lake less susceptible to large influxes of contaminants as occurs in the EAA.

All egg volumes first were measured in order to calculate contaminant concentrations with loss of moisture and volume during incubation and storage. Then the contents were removed, stored in chemically cleaned jars, labelled, and frozen for later laboratory analysis. Liver tissues were removed from the collected waterbirds, placed in aluminum foil, tagged, and also frozen for later laboratory analysis. All concentrations in Tables 1-2 and the text are in parts per million (ppm: mg/kg) wet weight of tissue. Because the data for heavy metal and pesticide concentrations were generally skewed, all data were first log-transformed before statistical analyses. Mean values in Tables 1-2 represent geometric means.

RESULTS

Levels of PCBs (<0.05 ppm), chlordane (<0.5 ppm), endrin (<0.5 ppm), toxophene (<0.5 ppm), heptachlor (<0.05 ppm), and *trans*-nonachlor (<0.05) concentrations were found at the minimum limit of de-

tection for most species (Tables 1-2). Some pesticides and heavy metals were found at higher concentrations that allowed comparison within and between the EAA, Lake Okeechobee, and Lake Kissimmee sites.

Mercury (Hg).—Mean and maximum concentrations among waterbirds at all three sites were generally low (Tables 1-2). However, White Ibis (*Eudocimus albus*) and a single Great Blue Heron (*A. herodias*) had elevated levels suggesting possible effects. No significant difference (*t*-test, $P > 0.05$) was detected in Hg concentrations of Anhingas (*Anhinga anhinga*), Little Blue Herons, Snowy Egrets (*E. thula*), and Snail Kites between the EAA/Lake Okeechobee and Lake Kissimmee.

Lead.—White Ibis exhibited higher levels of lead than that of other species of waterbirds (Table 1).

DDT/DDE/DDD.—As expected, most tissues exhibited low concentrations of DDT. However, its metabolites (DDE and DDD) were found in higher concentrations in most tissues. No significant difference (*t*-test, $P > 0.05$) was detected between DDD concentrations between EAA/Lake Okeechobee and Lake Kissimmee. However, DDE concentrations were significantly greater in Anhingas ($t = 1.82$, $P = 0.01$) and Little Blue Herons ($t = 1.77$, $P = 0.01$) in the EAA/Lake Okeechobee compared to Lake Kissimmee.

Dieldrin.—A single Great Egret egg contained an elevated concentration of 1.60 ppm.

DISCUSSION

The results of this study indicate only DDE was present in higher concentrations in egg and liver tissues of waterbirds collected from the EAA and Lake Okeechobee compared to Lake Kissimmee. However, the concentrations of DDE and other contaminants found in tissues from each of the three sites were generally low and probably do not pose a hazard for most individuals at this time. Many pesticides (e.g., chlordane, endrin, toxaphene, heptachlor, PCBs) were not found at their minimum limits of detection in most samples.

It is generally acknowledged that Hg and pesticide concentrations are highest in species that eat fish and other birds (Custer et al. 1983, Ohlendorf et al 1988). In addition, Hg interacts with elevated temperatures and some pesticides (e.g., DDE) to produce synergistic toxicity (Eisler 1987). For comparison with the values in Tables 1-2, Hg concentrations in animal tissues are usually < 1.0 ppm at sites not affected by human activities, and body loads of Hg in experimentally poisoned (LD 50) birds usually exceed 20 ppm (Eisler 1987). Hg concentrations of ≥ 2.0 ppm for eggs and ≥ 3.0 ppm for organ tissues and DDE concentrations of ≥ 10 ppm for eggs and ≥ 25 ppm for organ tissues are generally considered to represent minimum thresholds deemed hazardous to

Table 1. Concentrations of pesticides and heavy metals in waterbird tissues collected in the Everglades Agricultural Area and Lake Okeechobee of south Florida during the breeding seasons of 1992 and 1993. All concentrations are given as ppm (mg/kg) of wet weight.

Species	Contaminant	Number	Mean±Std	Range
Anhinga ^a	Mercury	9	0.13±0.14	0.04-0.85
	Lead	9		<0.01-0.15
	PCBs ^b	9	<0.05	
	DDT	9		<0.01-0.12
	DDE	9	0.44±0.41	0.08-1.30
	DDD	9	<0.05	
	dieldrin	9	<0.05	
	chlordane	9	<0.5	
	endrin	9	<0.5	
	toxaphene	9	<0.5	
	heptachlor	9	<0.05	
	<i>trans</i> -nonachlor	9	<0.05	
Great Blue Heron ^c	Mercury	1	12.00	
	Lead	1	0.08	
	PCBs ^b	1	<0.05	
	DDT	1	<0.01	
	DDE	1	1.60	
	DDD	1	<0.05	
	dieldrin	1	<0.05	
	chlordane	1	<0.5	
	endrin	1	<0.5	
	toxaphene	1	<0.5	
	heptachlor	1	<0.05	
	<i>trans</i> -nonachlor	1	0.07	
Great Egret ^a	Mercury	6	0.08±0.04	0.04-0.18
	Lead	6	<0.01	
	PCBs ^b	6	<0.05	
	DDT	6		<0.05-0.17
	DDE	6	0.08±0.40	<0.05-7.00
	DDD	6	0.04±0.22	<0.05-7.00
	dieldrin	6	0.10±0.38	<0.05-1.60
	chlordane	6	<0.5	
	endrin	6	<0.5	
	toxaphene	6	<0.5	
	heptachlor	6	0.02±0.06	<0.05-0.27
	<i>trans</i> -nonachlor	6	0.14±0.19	<0.05-0.42
Little Blue Heron ^a	Mercury	6	0.09±0.08	0.04-0.30
	Lead	6	<0.01	
	PCBs ^b	6	<0.05	

^aTissue source was eggs.

^bPolychlorinated biphenyl isomers were 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

^cTissue source was liver.

Table 1. (Continued) Concentrations of pesticides and heavy metals in water-bird tissues collected in the Everglades Agricultural Area and Lake Okeechobee of south Florida during the breeding seasons of 1992 and 1993. All concentrations are given as ppm (mg/kg) of wet weight.

Species	Contaminant	Number	Mean±Std	Range
	DDT	6	<0.05	
	DDE	6	0.34±0.52	0.05-1.70
	DDD	6	<0.05	
	dieldrin	6		<0.05-0.20
	chlordane	6	<0.5	
	endrin	6	<0.5	
	toxaphene	6	<0.5	
	heptachlor	6	<0.05	
	<i>trans-nonachlor</i>	6		<0.05-0.26
Snowy Egret ^a	Mercury	5	0.47±0.44	0.18-1.80
	Lead	5	0.01±0.05	<0.01-2.40
	PCBs ^b	5	<0.05	
	DDT	5		<0.05-0.15
	DDE	5	0.57±0.93	<0.05-4.60
	DDD	5		<0.05-0.15
	dieldrin	5		<0.05-0.14
	chlordane	5	<0.5	
	endrin	5	<0.5	
	toxaphene	5	<0.5	
	heptachlor	5	<0.05	
	<i>trans-nonachlor</i>	5		<0.05-0.32
Cattle Egret ^a	Mercury	8	0.02±0.06	<0.01-0.18
	Lead	8	0.01±0.01	<0.01-0.62
	PCBs ^b	8	<0.05	
	DDT	8	<0.05	
	DDE	8		<0.10-1.30
	DDD	8		<0.05-1.00
	dieldrin	8		<0.05-0.31
	chlordane	8	<0.5	
	endrin	8	<0.5	
	toxaphene	8	<0.5	
	heptachlor	8	<0.05	
	<i>trans-nonachlor</i>	8	<0.05	
White Ibis ^c	Mercury	3	0.72±0.89	0.35-3.00
	Lead	3	0.22±0.29	0.05-0.71
	PCBs ^b	3		<0.05-0.63
	DDT	3	<0.05	
	DDE	3	1.92±0.53	1.40-2.30
	DDD	3	<0.05	

^aTissue source was eggs.

^bPolychlorinated biphenyl isomers were 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

^cTissue source was liver.

Table 1. (Continued) Concentrations of pesticides and heavy metals in water-bird tissues collected in the Everglades Agricultural Area and Lake Okeechobee of south Florida during the breeding seasons of 1992 and 1993. All concentrations are given as ppm (mg/kg) of wet weight.

Species	Contaminant	Number	Mean±Std	Range
	dieldrin	3		<0.05-0.33
	chlordane	3	<0.5	
	endrin	3	<0.5	
	toxaphene	3	<0.5	
	heptachlor	3		<0.05-0.09
	<i>trans</i> -nonachlor	3	<0.05	
Snail Kite ^a	Mercury	7	0.08±0.07	0.02-0.35
	Lead	7		<0.01-0.17
	PCBs ^b	7	<0.05	
	DDT	7	<0.05	
	DDE	7		<0.05-0.05
	DDD	7		<0.05-0.05
	dieldrin	7	<0.05	
	chlordane	7	<0.5	
	endrin	7	<0.5	
	toxaphene	7	<0.5	
	heptachlor	7	<0.05	
	<i>trans</i> -nonachlor	7	<0.05	

^aTissue source was eggs.

^bPolychlorinated biphenyl isomers were 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

^cTissue source was liver.

cause disruption of the behavior and physiology of sensitive avian species (Faber et al. 1972, Blus et al. 1980, Cheney et al. 1981, Eisler 1987). Only a single Great Blue Heron collected in the EAA exhibited Hg concentration (12 ppm) that exceeded the critical value for Hg. The elevated Hg levels in White Ibis warrant further study to determine if this heavy metal is affecting the species in south Florida. The highest concentration of DDE in tissues from the EAA was from a Great Egret egg (7.0 ppm). Dieldrin concentrations of 1-5 ppm can cause eggshell thinning. Though low in most of the species studied, dieldrin contamination was of concern with one Great Egret egg containing 1.60 ppm dieldrin, suggesting possible problems associated with this pesticide.

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Table 2. Concentrations of pesticides and heavy metals in waterbird tissues collected in Lake Kissimmee of central Florida during the breeding seasons of 1992 and 1993. All concentrations are given as ppm (mg/kg) of wet weight.

Species	Contaminant	Number	Mean±Std	Range		
Anhinga ^a	Mercury	4	0.05±0.03	0.03-0.13		
	Lead	4	<0.01			
	PCBs ^b	4	<0.05			
	DDT	4	<0.01			
	DDE	4	0.14±0.04			
	DDD	4	<0.05			
	dieldrin	4	<0.05			
	chlordane	4	<0.5			
	endrin	4	<0.5			
	toxaphene	4	<0.5			
	heptachlor	4	<0.05			
	<i>trans</i> -nonachlor	4	<0.05			
Little Blue Heron ^a	Mercury	5	0.16±0.03	0.03-0.13		
	Lead	5	<0.01			
	PCBs ^b	5	<0.05			
	DDT	5	<0.05			
	DDE	5	<0.05			
	DDD	5	<0.05			
	dieldrin	5			<0.05-0.20	
	chlordane	5	<0.5			
	endrin	5	<0.5			
	toxaphene	5	<0.5			
	heptachlor	5	<0.05			
	<i>trans</i> -nonachlor	5				<0.05-0.26
Snowy Egret ^a	Mercury	5	0.22±0.05	0.16-0.27		
	Lead	5	<0.01			
	PCBs ^b	5	<0.05			
	DDT	5	<0.05			
	DDE	5	<0.05			
	DDD	5	<0.05			
dieldrin	5	<0.05				
chlordane	5	<0.5				
endrin	5	<0.5				
toxaphene	5	<0.5				
heptachlor	5	<0.05				
<i>trans</i> -nonachlor	5	<0.05				
Snail Kite ^a	Mercury	3	0.06±0.06	0.03-0.18		
	Lead	3	<0.05			
	PCBs ^b	3	<0.05			
	DDT	3	<0.05			

^aTissue source was eggs.

^bPolychlorinated biphenyl isomers were 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Table 2. (Continued) Concentrations of pesticides and heavy metals in waterbird tissues collected in Lake Kissimmee of central Florida during the breeding seasons of 1992 and 1993. All concentrations are given as ppm (mg/kg) of wet weight.

Species	Contaminant	Number	Mean±Std	Range
	DDE	3	<0.05	
	DDD	3	<0.05	
	dieldrin	3	<0.05	
	chlordane	3	<0.5	
	endrin	3	<0.5	
	toxaphene	3	<0.5	
	heptachlor	3	<0.05	
	<i>trans</i> -nonachlor	3	<0.05	

^aTissue source was eggs.

^bPolychlorinated biphenyl isomers were 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

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