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Organochlorine Pesticide Contamination in Neotropical Avifauna from Northwest Costa Rica

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Abstract

We collected baseline data on organochlorine (OC) pesticide contamination in resident passerine birds from northwest Costa Rica in an area where pesticides had not been used in at least 30 years. Results were compared with a previous study of OC contamination in mayfly larvae (*Euthyplocia hecuba*) collected from the same region. Thirteen OC compounds were detected in the ng/g range for 19 of 56 birds sampled, and the highest OC frequencies were found in birds collected from Pitilla, the site closest to agricultural areas. Atmospheric transport could be a mechanism by which the pesticides are traveling from agricultural areas to areas where pesticides have never been used. OC levels were lower in birds than in mayfly larvae, which suggests that either the birds were not in the same food chain as the mayflies, or that the birds may have been younger that the larvae collected. Moreover, the OC contamination of the birds was dominated by p,p'-DDE, in contrast endosulfan dominated the mayfly OC contamination.

Introduction

Since Rachel Carson woke the American consciousness with her book entitled Silent Spring, the United States has made efforts to understand the effects of pesticide use on wildlife, eventually leading to the elimination of most OC pesticide use in the United States (1, 2, 3, 4, 5). OC pesticide contamination has been correlated with a decrease in growth and reproductive success in several taxa (5, 6) and suggested as a contributing factor in the population declines of certain species (1). OC pesticides have also been linked to health problems in humans (7). Although most OC pesticide use has been banned in the United States, some OCs continue to be used in Central and South America (7). Little information exists, however, on the extent of contamination of Central and South American wildlife.

Costa Rica is one Central American country that documents pesticide imports and estimates the amount and type of OC pesticides used on different types of plantations (7). According to 1991 records, Costa Rica imported about 9000 metric tons of OC pesticides that year (7), and in the last two decades many OC pesticides (e.g., p,p'-DDT, endrin, aldrin, and dieldrin) have been banned from agricultural use. However, heptachlor and endosulfans are still used on crops (7). Most pesticides are currently used on banana, coffee, and sugar plantations in eastern Costa Rica (7). These agricultural areas lie to the east of the shaded region in figure 1.

Standley and Sweeney (8) documented the presence of 12 OC pesticides in stream mayfly larvae (*Euthyplocia hecuba*) and in tree bark and leaf litter from forested regions of northwest Costa Rica where these pesticides had not been applied in at least 30 years. Their sites were in a forest preserve called the Area de Concervacion Guanacaste (ACG) (Fig. 1). They collected specimens from catchments in rivers around Area Maritza and Area Pitilla (Fig. 1). Standley and Sweeney used *Euthyplocia hecuba* because they have a two-year aquatic larval cycle (Standley and Sweeney, personal communication), allowing the pesticides to accumulate more in this species than in most invertebrates. Endosulfans and endosulfan sulfate in the ng/g range accounted for most of the organochlorine contamination in the mayfly larvae (8), whereas a single OC pesticide did not dominate the contamination frequency and level of the leaf and bark litter (8).

Standley and Sweeney (8) suggested that long-range atmospheric transport was the mechanism by which OC pesticides were deposited in this region. Weather and topography are the two major factors that influence the atmospheric transport of pesticides in northwestern Costa Rica. During the rainy season (from mid-May until the end of December), the winds are mild and multidirectional. However, in the dry season, the winds over Costa Rica are primarily from the northeast. After picking up pesticides from the eastern agricultural areas, the winds go over the Cordilleras Guanacaste, a volcanic mountain range that divides the country into Caribbean and Pacific slopes. Moisture in the air cools and condenses into rainfall on the Caribbean slope of the mountain range and pesticides also condense out of the air when it cools (8). This creates a rain shadow on the Pacific slopes of the Cordilleras Guanacaste, therefore little rain and OC pesticides fall in this region.

Standley and Sweeney's results support this idea. Pitilla is on the Caribbean side of the Cordilleras Guanacaste closest to the agricultural areas, and Maritza is on the Pacific side (Fig. 1). Therefore if long-range atmospheric transport were the mechanism for pesticide deposition, mayfly larvae and leaf litter from Pitilla should have higher pesticide levels than larvae and litter from Maritza. Standley and Sweeney (8) did find that mayfly larvae and leaf litter from Pitilla had significantly higher pesticide levels than mayfly larvae and litter from Maritza (8), thus suggesting that long-range atmospheric transport is the mechanism for pesticide deposition.

OC contamination has been examined in Neotropical migrant passerines, and in these studies pesticide levels were higher in insectivores than in non-insectivores (3, 4, 9, 10). This result can be explained by biomagnification. Biomagnification occurs when there is an increase in accumulation of a compound in organisms at higher trophic levels. Non-insectivorous birds, because they consume primarily fruits and nuts, are at a lower trophic level than insectivorous birds, which would explain why higher pesticide levels exist in insectivorous birds. For biomagnification to occur between two species, it is generally assumed that the organisms under comparison are in the same food chain. The insectivorous passerines that were collected in this study, may be consumers of the adult mayfly species that Standley and Sweeney collected; therefore, biomagnification could occur between these two trophic levels (8). We investigated the degree to which pesticide contamination in higher trophic level organisms may be predicted by patterns of contamination in organisms at lower trophic levels.

The purpose of our study was twofold. Our first goal was to collect baseline data on the levels of OC contamination in insectivorous avifauna from regions in Costa Rica where pesticides have not been applied in at least 30 years, since no known literature exists on the contamination of avifauna in Costa Rica. Our second goal was to examine birds from around the same catchments examined by Standley and Sweeney (8) in order to compare our data with theirs and to examine OC contamination at higher trophic levels. To compare OC levels and patterns of contamination, we collected birds from around Pitilla and Maritza, the same sites used by Standley and Sweeney (8) (see Fig. 1). We also collected birds at a lowland dry forest site, Santa Rosa, located west of the former sites, to see if the theory of long-range atmospheric transport was supported in other sites as well (see Fig. 1). Based upon the findings of Standley and Sweeney, we made the following predictions: 1) Endosulfan and endosulfan sulfate should be the most abundant OC contaminant in the birds collected, since endosulfans are still used today, and they dominated the contamination in the mayfly larvae collected by Standley and Sweeney (8), and 2) OC pesticide levels and contamination frequencies should be higher in birds collected from the Caribbean sites compared with those collected from the Pacific sites, due to long-range atmospheric transport. Specifically, birds from Pitilla should have the highest OC contamination, followed by Maritza, and then Santa Rosa.

Methods

Study Area

The study area was a region in northwest Costa Rica that is part of the Area de Conservacion Guanacaste (ACG) (see Fig. 1). Birds were collected from three discrete sites. Santa Rosa was the western-most site sampled, located on a plateau 200-300 m. above sea level;

it was the farthest site from the agricultural areas. Of the 80,000 ha of dry forest in the ACG, Santa Rosa contains the oldest secondary growth forest in the ACG. Maritza, which is situated in the western foothills of Volcan Orosi at an elevation of 500-600 m., contains various successional stages of dry and coniferous forest and is closer to the agricultural sites than Santa Rosa. Pitilla is the eastern-most site, closest to the agricultural areas, and is located on the foothills of the Caribbean slope at an elevation of 400-800 m. This site contains regenerating rainforest ranging from 1-80 years old, pastures, and undisturbed rainforest and cloudforest (J. Klemens, personal communication).

Birds sampled from the Caribbean and Pacific slopes (Pitilla and Maritza, respectively), were collected from riparian forests and forest edges surrounding the catchments sampled by Standley and Sweeney, except for *Nyctidromus albicollis*, which was collected from pastures adjacent to those riparian forests (See Table 1). Birds collected from Santa Rosa, the lowland dry forest site, were collected from the trails and roadsides throughout the area and were not restricted to collection near riparian forest.

Species Descriptions

Species descriptions are summarized in Table 1. The birds were separated into feeding guilds based upon where they forage (11, 12) and locations where the species were collected.

Pesticide Analysis

Birds were collected with a shotgun between 8 June and 15 July 1998 and were placed on ice shortly thereafter. Feet, bill, feathers, gut contents, and distal wing bones were removed from carcasses, then carcasses were frozen for a maximum of two and a half months. Endoparasites were removed from all viscera for use in another study, but viscera were put back with the carcass for pesticide analyses. Skins were removed with feathers only when there was no subcutaneous fat attached to the skin; this ensured that all subcutaneous fat was collected for analyses (see reference 9 for rationale). The left testicle was removed from all males for other studies. Once in Illinois, the carcasses were transported to an ultracold freezer (-80^{O}C) where they remained until the time of analysis.

We extracted pesticides according to the methods used in Frick et al. (3) and Harper et al. (4). A Hewlett Packard (HP) 5890 Series II gas chromatograph was used for pesticide detection following the procedure in Frick et al. (3), then data were collected and analyzed using HP environmental software. We surveyed the following 17 chemicals: aldrin; 2,2-Bis(4-chlorophenyl)-1,1-dichloroethane (p,p'-DDD); 2,2-Bis(4-chlorophenyl)-1,1-dichloroethane (p,p'-DDE); 2,2-Bis(4-chlorophenyl)-1,1-thrichloroethane (p,p'-DDT); dieldrin; endosulfan II; endosulfan sulfate; endrin; endrin aldehyde; heptachlor; heptachlor epoxide; alpha-hexachlorocyclohexane (a-BHC); beta-hexachlorocyclohexane (b-BHC); delta-hexachlorocyclohexane (d-BHC); gamma-hexachlorocyclohexane (g-BHC); lindane; and methoxychlor. Detection limits were 0.01 ug for all pesticides except heptachlor (0.02 ug), aldrin (0.03 ug), endosulfan I (0.03 ug), and endosulfan sulfate (0.10 ug) (3).

Data Analyses

Pesticides with no above-detection limit levels for any of the 56 birds examined were not included in the analysis; therefore, of the 17 pesticides examined, only 13 were used in the analyses. When comparing pesticide levels with Standley and Sweeney (8), mean levels were calculated for each pesticide by using half-detection-level values for zeros. For all other analyses, all pesticide levels below detection limits were treated as zeros. Because the data did not fit a normal distribution, non-parametric statistics were used. Levels were ranked in decreasing order for each pesticide detected. Rankings were from 1-56 (i.e. n=56 birds), and the bird with the highest pesticide level was ranked as 56. The ranking for all birds with zero values of each pesticide was calculated as half of the rank assigned to the bird with the lowest above-detection-limit level. For example, 6 of 56 birds had above-detection limit levels of p,p'-DDD. These were ranked from 56-51. Half of 51 (25.5) was then used as the rank for all 50 birds with zero levels of p,p'-DDD.

A Kruskal-Wallis in lieu of a nested ANOVA (13) was used to examine the effect of location on the ranked values. Species was the nesting variable because the amount of individual variation within a site could largely be due to species. Specifically, not all species were found at all locations (Table 1); therefore, the two variables would have interacted if a standard two-way ANOVA had been used. When either location or species was significant, a planned orthogonal contrast (13) was used to analyze differences among locations, or among foraging guilds, respectively. Foraging guild had to be used instead of species in these contrasts, because the sample sizes for individual species were too low, and not all species were found at all locations (Table 2). For location, birds from Pitilla were compared with birds from Santa Rosa and Maritza, then birds from Maritza and Santa Rosa were compared with each other. For foraging guilds, the following comparisons were made to see if the foraging guild had an effect on pesticide level: 1) understory foragers were compared with all other guilds; 2) canopy foragers were compared with all other guilds; and 3) edge foragers were compared with arial foragers. A two-by-three chi-square contingency table with correction factors for expected values less than five (13) was used to analyze differences in frequency of contamination among the three sites. Birds were either considered contaminated or not, and the number of birds contaminated out of the total number, was used to find the frequency of contamination. If a significant difference among sites was found, two-by-two contingency tables with correction factors for expected values less than five (13) were then used to examine the differences between individual sites.

Results

The highest level of organochlorine pesticide found was p,p'-DDE (593 ng/g) in one individual, followed by p,p'-DDT (107.8 ng/g), p,p'-DDD (94.1 ng/g), and endosulfan II (65.8 ng/g) (Table 2). In addition, p'p'-DDE was the most frequent pesticide found (Table 2). Table 2 shows the range of compound levels found in all three sites and the number of birds contaminated with each pesticide for each site. Maritza had only one sampled bird contaminated, but that bird had much higher pesticide levels (of the pesticides found in Maritza) than the maximum values at the other two sites (Table 2).

There was a significant effect of location on pesticide levels for p,p'-DDT and endosulfan I (Table 3). Birds collected in Pitilla had significantly higher levels of p,p'-DDT and endosulfan I than did birds collected at Santa Rosa and Maritza (Table 4 and 5). There was also a significant effect of location on the frequency of contamination with any OC compound (X^2=9.98, df=2, p<0.05) (Table 6). Significantly fewer birds from Maritza contained pesticides (1 of 16) than birds from Pitilla (9 of 15 birds, X^2= 9.46, df=1, p<0.005) or Santa Rosa (9 of 24 birds, X^2=5.38, df=1, p<0.005). However, there was no effect of location on the frequencies of individual pesticides (p,p'-DDE: X^2=0.407, df=2, p>0.05; endosulfan I: X^2=4.58, df=2, p>0.05; endosulfan II: X^2=5.53, df=2, p>0.05).

There was a significant effect of species by location on levels of p,p'-DDT, dieldrin, endosulfan I, endosulfan II, and heptachlor epoxide (Table 3). Canopy foragers had significantly lower levels of p,p'-DDT than all other species, and edge foragers had significantly lower levels than arial foragers (Table 4). There was a significant effect of species on dieldrin levels with *Nyctodromus albicollis* having the highest mean pesticide level, but there was no significant effect of foraging guild for dieldrin (Tables 4 and 5). Understory foragers had significantly lower endosulfan I levels than all other guilds, canopy foragers were significantly lower than all other guilds, and edge foragers had significantly higher levels than arial foragers (Tables 4 and 5). In contrast, understory foragers had significantly higher endosulfan II levels than all other guilds. There was no significant effect of foraging guild on the heptachlor epoxide levels detected (Tables 4 and 5).

Discussion

Our data did not support our first prediction. We predicted that endosulfans would dominate the levels of OC contamination for birds in Costa Rica, due to their continued use in banana plantations and their presence in mayfly larvae (8). However, p,p'-DDE dominated the OC contamination of birds instead. The most common breakdown product of p,p'-DDT is p,p'-DDE which should be in greater abundance than p,p'-DDT, or the other metabolite p,p'-DDD. This may explain why p,p'-DDE dominates the contamination of birds examined, as opposed to p,p'-DDT, or p,p'-DDD. The half life of p,p'-DDE is greater than 2 years and up to 150 years depeding on the circumstances (14,15), which is greater than most other pesticides; therefore, p,p'-DDE could be in high abundance due to its persistence in nature. The relative solubility of p,p'-DDE and the endosulfans may explain why endosulfans were found more frequently in mayfly larvae, and p,p'-DDE was found more frequently in the birds examined. The aqueous solubility of p,p'-DDE is 0.010 mg/L (14), which is less than that of endosulfan (0.32 mg/L) (15). As a result, endosulfan has a greater capacity than p,p'-DDE to be dissolved in water and is therefore more likely than p,p'-DDE to be found in streams (15) where the stream mayfly larvae would pick up the pesticides. Thus, based upon the chemical properties of p,p'-DDE and endosulfan, stream dwelling invertebrates should have higher levels of endosulfan than birds.

We also found that birds generally had lower mean pesticide levels than the mayfly larvae (Table 7), a finding that is inconsistent with biomagnification. Although we do not have quantitative data on the stomach contents of the birds collected, insect orders that predominated a qualitative examination of the stomach contents include Lepidoptera, Hymenoptera, Diptera and Coleoptera. No Ephemopterans, which is the order to which mayflies belong, were found in the gut contents. This could mean that the birds are not consuming the adult mayflies, which begins to explain why the results were inconsistent with biomagnification, since the assumption of biomagnification is not supported. We do not have data on the pesticide levels of other invertebrates and therefore cannot support whether biomagnification is occurring between the birds examined and other invertebrates.

There is another explanation for why pesticide levels in our birds were lower compared to the mayfly larvae collected by Standley and Sweeney (8). We found that the mayfly larvae remain in the water column in their larval stage of life for about two years, and it was at the end of these two years that Standley and Sweeney collected them (Standley and Sweeney, personal communication). Therefore the larvae could be older than the birds collected. As a result, mayfly larvae may have been able to pick up more chemicals than the birds, which is consistent with the relative pesticide levels that we found. The leaf litter collected in the stream by Standley and Sweeney also had higher overall pesticide levels that the birds collected (Table 7). However the litter could be from any age tree and could have spent any amount of time in the water, so the tree could have had a much longer time to accumulate pesticides.

The results for two compounds (p,p'-DDT, and endosulfan I) supported our third prediction that pesticide levels should be higher in birds collected from Caribbean sites compared with those from Pacific sites. Birds from Pitilla had higher levels of p,p'-DDT and endosulfan I than Maritza and Santa Rosa (Tables 4 and 5) . Only one of sixteen birds collected in Maritza was contaminated with any OC pesticide. This may indicate that some pesticides such as endosulfan and p,p'-DDT tend to remain close to the site of application (2, 8).

Both Santa Rosa and Pitilla had a higher frequency of overall pesticide contamination compared to Maritza, which seems to argue against the hypothesis of long-range atmospheric transport. Santa Rosa should have the lowest frequency of contamination if long-range atmospheric transport were the only mechanism by which the pesticides were accumulating at these sites. However, pesticides banned for agricultural use in Costa Rica, specifically p,p'-DDT, are still used in some areas to control mosquito populations which prevent malarial outbreaks (7). Santa Rosa has a larger human population than Maritza and is relatively close to other towns; therefore, Santa Rosa is more likely than Maritza to be receiving pesticide treatments for mosquitoes. Most of the birds from Santa Rosa were contaminated with at least p,p'-DDE, the most common break-down product of p,p'-DDT (Table 7). The p,p'-DDT use for malarial control may then be the major factor causing high frequencies of contamination in Santa Rosa. Overall, our data support the results of Standley and Sweeney (8) that suggest that long-range atmospheric transport is an explanation for the existence of pesticides where no pesticides had been previously applied.

We also examined the effect of foraging guild on pesticide levels. For p,p'DDT, dieldrin, endosulfan I, endosulfan II, and heptachlor epoxide, there was a significant effect of species within location on pesticide level. However, when the species were grouped into guilds, there was no significant effect on dieldrin and heptachlor epoxide levels, suggesting that differences in contamination exist among individual species and that patterns cannot be explained by foraging habits for these species. We chose not to examine the individual species, however, because even if the data were different among species, sample sizes would be insufficient for statistical analyses. For p,p'-DDT, canopy foragers had a significantly lower pesticide level than all other foragers (Table 4 and 5). Therefore, *Vireo flavoviridis* and *Hylophilus decurtatus* had lower pesticide levels than all other species. This could be due to the pesticides running down from the canopy to the understory. Edge foragers also had significantly lower pesticide levels than did arial foragers. Arial foragers feed over a much wider area than edge foragers do (11, 12), which may explain this phenomenon.

For endosulfan I, understory foragers had significantly lower pesticide levels than all other foragers, canopy foragers had significantly lower levels than all other guilds, and the edge foragers had significantly higher levels of pesticide than arial foragers (Tables 4 and 5). The edge forager *Elaenia flavogaster* from Pitilla had the highest mean level of contamination in any of the species examined; therefore, the edge foragers may not accumulate pesticides more than other foraging guilds, but this particular species is better at concentrating endosulfan than other birds. *Elaenia flavogaster* is found throughout Central and South America, and its wider migratory range may allow it to pick up higher levels of pesticides than some of the other birds. However, we are still uncertain why this trend was only observed for endosulfan I. For endosulfan II, the understory foragers had significantly higher pesticide levels than did all other guilds (Tables 4 and 5). Specifically, *Geothlypis poliocephala* from Pitilla had the highest endosulfan II levels compared to all other guilds. This again could be due to the pesticides running off from the canopy down to the understory.

It is unlikely that the OC levels found in birds in this study have a significant effect on their reproductive success and survival (16, 17, 18, 19). Many studies have found that pesticide levels must be in at least the ug/g range for endocrine disruption to occur. Many of the harmful effects that occur due to pesticides, are a result of endocrine disruption. Our data only recorded pesticides in the ng/g range. However, biomagnification could be occurring between other insectivorous animals that actually eat these stream mayfly larvae, which could cause the high levels required for endocrine disruption. Future studies of OC contamination in this region should include older organisms and organisms at both higher and lower trophic levels to examine how pesticides accumulate through the biota, and the impact that pesticide use has had on the wildlife of Costa Rica. Research should also focus on members of known food chains to really approach the concept of biomagnification.

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Table 1. Species descriptions and collection locations.

Species	Common Name	Location Collected	Mean Mass (g)[b]	Foraging Guild
Bastileuterus rufifrons	Rufous-capped warbler	SR, P, M[a]	11.5	Understory
Elaenia flavogaster	Yellow-bellied elaenia	P	25.0	Edge
Geothlypis poliocephala	Gray-crowned yellowthroat	P	15.5	Understory
Hylophilus decurtatus	Lesser greenlet	P, M	9.0	Canopy
Myiarchus tyrannulus	Brown-crested flycatcher	SR, P, M	34.0	Edge
Nyctodromus albicollis	Common nightjar	SR, P, M	55.0	Arial
Vireo flavoviridis	Yellow-green vireo	SR	18.0	Canopy

[a] SR= Santa Rosa, P=Pitilla, M=Maritza.

[b] As given in Stiles and Skutch (12).

Table 2. Range of minimum and maximum values (ng/g) and the number of birds with above detection limit levels of these compounds.

	Santa Rosa		Maritza[a]		Pitilla	
Compound	Range	N	Range	N	Range	N
a-BHC					0.00-15.91	2
b-BHC					0.00-26.04	1
d-BHC					0.00-18.66	2
g-BHC					0.00-22.38	2
Heptachlor			0.00-16.17	1	0.00-24.02	1
Heptachlor epoxide	0.00-11.30	1	0.00-16.17	1	0.00-21.77	3
Dieldrin	0.00-12.24	2			0.00-17.36	3
Aldrin	0.00-14.12	1				
Endosulfan I					0.00-34.20	3
Endosulfan II	0.00-65.76	3				
p,p'-DDT			0.00-107.82	1	0.00-34.83	4
p,p'-DDD	0.00-94.05	2	0.00-53.91	1	0.00-27.78	2
p,p'-DDE	0.00-16.40	6	0.00-592.99	1	0.00-45.30	7

[a] all the compounds from Maritza were found in a single specimen.

Table 3. Effects of location and species within location on OC levels.

Compound	Location		Species [Location]	
	F	p	F	p
a-BHC	0.8297	0.4430	0.5144	0.8705
b-BHC	0.5267	0.5943	1.0511	0.4194
g-BHC	1.7483	0.1862	1.5021	0.1718
p,p'-DDD	1.9828	0.1501	1.9343	0.0663
p,p'-DDE	0.8610	0.4299	1.6896	0.1145
p,p'-DDT	6.1450	0.0045*	15.0948	<0.0001*
Dieldrin	1.2049	0.3096	3.2833	0.0031*
Endosulfan I	991.0972	<0.0001*	1977.771	<0.0001*
Endosulfan II	2.5685	0.0884	2.0848	0.0472*
Heptachlor	0.6803	0.5118	1.0656	0.4086
Heptachor Epoxide	0.8175	0.4483	3.8541	0.0009*
Aldrin	0.5003	0.6098	0.6536	0.7597

* Indicates significance at alpha = 0.05.

Table 4. Planned contrasts between locations and foraging guilds.

Compound		Contrast	t	p
p,p'-DDT	Loc.[a]	Pitilla vs. Santa Rosa and Maritza	3.101	0.0034*
		Santa Rosa vs. Maritza	1.3866	0.1727
	Guild	Understory vs. all other guilds	1.982	0.0539
		Canopy vs. all other guilds	3.484	0.0012*
		Edge vs. arial foragers	2.6645	0.0108*
Dieldrin	Guild	Understory vs. all other guilds	0.979	0.333
		Canopy vs. all other guilds	0.79	0.4337
		Edge vs. arial foragers	1.6501	0.1062
Endosulfan I	Loc.	Pitilla vs. Santa Rosa and Maritza	44.38	<0.0001*
		Santa Rosa vs. Maritza	2E-14	1.0000
	Guild	Understory vs. all other guilds	18.49	<0.0001*
		Canopy vs. all other guilds	32.5	<0.0001*
		Edge vs. arial foragers	49.717	<0.0001*
Endosulfan II	Guild	Understory vs. all other guilds	2.5291	0.0152*
		Canopy vs. all other guilds	0.084	0.9338
		Edge vs. arial foragers	0.5755	0.568
Heptachlor Epoxide	Guild	Understory vs. all other guilds	1.152	0.2558
		Canopy vs. all other guilds	1.134	0.2632
		Edge vs. arial foragers	1.1474	0.2575

[a] Location.

* Indicates significance at alpha = 0.05.

Table 5. Mean ranks for pesticides with significant effects for location and species (N=56). Higher rank indicates higher levels of compound.

	Location or Species (N)	p,p'-DDT	Dieldrin	End I[a]	End II[b]	Hept Epox[c]
Location	Pitilla (15)	32.97*	31.33	33.60*	27.87	31.33
	Maritza (16)	27.41	25.50	26.00	26.00	27.28
	Santa Rosa (25)	25.50	27.70	26.00	29.44	26.56
Foraging	Understory (10)	25.50	25.50	26.00*	28.80*	25.50
Guild	All guilds except understory (46)	28.60	28.60	28.48	27.87	28.60
	Canopy (13)	25.50*	27.69	26.00*	28.23	27.54
	All guilds except canopy (43)	28.81	28.15	28.65	27.98	28.20
	Flycatchers (28)	16.75*	15.88	26.00*	14.07	15.88
	Nightjars (19)	27.11	26.89	17.07	27.42	27.00

[a] Endosulfan I.

[b] Endosulfan II.

[c] Heptachlor epoxide.

* Indicates significance at alpha = 0.05. For Locations, * indicates that the mean is significantly different than the combined mean from the two other locations. For Species, * indicates the mean is significantly different from the mean directly following it.

Table 6. Frequency (i.e., number of birds out of 56 with pesticides found above detection limits) of contamination for the most frequently detected compounds

	p,p'-DDE	Endosulfan II	Endosulfan I	p,p'-DDD	p,p'-DDT	Dieldrin	Total[a]
Santa Rosa	6	3	0	2	0	2	25
Maritza	1	0	0	1	1	0	16
Pitilla	7	0	4	2	4	3	15
Total	14	3	4	5	5	5	56

[a] the total number of birds collected at each site.

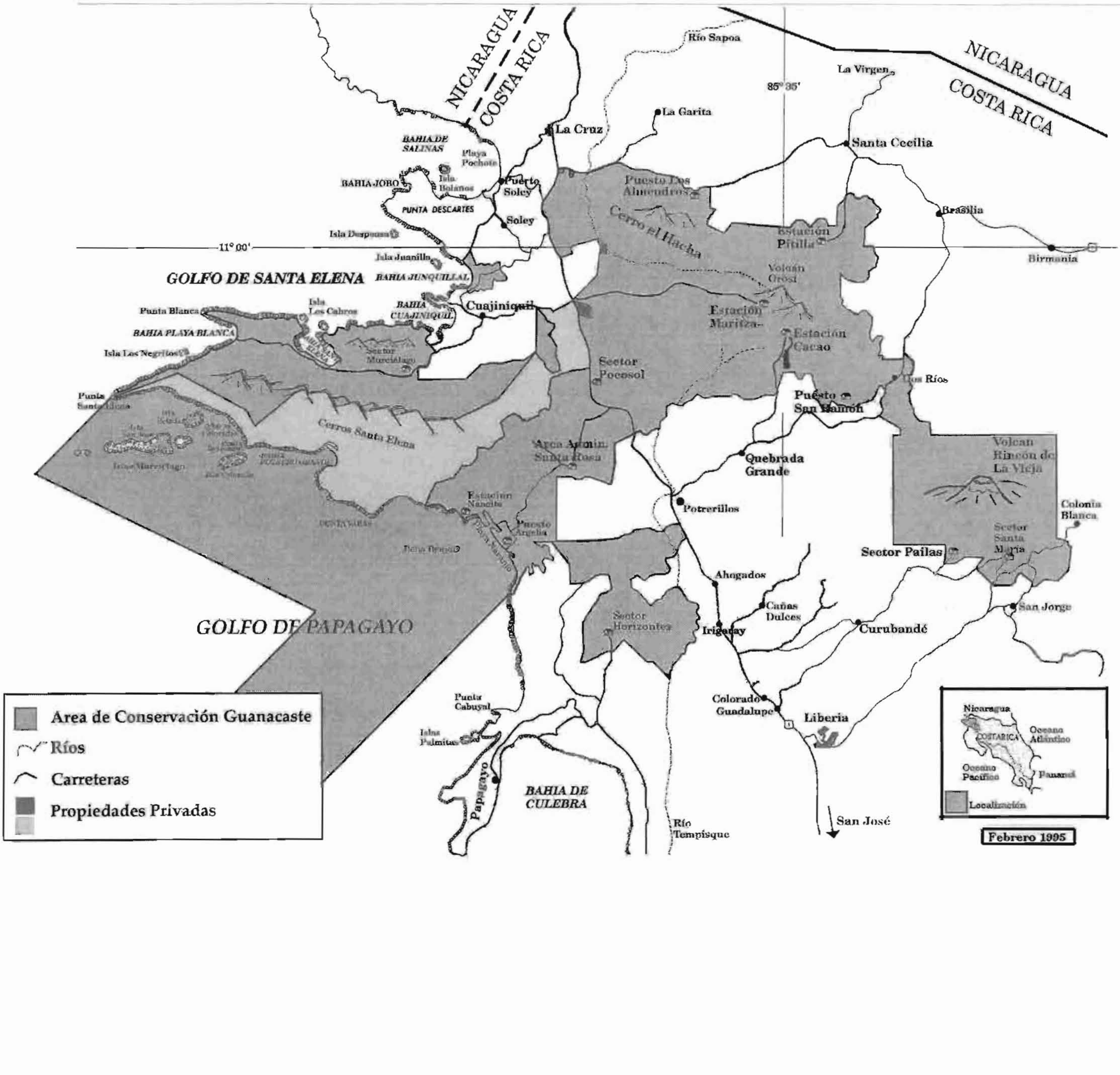
Table 7. Comparison of mean pesticide levels of birds collected in this study with mayflies and leaf litter collected by Standley and Sweeney (11).

	Compounds (ng/g)				
Organism	Heptachlor Epoxide	Endosulfan II	p,p-DDE	p,p-DDT	Dieldrin
Birds	1.5	2.45	3.83	3.61	1.07
Mayflies	20.0	7.0	60.0	n.c.[a]	48.0
Leaves[b]	21.0	n.c.	n.c.	n.c.	41.0

[a] n.c.= not calculated because detected limits were so low (8).

[b] leaves were collected from the river, Rio Tempisquito, Pitilla.

Fig. 1 Area de Concervacion Guanacaste and the surrounding areas of Costa Rica.



NICARAGUA
COSTA RICA
Río Sapoa
La Virgen
85° 35'
La Garita
La Cruz
Santa Cecilia
BAHIA DE SALINAS
Playa Pochote
BAHIA JOBO
Isla Bolaños
Puerto Soley
Puesto Los Almendros
PUNTA DESCARTES
Soley
Cerro el Hacha
Brasilia
Estación Pitilla
Isla Despensa
11° 00'
Birmania
Isla Juanilla
Volcán Orosi
GOLFO DE SANTA ELENA
BAHIA JUNQUILLAL
Isla Los Cabros
BAHIA CUAJINIQUIL
Cuajiniquil
Punta Blanca
Estación Maritza
Estación Cacao
BAHIA PLAYA BLANCA
Isla Los Negritos
Sector Murciélago
Sector Pocosol
Dos Ríos
Punta Santa Elena
Puesto San Ramón
Cerros Santa Elena
Area Admin. Santa Rosa
Quebrada Grande
Volcán Rincón de La Vieja
Islas Murciélago
Estación Nancite
Potrerillos
Colonia Blanca
Puesto Argelia
Sector Santa María
Sector Pailas
Ahogados
Cañas Dulces
San Jorge
GOLFO DE PAPAGAYO
Sector Horizontes
Irigaray
Curubandé
Punta Cabuyal
Colorado
Guadalupe
Liberia
Isla Palmitas
Papagayo
BAHIA DE CULEBRA
Río Tempisque
San José
Nicaragua
COSTA RICA
Oceano Atlántico
Oceano Pacífico
Panamá
Localización
Febrero 1995
Area de Conservación Guanacaste
Ríos
Carreteras
Propiedades Privadas