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Organochlorine Pesticide Contamination in New World Passerines

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Abstract

Organochlorine pesticide contaminants detrimentally affect wildlife in many ways, including lowered reproductive success, endocrine disruption, and embryonic defects. Most organochlorine pesticides have been banned in the United States after the recognition of these effects. However, these pesticides are still used in Central and South America, and little information is available concerning the levels of pesticide contamination in wildlife from these areas. Furthermore, little data exist regarding organochlorine pesticide contamination in passerines (songbirds). The purpose of this study was to determine the presence in passerines of organochlorine pesticides that are of concern to the Environmental Protection Agency. Neotropical resident species (i.e. those living year-round Central and South America) were collected from Argentina and Peru in 1996, Neotropical migrant species (i.e. those that winter in Central and South America and breed in North America) were collected in central and western Illinois from 1991-1996, and Nearctic resident species (i.e. those living year-round in North America) were collected in central Illinois in 1995 and 1996. Contamination levels were compared between each of the above geographic locations. Predominate pesticides found in Nearctic resident and Neotropical migrant species included DDE, dieldrin and heptachlor epoxide. No significant levels of organochlorine pesticides were found in the Neotropical resident birds. Significantly higher pesticide levels were found in Neotropical migrants than in Neotropical residents. No difference was found in pesticide levels among the Neotropical migrants in relation to age class. These findings suggest that passerines may be acquiring organochlorine pesticides in North America.

Introduction

Organochlorine pesticides have been widely used as effective insecticides throughout the world. DDT, for example, is a highly efficient pest controller. It was first synthesized in 1874, and its insecticidal properties were discovered in 1939 (Kirk and Othmer 1981). Since then, it has been used widely for insect control. It has all the qualities desirable in a pesticide: it is very persistent with a low water solubility, low vapor pressure, high fat solubility, and the ability to absorb quickly through insect chitin (Elvers *et al.* 1989). Unfortunately, DDT has adverse effects on other wildlife as well as insects, and the very characteristics which made DDT desirable as a pesticide have caused it to be one of the most insidious environmental contaminants.

The negative effects of organochlorine pesticides became evident in the United States in the late 1960's when a correlation between eggshell thinning and organochlorine pesticide contamination was discovered in Bald Eagles (*Haliaeetus leucocephalus*) and Peregrine Falcons (*Falco peregrinus*) (Anthony *et al.* 1993, Wiemeyer *et al.* 1984). Recent laboratory studies documented that DDT, DDE and other organochlorine contaminants caused reduced reproductive successes of these species and others, including Prairie Falcon (*Falco mexicanus*) and White-faced Ibis (*Plegadis chihi*) (Jarman *et al.* 1996, Henny and Herron 1989). It has been suggested that organochlorine pesticide contaminants are also linked to lethal effects in many other species of birds, including Neotropical migrants (Gard and Hooper 1995).

This information led to the ban of most organochlorine pesticides used in the United States (Kirk and Othmer 1981). However, following the ban, these contaminants continue to persist in wildlife in the US. DDT, DDE and other organochlorine pesticides are still detected in birds in much of North America, including the Rio Grande area (White and Krynitsky 1986), Northwest Mexico (Mora and Anderson 1991), and much of the western United States (DeWeese *et al.* 1986). The continued existence of contaminants in North America may be due to the persistence of these compounds in the environment. Some organochlorine compounds, such as hexachlorobenzene and hexachlorocyclohexane, may move to colder, higher latitudes from warmer, tropical areas by airborne vectors, possibly entering North America via this route (Simonich and Hites 1995). The continued presence of these contaminants in avian fauna may also be due to the continued use of organochlorine pesticides in the Latin American wintering grounds of many migratory species (Henny *et al.* 1982, Kannan 1991). However, there are few data concerning pesticide use in Central and South America (DeWeese *et al.* 1986). Currently used commercial herbicides and pesticides in the United States may also contribute to organochlorine contamination. For example, Dicofol, an insecticide, contained up to 15 percent DDT by weight until 1988 (Clark *et al.* 1995).

Recent discoveries have shown that these pesticides may have harmful effects on other wildlife as well as birds. DDT, DDE, and other organochlorine compounds cause myriad effects on wildlife and humans, including decreased fertility, masculinization of females, feminization of males, and alteration of immune system responses in fish, birds, and mammals (Colborn *et al.* 1993). These organochlorine pesticide contaminants, although not structurally similar to estrogen, bind to estrogen receptors, resulting in reproductive and developmental problems (Rattner *et al.* 1984). DDT also blocks androgen receptors in males, causing abnormalities in their sexual development (Kelce *et* *al.* 1995). In humans, organochlorine contaminants may be linked to breast cancers (Davis *et al.* 1993, Raloff 1993).

Population declines have been noted in many species of Neotropical migratory passerines (i.e. songbirds), which may be linked in part to the presence of organochlorine pesticides in the environment (Gard *et al.* 1992, Rappole and McDonald 1994). Studies have shown a higher concentration of pesticides in migratory insectivores than in other migrants (DeWeese *et al.* 1986). Insectivores are at a higher trophic level than frugivores and granivores, and may have higher pesticide levels due to greater bioaccumulation of pesticides.

Little data exist concerning organochlorine pesticide contamination levels south of the United States (Gard and Hooper 1995). The purpose of this study is to examine and compare organochlorine pesticide levels in Neotropical resident birds (Central and South American and Caribbean birds), Neotropical migrants (birds that breed in North America and winter in South and Central America and the Caribbean), and Nearctic residents (North American). This will give an indication of the relative levels of organochlorine pesticide contamination reaching birds in both Nearctic and Neotropical realms. In the Neotropical migrants I will also concentrate on studying pesticide levels in relation to age class and gender. Age class may indicate where most of the pesticides are being acquired. If pesticide contamination is greater in the Neotropics than in North America, then Hatching Year birds (i.e. those that have not been to the wintering grounds) should have significantly less pesticides than After Hatching Year birds. Males and females of some species may have different wintering grounds; gender comparisons of these species will reveal if some contaminations are sex-specific.

I hypothesized that there would be a significantly higher level of pesticides in the Neotropical resident species due to uncontrolled pesticide use in many of the Neotropical countries (Raloff 1996). Nearctic resident species should contain the lowest levels of contamination, as the ban on organochlorines should decrease the amount of pesticides in the environment. The Neotropical migrants' contamination levels should fall somewhere between those of the Nearctic resident and Neotropical residents, due to time spent in both pesticide-low and pesticide-high areas.

Methods

Collection and study skin preparation:

Fourteen birds were collected from two sites in Argentina during January 1996 (27° 21' 45" S, 55° 24' 39" W, ca 200m, and 25° 51' 31" S, 54° 10' 07" W). An additional sixty-eight Neotropical residents were collected at three locations in Peru (7° 9' S, 75° 44' W ca 200m, 7° 8' S, 75° 41' W ca 400m, and 7° 5' S, 75° 39' W ca 1000-1500m) from June to August, 1996. The Neotropical residents were collected by Dr. Angelo Capparella of Illinois State University. The skins were removed for study skin analysis. The Argentinean skins were housed at the American Museum of Natural History, while the Peruvian skins were housed in the Louisiana State University collection. The Neotropical migrant and Nearctic resident birds were collected via mist nets or salvaged from tower kills in McLean, Vermilion, and Piatt counties, Illinois from 4 May 1991 to 11 September 1994 (Harper *et al.* 1996). Additional Nearctic resident birds were collected in this area during the winter of 1996. Neotropical migrant birds were also collected in mist nets at the Mark Twain National Wildlife Refuge in Mercer County, Illinois (41° 06' 24.63" S, 90° 56' 53.87" W). The stomach of each bird was removed and preserved for further studies. Age class was determined by examination of the bursa of Fabricius and the degree of skull ossification (partial ossification indicated a HY bird, complete ossification indicated an After Hatch Year (AHY) bird). Sex was determined by examination of the gonads. The South American carcasses were placed in liquid nitrogen for transport, while the Neotropical migrant and Nearctic resident specimens were placed on dry ice. All were later transferred to a -80°C freezer until thawed for study skin and contaminant analysis.

Chemical Analysis

The residue analysis methods used here were taken from Harper *et al.* (1996). For analysis, the specimen was thawed and the digestive tract was carefully rinsed to remove any undigested matter to prevent possible contamination from unmetabolized pesticides still present in the food matter. Harper *et al.* (1996) removed the digestive tract instead of rinsing. The bird was then homogenized with anhydrous sodium sulfate (approximately 1 g Na_2SO_4 to 3 g bird) to remove water present in the sample. This homogenate was transferred to a soxhlet thimble and extracted with approximately 150 ml of pesticide grade hexanes for 16-20 hours.

Following this, the residue was concentrated to approximately 10 ml and placed in a chromatography column containing 20 g of Florisil (activated 16-20 h at 140°C) and 2 cm of anhydrous sodium sulfate (prewashed with 100 ml of hexane). Florisil was used to remove many of the biological components extracted with the hexane. The column was then eluted with 200 ml each of 6% ethyl ether in hexane, 15% ethyl ether in hexane, and 50% ethyl ether in hexane. Each fraction was condensed to approximately 5 ml and diluted up to 10 ml. Each fraction was split into two 12 ml amber sample vials (to prevent photo-degradation of the chemicals) and stored in refrigeration to await gas chromatography.

Gas chromatography analysis procedures followed those detailed in Harper *et al.* (1996). Each fraction was analyzed by a Hewlett Packard 5890 Series II gas chromatograph equipped with two Ni^{63} electron capture detectors operated at 300°C. Two µl injections were made with an autosampler (HP 7673A) into a split/splitless injector operated at 230°C. This was separated on two different fused silica capillary gas chromatograph columns using helium as the carrier gas. A 30 m DB-35 (0.32 mm inside diameter) served as the primary column for pesticide quantification while a 30 m DB-1701 (0.32 mm inside diameter) was used for pesticide confirmation. The oven temperature was ramped from an initial temperature of 150°C to 200°C at a rate of 8°C/min. The temperature was then ramped to 290°C at 4°C/min and maintained at 290°C for 7 min. Data were collected and analyzed with HP 3365 operating software. Peak areas from the calibration standards were used to calculate response factors. Linearity of each calibration curve was verified by determining the Relative Standard Deviation ([standard deviation of five response factors/mean response factor] ± 100) of the five response factors for each pesticide. The pesticides analyzed for were aldrin, alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, p,p'-DDD, p,p'DDT, p,p'DDE, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, heptachlor, heptachlor epoxide, lindane, and methoxychlor. These pesticides are of interest to the United States Environmental Protection Agency.

Results

The results are summarized in Table 1. Pesticides were detected in three individuals of thirty-seven species of Neotropical residents and in twenty-six individuals of eleven species of Neotropical migrants. Pesticides were present in three Northern Cardinals (*Cardinalis cardinalis*), which are Nearctic residents. However, no statistical analyses could be performed on the Nearctic residents because of the small sample size. There was a significantly higher level of total organochlorine pesticides in Neotropical migrants than in Neotropical resident birds (see Figure 1). In the Neotropical migrants, pesticide levels were not significantly different in relation to age class or gender (see Figures 2 and 3). Likewise, they were not statistically different in relation to age class and gender in Swainson's Thrushes (see Figures 4 and 5).

Discussion

Contrary to my prediction, Neotropical migrant birds had much higher pesticide levels than Neotropical residents. This, along with the pesticides found in the Cardinals, suggests that the pesticides may be acquired somewhere other than Central and South America. A few other studies of Neotropical migrants have resulted in similar conclusions. In a study of Neotropical migrant passerines, Kannan (1991) detected organochlorine pesticides in thirteen of twenty-four species, including some members of the same species in this study. He concluded that there are areas of the United States that still contain organochlorine contamination. Simonich and Hites (1995) performed a global study of organochlorine pesticide levels in tree bark samples. Their target pesticides included some of the pesticides I studied, such as endosulfan, DDT, and dieldrin. They found that many North American sites still contained high amounts of several of the organochlorine pesticides studied. There even appeared to be some "hotspots" of pesticide contamination in the United States. Bishop *et al.* (1994) also located some "hotspots" of pesticide contamination along the Great Lakes and St. Lawrence River basin, with organochlorine levels in Red-winged Blackbirds (*Agelaius phoeniceus*) and Tree Swallows (*Tachycineta bicolor*) five to fifteen times higher than at other sites in the same Great Lakes area. A study of passerines from Northwest Mexico also revealed the presence of DDT, DDE, and dieldrin (Mora and Anderson 1991). Baril *et al.* (1990) found some of the highest levels of pesticide contamination in Red-necked Grebes (*Podiceps grisegena*), birds that do not migrate outside of North America. This also suggests the presence of pesticides in North America.

The lack of significant differences in pesticide levels in relation to age class in the Neotropical migrants further suggests that organochlorine pesticide contamination may be acquired in North America. If pesticide contamination was higher in Neotropical areas, the HY birds (those that have not yet migrated to those regions) should have had lower pesticide levels than AHY birds. However, this was not observed. Pesticide levels in HY birds may be passed from the mother, but Custer and Custer (1995) concluded that pesticide levels in the hatchlings would be diluted considerably as their bodies approached adult size.

While little information is available concerning organochlorine pesticide levels in passerines, other birds, including raptors, have been extensively studied in this regard. In the late 1960's and early 1970's, studies found organochlorine levels in raptors such as Peregrine Falcons and Bald Eagles to be alarmingly high, with mean levels of 20-40 ppm DDE and levels reaching over 100 ppm DDE in some birds (Lincer *et al.* 1970, Cromartie *et al.* 1975). As a result, populations of these birds began to decrease rapidly. Following the ban on organochlorines, however, pesticide contamination levels dropped and populations began to increase in numbers (Kaiser *et al.* 1980, Ambrose *et al.* 1988, Henny *et al.* 1996). Henny *et al.* (1996) also found patterns which suggest that pesticide accumulations of migratory Peregrine Falcons were reduced from 1978 to 1994. Levels in these later studies ranged from 1-20 ppm DDE, with mean levels much lower than those of earlier studies.

Pesticide levels found in this study range were almost an order of magnitude lower than previous studies done in 1980 and 1983 (DeWeese *et al.* 1986, White and Krynitsky 1986). These studies were conducted more than a decade prior to my study. Kannan (1991) conducted a similar study on migratory passerines in 1986, and found levels much closer to those observed in my study. This suggests that pesticide levels may be dropping, but bioaccumulation of these contaminants may still result in adverse effects in higher tropic levels. Insectivorous passerines have been found to contain higher pesticide levels than omnivorous and granivorous species (Fyfe *et al.* 1990).

It is uncertain where these organochlorine contaminants are originating. As mentioned earlier, some of these pesticides were recently used in the United States. Dicofol, a miticide used primarily on orchards, contained 15 percent DDT until 1988 (Clark *et al.* 1995). Dieldrin, another organochlorine, was also legally used on the interiors and exteriors of buildings as a termiticide until 1988 (Wallace *et al.* 1996). As these pesticides have been recently used in the United States, it is possible that they still remain in the environment. DDT, for example, has a soil half-life of 2.5 to 10 years (Kirk and Othmer 1981). This pesticide could still be present from the time of legal use. Some of these pesticides, such as heptachlor, vaporize into the air column, allowing transportation along airborne routes (Spencer and Cliath 1990). Current use of organochlorines in the United States may also be occurring, either legally through loopholes in the restriction laws, or illegally.

One area of concern in this study was the lack of adipose tissue in the Neotropical resident birds. Organochlorine pesticides are lipophilic, and therefore tend to accumulate in the fatty deposits. Findlay and DeFreitas (1971) reported that DDT moves from adipose tissues to muscle tissue as the adipose tissue is metabolized. Because the skins were not included in any of the pesticide analyses in this study, some of the pesticides may have accumulated in the lipids of the epidermis as well as in the muscles, giving artificially low pesticide levels. Determining the proportion of pesticides accumulating in the skin of these passerines is an area for future work.

There were a few shortcomings to this study. The study only sampled three South American sites in two countries, which is insufficient to provide a comprehensive picture of the levels of contamination in the Neotropics. Only one of these sites, an Argentinean tree farm, could be considered "disturbed". The other site in Argentina was a provincial park located near agricultural areas, and the Peruvian site was pristine lowland rain forest. Future studies should include birds from additional Central and South American sites. In addition, the number of Nearctic residents analyzed should be increased. This study focused only on organochlorine pesticides--future studies should examine other pesticide contaminants, such as polychlorinated biphenyl (PCB) and organophosphorous pesticides.

Acknowledgments. R. G. Harper and J. A. Frick provided assistance in analyzing and reporting the data. A. P. Capparella collected and prepared the Neotropical resident and many of the Neotropical migrant and Nearctic resident species. I would also like to thank Daily Analytical Laboratories, Peoria, IL, for conducting the gas chromatography analyses. J. A. Klemens assisted in the extraction of pesticides from the birds. F. Hollingworth discovered many of the resources used in this paper.

Table 1. New World passerines examined in this study. Pesticide levels are expressed in ng/g.

Bird #	Species	Common Name	Age Class	Gender	Residency	DDT	DDE	DDD	Dieldrin	Hept Epoxide	Endosulfan
1	Dumtella carolinensis	Gray Catbird	AHY	F	Migrant		3.97		11.9	5.67	
2	Setophaga ruticilla	American Redstart	HY	M	Migrant		9.27		3.71		
3	Catharus ustulatus	Swainson's Thrush	AHY	F	Migrant		1.17				
4	Passerina cyanea	Indigo Bunting	AHY	F	Migrant		3.34		1.67	1.67	
5	Catharus ustulatus	Swainson's Thrush	HY	M	Migrant						
6	Catharus ustulatus	Swainson's Thrush	AHY	M	Migrant		2.75		0.385		
7	Catharus ustulatus	Swainson's Thrush	HY	F	Migrant		1.36				
8	Serius aurocapillus	Ovenbird	HY	M	Migrant		1.33		2.66	2.11	
9	Serius aurocapillus	Ovenbird	AHY	M	Migrant		3.89		0.963		
10	Serius aurocapillus	Ovenbird	HY	F	Migrant	1.18	10.39		3.54	17.71	
11	Serius aurocapillus	Ovenbird	AHY	M	Migrant		2.51		3.72	2.79	
12	Dendroica castanea	Bay-breasted warbler	HY	M	Migrant		8.92		7.65	8.92	
13	Dumtella carolinensis	Gray Catbird	AHY	F	Migrant	1.04	24.18	5.04	0.806		
14	Dumtella carolinensis	Gray Catbird	AHY	F	Migrant		0.863		2.16	1.3	
15	Icterus galbula	Baltimore Oriole	AHY	M	Migrant		2.61		1.05		
16	Catharus ustulatus	Swainson's Thrush	AHY	M	Migrant		2.22		1.48		
17	Vireo olivaceous	Red-eyed Vireo	AHY	M	Migrant				0.85	0.85	
18	Catharus ustulatus	Swainson's Thrush	HY	M	Migrant		2.67			2.01	
19	Geothlypis trichas	Common Yellowthroat	AHY	M	Migrant		27.4		19.57	19.57	
20	Passerina cyanea	Indigo Bunting	AHY	M	Migrant		1.09		1.09		
21	Passerina cyanea	Indigo Bunting	AHY	M	Migrant						
26	Catharus ustulatus	Swainson's Thrush			Migrant						
27	Catharus ustulatus	Swainson's Thrush			Migrant	3.55	3.48		3.63	3.06	1.06
28	Catharus ustulatus	Swainson's Thrush			Migrant				1.35		
29	Pheucticus ludovicianus	Rose-breasted Grosbeak			Migrant	0.87	1.39		7.7	2.38	
30	Pheucticus ludovicianus	Rose-breasted Grosbeak			Migrant		0.596		0.708		
31	Catharus ustulatus	Swainson's Thrush			Migrant						
32	Pheucticus ludovicianus	Rose-breasted Grosbeak			Migrant		0.558		1.36	0.941	
33	Pheucticus ludovicianus	Rose-breasted Grosbeak			Migrant				0.608	0.465	
34	Mniotilta varia	Black-and-White Warbler			Migrant	5.22	19.4			1.94	
35	Turdus albicollus				Argentina		0.627				
36	Schiffornis virescens				Argentina						
37	Pyrrhocoma ruficeps				Argentina						
38	Zonotrichia capensis				Argentina						
39	Basileuterus leucoblepharus				Argentina			1.85	6.34		
40	Vireo olivaceous				Argentina						
41	Tachyphonus coronatus				Argentina						
42	Trichothreupis melanops				Argentina						
43	Vireo olivaceous				Argentina						
44	Myiodynastes mirulatus				Argentina						

Table 1 continued. New World passerines examined in this study. Pesticide levels are expressed in ng/g.

Bird #	Species	Common Name	Age Class	Gender	Residency	DDT	DDE	DDD	Dieldrin	Hept Epoxide	Endosulfan
45	Geothlypis aequinoctialis				Argentina		4.3				
46	Cardinalis cardinalis	Northern Cardinal			Nearctic Res.		0.404		0.448	0.673	
47	Cardinalis cardinalis	Northern Cardinal			Nearctic Res.		9.46			1.21	
48	Cardinalis cardinalis	Northern Cardinal			Nearctic Res.		0.607		0.536		
49	Hylophylax naevia		HY	M	Peru						
50	Pipra fasciicauda		AHY	F	Peru						
51	Microerculus marginatus		AHY	M	Peru						
52	Hylophylax poecilonota		AHY	M	Peru						
53	Glyphorhynchus spririus		AHY	F	Peru						
54	Dendrocincla merula		AHY	F	Peru						
55	Tangara schrankii		AHY	F	Peru						
56	Habria rubica		AHY	F	Peru						
57	Pipra erythrocephala		AHY	F	Peru						
58	Hylophilus ochraceiceps		AHY	M	Peru						
59	Conopophaga peruviana		AHY	F	Peru						
60	Cyanocompsa cyanoides		AHY	M	Peru						
61	Myrmoborus myotherinus		AHY	M	Peru						
62	Dendrocincla fulginosa		HY	F	Peru						
63	Machaeropterus regulus		??	F	Peru						
64	Automolus infuscatus		AHY	M	Peru						
65	Terenotriccus erythrurus		AHY	M	Peru						
66	Xiphorhyncus spixii		AHY	M	Peru						
67	Myrmotherula hauxwelli		AHY	M	Peru						
68	Deconychura longicauda		AHY	M	Peru						
69	Mionectes oleagineus		??	M	Peru						
70	Platycichla flavipes		AHY	M	Peru						
71	Myrmotherula erythrurus		AHY	M	Peru						
72	Phlegopsis nigromaculata		AHY	F	Peru						
73	Turdus albicollus		HY	F	Peru						
74	Sclerurus caudacius		AHY	M	Peru						
75	Aneistrops strigilatus		AHY	M	Peru						
76	Myrmeciza hyperythra		AHY	M	Peru						
77	Pipra erythrocephala		HY	F	Peru						
78	Hylophilus ochraceiceps		AHY	M	Peru						
79	Terenotriccus erythrurus		HY	F	Peru						
80	Dendrocincla merula		AHY	F	Peru						

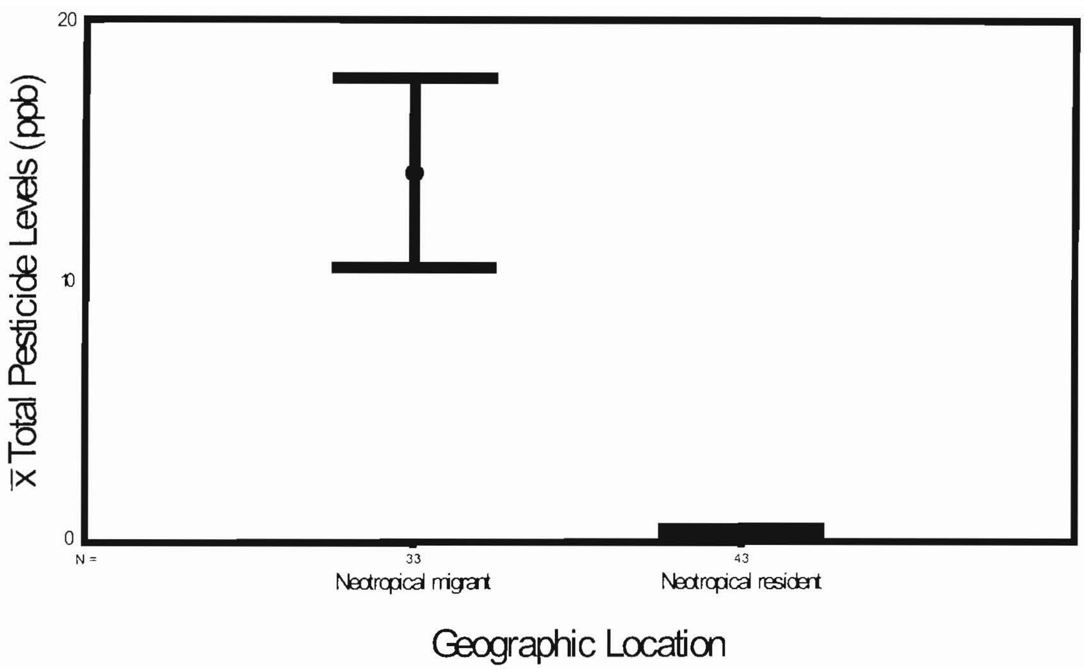

Figure 1. x̄ (±SE) total organochlorine pesticide levels in relation to geographic location. $F_{1,74} = 18.40$, $p = 0.0001$.

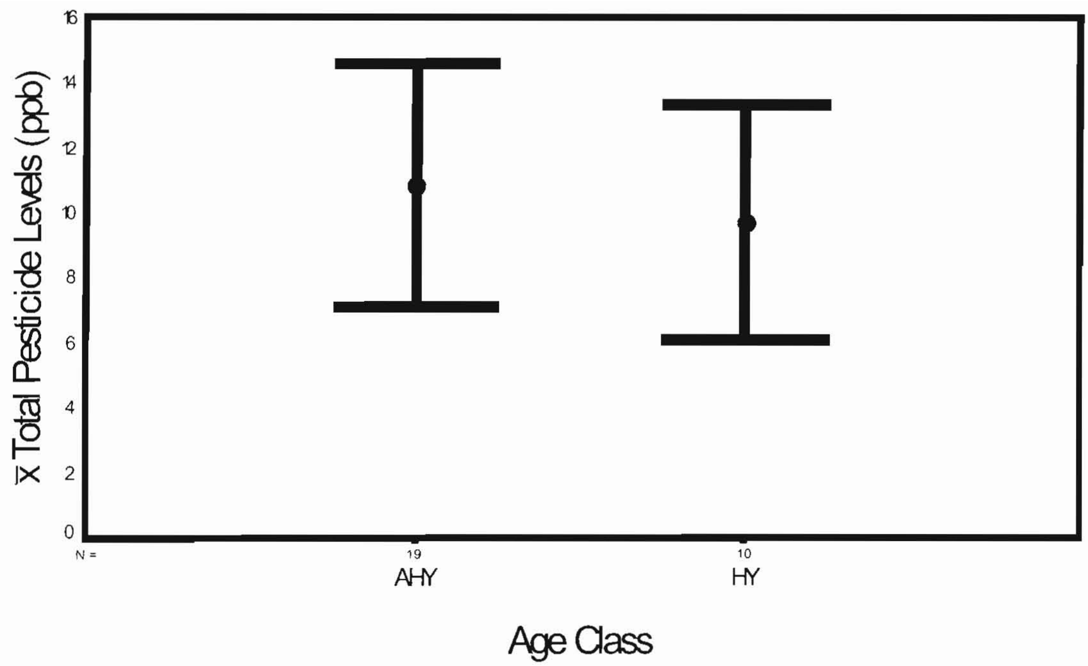

Figure 2. x̄ (±SE) total organochlorine pesticide levels in Neotropical migrants in relation to age class. $F_{1,25} = 0.003$, $p = 0.953$.

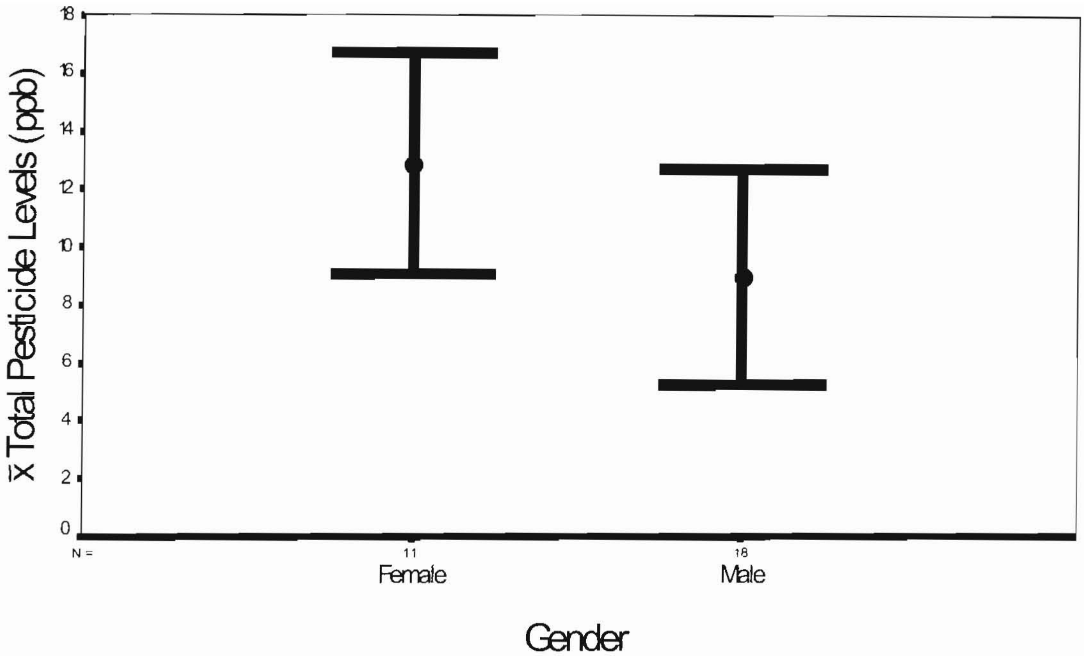

Figure 3. x̄ (±SE) total organochlorine pesticide levels in Neotropical migrants in relation to gender. $F_{1,25} = 0.639$, $p = 0.432$.

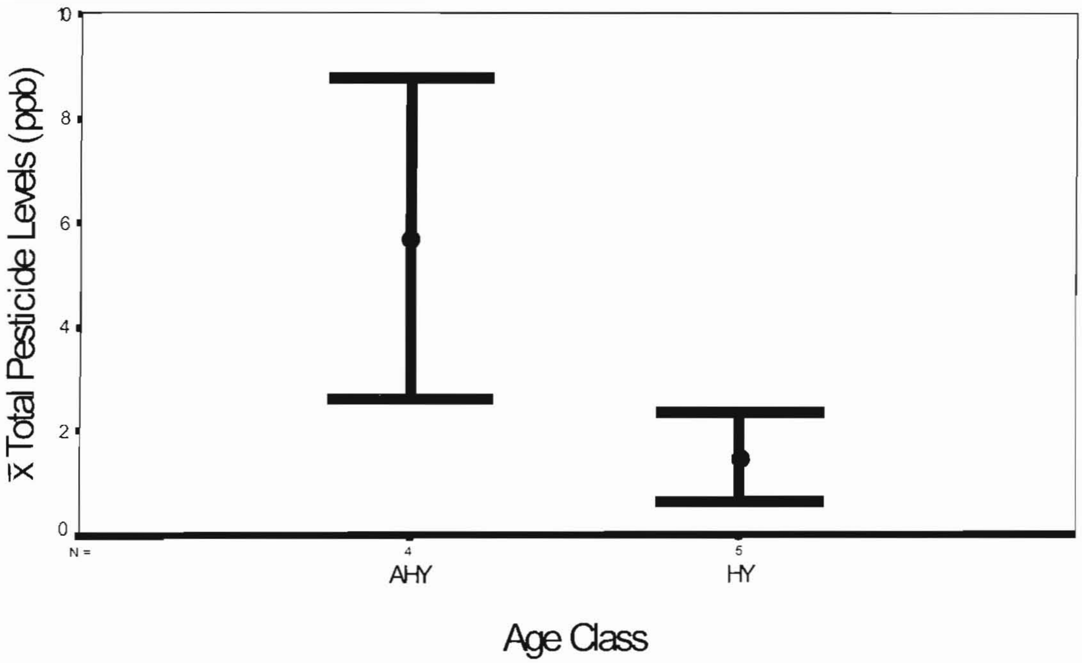

Figure 4. $\bar{x}$ (±SE) total organochlorine pesticide levels in Swainson's Thrushes in relation to age class. $F_{1,5} = 0.582$, $p = 0.480$.

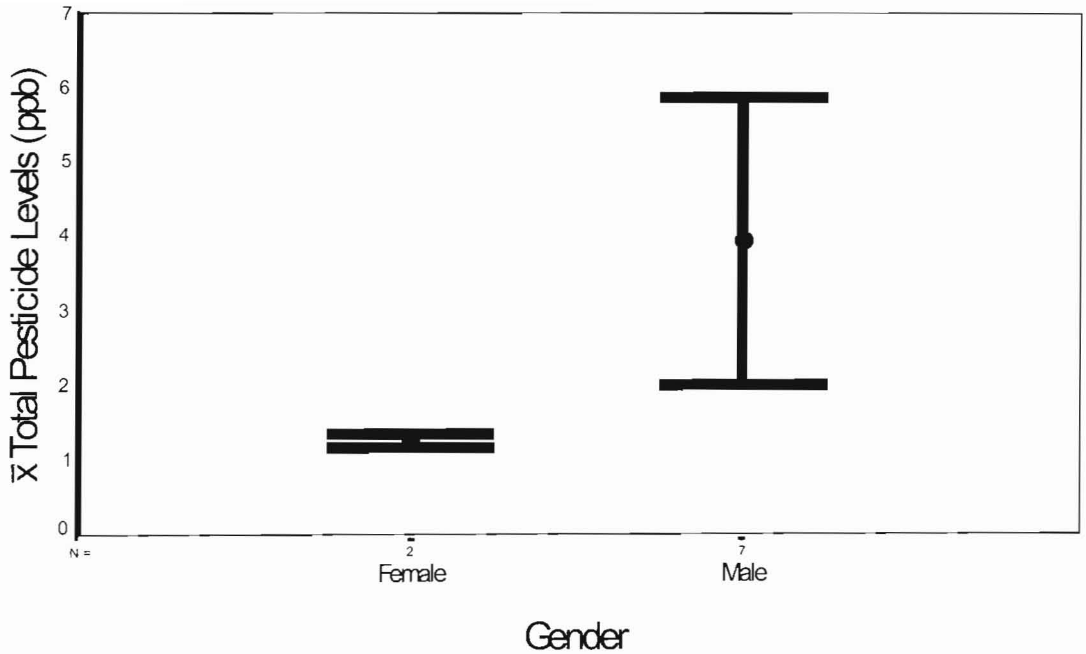

Figure 5. $\bar{x}$ (±SE) total organochlorine pesticide levels in Swainson's

Thrushes in relation to gender. $F_{1,5} = 0.733$, $p = 0.431$.

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