

PREDICTING MATERNAL BODY BURDENS OF ORGANOCHLORINE PESTICIDES
FROM EGGS AND EVIDENCE OF MATERNAL TRANSFER IN
*ALLIGATOR MISSISSIPPIENSIS*RICHARD H. RAUSCHENBERGER,*†‡ MARÍA S. SEPÚLVEDA,†‡ JON J. WIEBE,†‡ NANCY J. SZABO,§ and
TIMOTHY S. GROSS†‡

†University of Florida, College of Veterinary Medicine, P.O. Box 100144, Gainesville, Florida 32610, USA

‡U.S. Geological Survey, Florida Integrated Science Center, 7920 Northwest 71st Street, Gainesville, Florida 32653

§University of Florida, Analytical Toxicology Core Laboratory, P.O. Box 110885, Gainesville, Florida 32611, USA

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Abstract—Few data exist regarding maternal–embryonal transfer of organochlorine pesticides (OCPs) in reptiles. The objective of the present study was to evaluate maternal transfer of OCPs in American alligators (*Alligator mississippiensis*) from low-, intermediate-, and high-OCP-exposure sites. Overall, total OCP burdens ranged from less than 0.8 ppb in blood to more than 44,000 ppb in abdominal adipose tissue (wet wt concentrations). Lipid-adjusted ratios of maternal adipose burdens (total OCPs) to yolk burdens were close to one ($0.94 \pm 0.31:1$), suggesting that animals were in steady state and that OCPs in eggs originated from adipose lipids. In contrast, lipid-adjusted muscle and liver OCP burdens were greater than yolk OCP burdens, suggesting that lipids in muscle were not utilized during oogenesis and that nonlipid liver tissue sequesters OCPs. Predictive equations were derived for several tissues and several OCP analytes with r^2 values ranging from 0.40 to 0.99 ($p < 0.05$). We suggest that yolk burdens are predictive of maternal tissue burdens for certain tissues and OCPs and that certain OCPs are maternally transferred in the American alligator. Furthermore, we suggest that future studies should investigate the applicability of these predictive equations for assessing maternal exposure in other crocodylian species.

Keywords—Organochlorine pesticides Reptile Maternal transfer Egg

INTRODUCTION

Organochlorine pesticides (OCPs) were widely applied across the United States from the early 1940s to the 1960s in an effort to control malarial mosquitoes and crop-destroying insects. Unfortunately, adverse reproductive effects in several species of wildlife were associated with OCP exposure. One classic example of OCP-associated effects is eggshell thinning in wild birds exposed to DDT [1,2]. As a result, by the late 1980s, almost all OCPs had been banned from U.S. markets. Many of these pesticides, however, are still being applied in developing countries to control malarial mosquitoes [3,4], raising some concern regarding potential risks to subtropical and tropical wildlife. Specifically, many crocodylian species inhabit subtropical and tropical habitats, and of the 23 extant species, 17 are listed as either threatened or endangered ([5]; <http://www.cites.org/eng/append/appendices.pdf>).

Indeed, OCP residues have been detected in eggs and/or somatic tissues of several crocodylian species, such as the American alligator (*Alligator mississippiensis*) [6], the American crocodile (*Crocodylus acutus*) [7,8], Morelet's crocodile (*C. moreletti*) [9], and the Nile crocodile (*C. niloticus*) [10]. Furthermore, alligator populations inhabiting Lake Apopka (FL, USA), where an OCP spill occurred in the 1980s, and other central Florida (USA) lakes contaminated with OCPs (through historic OCP use) produce eggs that contain concentrations of total OCPs more than 100-fold higher than concentrations found in eggs from reference lakes [11,12]. In ad-

dition, the alligator populations inhabiting the OCP-contaminated lakes experience increased (and highly variable) rates of embryonic mortality, leading to reduced clutch success, and these juvenile alligators appear to have abnormal sex hormone concentrations compared to those at reference sites [11–14]. A clear dose–response relationship, however, has not been established with respect to individual or total OCP concentrations in egg yolks and reduced clutch success [6]. The lack of a clear dose–response suggests that other cofactors (e.g., diet, population dynamics, specific OCP mixtures) might be involved and/or that developmental effects result from altered maternal physiology (caused by OCP exposure) as opposed to direct embryotoxicity.

Maternal exposure suggests that OCPs may be maternally transferred from the adult female alligator to her offspring, as has been reported for other oviparous vertebrates [15]. Assuming OCPs are maternally transferred, the possibility exists that yolks could be used as predictors of maternal exposure. A noninvasive method such as this would aid in ecological risk assessments to understand exposure levels for rare/endangered crocodylian species without having to capture and/or remove adults from the breeding population. Therefore, the objectives of the present study were to examine maternal transfer as a potential route for embryonic OCP exposure and to evaluate the use of yolk burdens for predicting OCP burdens in maternal tissues of alligators. Our hypothesis was that OCP burdens in maternal tissues and yolks would be strongly correlated, which would allow yolk burdens to be used in predicting maternal body burdens and suggests maternal transfer of OCPs as the major route for embryonic OCP exposure.

* To whom correspondence may be addressed
(heath.rauschenberger@usgs.gov).

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MATERIALS AND METHODS

Site descriptions

Lakes Apopka (28°35'N, 81°39'W), Griffin (28°53'N, 81°49'W), and Lochloosa (29°30'N, 82°09'W) in Florida were selected as collection sites, because previous studies by our laboratory indicated vastly different levels of OCP exposure across these sites. All three lakes are part of the Ocklawaha Basin. Lake Lochloosa, which is connected to Orange Lake, was selected as a low-exposure (reference) site. Four years (1999–2002) of data indicate mean total OCP concentrations in egg yolks from the reference sites (Lakes Orange and Lochloosa) of 231 ± 30 ppb (mean \pm standard deviation [SD], $n = 56$ clutches), with a concurrent mean clutch viability rate (number of live hatchlings/total number of eggs in a nest) of $71\% \pm 21\%$ (T.S. Gross, unpublished data). Lake Griffin was selected as an intermediate-exposure site, because yolk concentrations averaged $4,414 \pm 617$ ppb ($n = 47$ clutches) for the same period (T.S. Gross, unpublished data). Lake Apopka was selected as a high-exposure site, because yolk concentrations averaged $15,911 \pm 1,786$ ppb ($n = 42$) for the same time period (T.S. Gross, unpublished data). Furthermore, mean clutch viability rates during this period for Lakes Apopka ($51\% \pm 31\%$, $n = 42$) and Griffin ($44\% \pm 33\%$, $n = 47$) have been less than the rates observed for the reference site [11,13].

Animal collections

Adult female alligators and their corresponding clutches of eggs were collected from Lakes Apopka ($n = 4$), Griffin ($n = 8$), and Lochloosa ($n = 3$) during the course of two nesting seasons (June 2001 and June 2002). Nests were located by aerial survey (helicopter) and/or from the ground (airboat). Once nests were located, all eggs were collected, and the nest cavity was covered. A snare-trap was set perpendicular to the tail-drag to capture the female as she crossed over the nest. After the traps were set, one member of the trapping crew subsequently transported the eggs to the Florida Fish and Wildlife Conservation Commission's Wildlife Research Unit (Gainesville, FL, USA) and placed the eggs in a temperature-controlled incubator. Snare-traps were checked later in the evening and early the next morning.

Trapped females were secured and transported from each lake to the U.S. Geological Survey's Florida Integrated Science Center ([USGS; Gainesville, FL, USA). On arrival, the animals were weighed and measured, and blood samples were collected from the postoccipital sinus. Adult alligators were then killed by cervical dislocation followed by double pithing. A full necropsy was performed on each female. Samples of bile, liver, adipose (composite of abdominal fat and abdominal fat pad), and tail muscle were collected for later determination of OCP burdens. Liver, adipose tissue, and muscle were wrapped in aluminum foil, whereas bile and blood were placed in scintillation vials. All samples were grouped according to nest identification number (ID), placed in plastic bags labeled with the appropriate ID, and stored in a freezer at -80°C . Each female's corresponding clutch of eggs was then transferred from the Florida Fish and Wildlife Conservation Commission's Wildlife Research Unit to the USGS, where yolk samples were collected (two eggs/clutch) and stored with the corresponding maternal tissues. The remaining eggs were set for incubation in a temperature- and humidity-controlled incubator ($31\text{--}33^{\circ}\text{C}$, 88–92% relative humidity) at the USGS.

Analysis of OCPs in maternal tissues and yolk

Analytical-grade standards for the following compounds were purchased from the sources indicated: Aldrin, α -benzene hexachloride (BHC), β -BHC, lindane, δ -BHC, p,p' -dichlorodiphenyldichloroethane (p,p' -DDD), p,p' -dichlorodiphenyldichloroethylene (p,p' -DDE), DDT, dieldrin, endosulfan, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, heptachlor, heptachlor epoxide, hexachlorobenzene, kepone, methoxychlor, mirex, *cis*-nonachlor, and *trans*-nonachlor from Ultra Scientific (Kingstown, RI, USA); *cis*-chlordane, *trans*-chlordane, and the 525/525.1 polychlorinated biphenyl mix from Supelco (Bellefonte, PA, USA); oxychlordane from Chem Service (West Chester, PA); o,p' -DDD, o,p' -DDE, and o,p' -DDT from Accustandard (New Haven, CT, USA); and toxaphene from Restek (Bellefonte, PA, USA). All reagents were of analytical grade unless otherwise indicated. Water was doubly distilled and deionized.

Adipose, liver, bile, and yolk samples were analyzed for OCP content using methods modified from those described by Holstege et al. [16] and Schenck et al. [17]. For extraction, a 2-g tissue sample was homogenized with approximately 1 g of sodium sulfate and 8 ml of ethyl acetate. The supernatant was decanted and filtered through a Büchner funnel lined with Whatman no. 4 filter paper (Fisher Scientific, Hampton, NH, USA) and filled to a depth of 1.25 cm with sodium sulfate. The homogenate was extracted twice, with the filtrates collected together. The combined filtrate was concentrated to approximately 2 ml by rotary evaporation and then further concentrated under a stream of dry nitrogen until solvent-free. The residue was reconstituted in 2 ml of acetonitrile. After vortexing (30 s), the supernatant was applied to a C18 solid-phase extraction (SPE) cartridge (preconditioned with 3 ml of acetonitrile; Agilent Technologies, Wilmington, DE, USA) and was allowed to pass under gravity. This procedure was repeated twice, with the combined eluent collected in a culture tube. After the last addition, the cartridge was rinsed with 1 ml of acetonitrile, which was also collected. The eluent was then applied to a 0.5-g NH_2 SPE cartridge (Varian, Harbor City, CA, USA), allowed to pass under gravity, and collected in a graduated conical tube. The cartridge was rinsed with an additional 1-ml portion of acetonitrile, which was also collected. The combined eluents were concentrated under a stream of dry nitrogen to a volume of 300 μl and then transferred to a gas chromatographic vial for analysis.

Whole blood was analyzed for OCP content using methods modified from those described by Guillette et al. [18]. A 10-ml aliquot was transferred from the homogenized bulk sample and extracted in 15 ml of acetone by a vortex mixer. The mixture was centrifuged for 5 min at 3,000 rpm, after which the supernatant was transferred to a clean culture tube. This process was repeated, with the supernatants being collected and concentrated under a stream of dry nitrogen until solvent-free. The residue was re-extracted in 11.5 ml of methylene chloride:petroleum ether (1:1). After mixing, the sample was allowed to settle, and the upper layer was transferred to a clean culture tube. This extraction was performed twice, with the extracts being collected together. The combined extracts were then applied to a prepared florisil cartridge (5 ml; Fisher PrepSep; Fisher Scientific). The cartridge had been prepared by filling the reservoir to a depth of 1.25 cm with anhydrous sodium sulfate and by prewashing the modified cartridge with 10 ml of acetone: methylene chloride:petroleum ether (2:1:1).

Table 1. Morphological and reproductive characteristics of adult female alligators collected during June 2001 and June 2002 from Lakes Apopka, Griffin, and Lochloosa in central Florida (USA)^a

Parameter	Apopka	Griffin	Lochloosa
Females collected (n)	4	8	3
Total length (cm)	252 ± 38	258 ± 17	258 ± 7
Snout-vent length (cm)	142 ± 15	134 ± 9	129 ± 5
Mass (kg)	94 ± 30	70 ± 17	63 ± 4
Clutch mass (kg)	3.78 ± 0.98	3.33 ± 0.82	4.31 ± 0.45
Fecundity (eggs/clutch)	43 ± 10	40 ± 10	49 ± 6
Lipid, adipose (%)	47.0 ± 32.5A	78.1 ± 8.0B	81.4 ± 4.0B
Lipid, liver (%)	1.3 ± 1.0B	0.8 ± 0.2B	5.0 ± 2.3C
Lipid, muscle (%)	0.8 ± 0.9	1.3 ± 0.9	0.2 ± 0.02
Lipid, yolk (%)	19.9 ± 1.1	18.1 ± 1.7	18.2 ± 1.6

^a Values represent the mean ± standard deviation.

^b Capitalized letters indicate significant differences.

After the sample passed under gravity with the eluent collected in a 15-ml graduated conical tube, the cartridge was eluted with 4 ml of the 2:1:1 solvent mixture, which was also collected. The combined eluents were concentrated under a stream of dry nitrogen to a volume of 300 µl and then transferred to a gas chromatographic vial for analysis.

Gas chromatography-mass spectrometry

Analysis of all samples was performed using a Hewlett-Packard HP-6890 gas chromatograph (Wilmington, DE, USA) with a split/splitless inlet operated in splitless mode. The analytes were introduced in a 1-µl injection and separated across the HP-5 mass spectrometry column (length, 30 m; inner diameter, 0.25 mm; film thickness, 0.25 µm; J&W Scientific, Folsom, CA, USA) under a temperature program that began at 60°C, increased at 10°C/min to 270°C and was held for 5 min, then increased at 25°C/min to 300°C and was held for 5 min. Detection utilized an HP 5973 mass spectrometer in electron-impact mode. Identification for all analytes and quantitation for toxaphene was conducted in full-scan mode, in which all ions are monitored. To improve sensitivity, selected ion monitoring was used for the quantitation for all other analytes except kepone. The above program was used as a screening tool for kepone, which does not optimally extract with most organochlorines. Samples found to contain kepone were re-extracted and analyzed specifically for this compound.

For quantitation, a five-point standard curve was prepared for each analyte ($r^2 \geq 0.995$). Fresh curves were analyzed with each set of 20 samples. Each standard or sample was fortified to contain a deuterated internal standard (5 µl of US-108; 120 µg/ml; Ultra Scientific) added just before analysis. All samples also contained a surrogate (2 µg/ml of tetrachloroxylene; Ultra Scientific) added after homogenization. Duplicate quality-control samples were prepared and analyzed with every 20 samples (typically at a level of 1.00 or 2.50 µg/ml of γ -BHC, heptachlor, aldrin, dieldrin, endrin, and *p,p'*-DDT), with an acceptable recovery ranging from 70 to 130%. Limit of detection ranged from 0.1 to 1.5 ng/g for all OCP analytes except toxaphene (120–236 ng/g), and limit of quantitation was 1.5 ng/g for all analytes except toxaphene (1,500 ng/g). Repeated analyses were conducted as allowed by matrix interferences and sample availability.

Data analysis

The OCP concentrations in maternal tissues and egg yolks were lipid-adjusted (wet wt concentration/proportion of lipid in tissue), and lipid-adjusted tissue to egg yolk ratios (maternal

tissue OCP concentrations/egg OCP concentrations) were examined. Predictive models were determined by linear regression analysis of OCP concentrations in yolk against those of maternal tissues (log-transformed wet wt concentrations). Each model's ability to fit the data was evaluated by examining the *p* value ($\alpha = 0.05$), the r^2 value, and the residual plots [19]. Analysis of variance was used for intersite comparisons of adult female and clutch characteristics, and the Tukey test was used for multiple comparisons among sites. The relationship between maternal mass (kg) and concentrations of OCPs in eggs and maternal tissues (log-transformed wet wt concentrations) was evaluated using linear regression to assess whether increasing mass was associated with increasing concentrations of OCPs in eggs and maternal tissues, which may suggest that adult females continue to bioaccumulate OCPs as they grow throughout their life. Adult females were grouped by site, because the extreme differences in OCP exposure among sites otherwise would likely confound the results. Unless otherwise noted, values are reported as the mean ± SD.

RESULTS

Female morphological and reproductive characteristics

For all females, mass and snout-vent length (SVL) averaged 74 ± 20 kg (range, 44–114 kg) and 135 ± 11 cm (range, 119–156 cm), respectively. Clutch mass (mass of all eggs from a single nest) and fecundity (number of eggs collected from a single nest) of these individuals were 3.65 ± 0.86 kg (range, 1.84–4.82 kg) and 43 ± 10 eggs/nest (range, 19–56 eggs/nest), respectively. No significant differences were detected across sites with respect to female mass ($p = 0.14$), total length ($p = 0.90$), SVL ($p = 0.25$), tail girth ($p = 0.98$), head length ($p = 0.55$), clutch mass ($p = 0.23$), or fecundity ($p = 0.40$) (Table 1).

With respect to lipid concentrations in egg yolk and muscle, no significant differences were detected across sites ($p > 0.05$). Lipid concentration, however, was significantly higher ($p < 0.05$) in liver of Lochloosa females than in Apopka and Griffin females (which were not significantly different from one another). Furthermore, lipid concentration in abdominal adipose tissue of Apopka females was significantly less ($p < 0.05$) than in Lochloosa and Griffin females (Table 1).

OCP concentrations in yolk

Egg yolks from Lake Apopka females contained the highest total OCP concentration (15,108 ± 13,704 ng/g) and the greatest number of individual OCPs detected above the limit of

quantitation ($n = 18$), with p,p' -DDE (66%) and toxaphene (32%) being the main constituents. Lake Griffin females produced eggs with the next highest total OCP burdens (393 ± 300 ng/g, $n = 13$), being mainly composed of p,p' -DDE (69%), *trans*-nonachlor (10%), and dieldrin (7%). Lake Lochloosa females produced egg yolks with the smallest total OCP burden (124 ± 53 ng/g, $n = 9$), with the main constituents being p,p' -DDE (73%), *trans*-nonachlor (10%), and *cis*-nonachlor (4%) (Table 2). The OCP analytes with the highest average egg yolk concentrations were toxaphene ($4,862 \pm 4,177$ ng/g), which was detected above the limit of quantitation in 3 of 15 clutches, followed by p,p' -DDE ($2,828 \pm 5,968$ ng/g), dieldrin (191 ± 474 ng/g), and *trans*-nonachlor (126 ± 209 ng/g), which were above quantitation limit in all 15 clutches.

OCP concentrations in maternal tissues

Adipose tissue (a composite of abdominal fat and fat pad) contained the highest concentration of total OCPs ($12,805 \pm 31,678$ ng/g) of all tissues. The p,p' -DDE (67%) composed the majority of the total burden, followed by dieldrin (5%), and *trans*-nonachlor (3%). Although toxaphene was only detected in three individuals from Lake Apopka, its average burden in adipose tissue was $13,463 \pm 1,267$ ng/g (Table 2). In liver, OCP analytes were detected above the quantitation limit in 9 of 15 individuals, and total OCP concentrations averaged $1,008 \pm 1,245$ ng/g. Liver burdens were primarily composed of p,p' -DDE (76%) and dieldrin (6%). Total OCP concentrations in muscle averaged $716 \pm 1,053$ ng/g and were above quantitation limits in 10 of 15 individuals, with most of the burden being composed of p,p' -DDE (83%), dieldrin (6%), and *trans*-nonachlor (6%). Total OCP burdens in bile (412 ± 483 ng/g) were above quantitation limits in five individuals, with p,p' -DDE (86%) and dieldrin (6%) comprising the majority of the burden. Total OCP concentrations in blood (43 ± 21 ng/g) were above quantitation limits in four individuals, with p,p' -DDE (64%) and dieldrin (14%) comprising most of the burden. Overall, Lake Apopka alligators exhibited the highest OCP concentrations in maternal tissues and egg yolks, followed by Lakes Griffin and Lochloosa, respectively (Table 2).

Relationships between maternal tissue and yolk burdens

Examination of the relationship between lipid-adjusted maternal tissue and egg yolk burdens showed differences among tissues. With respect to total OCPs, the adipose burden to yolk burden ratio was close to one (95% confidence interval [CI], $0.76 \leq \mu \leq 1.11$). In contrast, the liver to yolk ratio was significantly greater than one (95% CI, $1.49 \leq \mu \leq 9.19$), and muscle ratios showed considerable variation (95% CI, $-1.17 \leq \mu \leq 37.35$). As would be expected, most individual OCPs followed the above trend; however, *cis*-chlordane was an exception: Liver ratios (95% CI, $2.85 \leq \mu \leq 6.75$) and muscle ratios (95% CI, $1.78 \leq \mu \leq 15.1$) were greater than one, whereas adipose ratios (95% CI, $0.59 \leq \mu \leq 0.84$) were less than one.

With respect to total OCP concentrations, significant linear relationships (predictive models) were found for adipose, liver, muscle, and bile ($p \leq 0.05$) (Fig. 1). With respect to individual OCP analytes, predictive models were derived for 12 of 14 (86%) of the OCPs codetected in adipose tissue and egg yolk, followed by liver (9/12, 75%), bile (8/11, 73%), and muscle (2/12, 17%) (Table 3). Although nine OCP analytes were concurrently detected in the blood of the females and their re-

spective egg yolks, no significant linear correlations were detected ($p > 0.05$).

As for individual OCP analytes, p,p' -DDE concentrations in yolk were significantly correlated with those of liver, muscle, bile, and adipose tissue. Blood p,p' -DDE concentrations did not exhibit a significant linear relationship ($p > 0.05$) with yolk p,p' -DDE concentrations. Heptachlor epoxide, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor, *cis*-nonachlor, mirex, and dieldrin concentrations in yolk were significantly correlated to their respective concentrations in adipose, liver, and bile. With respect to oxychlordane, significant correlations were only derived for liver and adipose tissue, and significant correlations for p,p' -DDD concentrations were found only for adipose and bile. Toxaphene and *o,p'*-DDT concentrations in adipose tissue were significantly correlated with respective egg yolk concentrations (Table 3).

Relationships between maternal mass and OCP concentrations in eggs and tissues

For females collected from Lakes Apopka ($n = 4$) and Lochloosa ($n = 3$), no significant correlations ($p > 0.05$) were found when maternal mass (kg) was compared against either individual or total OCP concentrations (log-transformed wet wt) in maternal tissues and eggs. Significant correlations might have been difficult to detect, however, because of the small sample size. In contrast, a larger number of Lake Griffin females ($n = 8$) were collected, and analyses indicated significant correlations between maternal mass and OCP concentrations in tissues and eggs, indicating that larger females have higher concentrations of OCPs in their tissues and eggs, which may suggest that females continue to bioaccumulate OCPs as they grow (i.e., increase in mass). For Lake Griffin females, OCP burdens in eggs had the greatest number of significant correlations ($p \leq 0.05$) with body mass (kg), which consisted of *cis*-nonachlor ($r^2 = 0.87$), *cis*-chlordane ($r^2 = 0.75$), *trans*-nonachlor ($r^2 = 0.73$), dieldrin ($r^2 = 0.69$), p,p' -DDE ($r^2 = 0.66$), *o,p'*-DDT ($r^2 = 0.61$), heptachlor epoxide ($r^2 = 0.59$), oxychlordane ($r^2 = 0.58$), *trans*-chlordane ($r^2 = 0.57$), and total OCPs ($r^2 = 0.71$). Following egg concentrations, correlations of abdominal fat OCP burdens to body mass were found for *cis*-nonachlor ($r^2 = 0.67$), *cis*-chlordane ($r^2 = 0.81$), *trans*-nonachlor ($r^2 = 0.63$), dieldrin ($r^2 = 0.62$), p,p' -DDE ($r^2 = 0.58$), heptachlor epoxide ($r^2 = 0.53$), oxychlordane ($r^2 = 0.51$), and total OCPs ($r^2 = 0.64$). Although egg burdens of *o,p'*-DDT and *trans*-chlordane were correlated with body mass, abdominal fat burdens were not. Finally, correlations of liver OCP burdens to body mass were found only for *trans*-nonachlor ($r^2 = 0.99$) and p,p' -DDT ($r^2 = 0.99$). No significant correlations were found for *cis*-chlordane, *trans*-chlordane, oxychlordane, dieldrin, heptachlor epoxide, *o,p'*-DDT, and *cis*-nonachlor.

DISCUSSION

The presence of OCPs in the eggs and tissues of alligators is not novel. The value of the present study is that OCP concentrations in maternal tissues and yolks appear to be strongly correlated with one another, allowing yolk burdens to be used as predictors of OCP burdens in tissues of adult reproductive alligators, which may be a useful, noninvasive technique for risk assessments involving endangered crocodylians. Furthermore, the present results are consistent with those of other studies that suggest OCPs are maternally transferred in wild alligators [20].

Table 2. Pesticide concentrations (ng/g wet wt) in tissues and yolks of adult female alligators collected during June 2001 and June 2002 from Lakes Apopka, Griffin, and Lochloosa in central Florida (USA)^a

Lake	Chemical ^c	Bile	Blood	Adipose	Liver	Muscle	Yolk
Apopka (4)	Aldrin	X	X	X	X	X	0.8
	α -BHC	X	X	X	X	X	X
	β -BHC	X	X	7.5 \pm 6.7	X	X	2.1 \pm 1.4
	<i>cis</i> -Nonachlor	9.5 \pm 3.2	1.5 \pm 0.4	520.6 \pm 602.7	30.6 \pm 6.7	23.2 \pm 18.3	123.2 \pm 81.9
	<i>cis</i> -Chlordane	4.35 \pm 1.9	0.6 \pm 0.4	189.8 \pm 241.2	10.9 \pm 9.1	14.1 \pm 11.7	62.0 \pm 59.2
	δ -BHC	X	X	X	X	X	X
	Dieldrin	38.4 \pm 10.2	4.8 \pm 0.4	2,376.1 \pm 3,770.9	104.7 \pm 80.2	67.7 \pm 48.3	662.5 \pm 803.0
	Endosulfan I	X	X	X	X	X	X
	Endosulfan II	X	X	X	21.3	X	X
	Endosulfan sulfate	X	X	X	X	X	X
	Endrin	X	X	X	X	X	X
	Endrin aldehyde	2.7 \pm 0.4	X	X	X	X	X
	Endrin ketone	X	X	X	X	X	X
	γ -BHC	X	X	X	X	X	X
	Heptachlor	X	X	X	X	X	X
	Heptachlor epoxide	3.3 \pm 2.1	0.3 \pm 0	66.5 \pm 81.5	5.9 \pm 2.2	8.2 \pm 11.7	1.4 \pm 0.04
	Hexachlorobenzene	0.8 \pm 0	0.75 \pm 0	0.8 \pm 0	0.8 \pm 0.0	4.1 \pm 3.6	25.5 \pm 15.0
	Kepon	X	X	X	X	0.8	0.8 \pm 0.0
	Methoxychlor	X	X	X	X	X	X
	Mirex	2.4 \pm 2.6	X	X	X	1.1 \pm 0.4	6.9 \pm 7.1
	<i>o,p'</i> -DDD	X	X	X	19.4 \pm 13.1	X	X
	<i>o,p'</i> -DDE	X	X	X	3.0 \pm 3.4	X	X
	<i>o,p'</i> -DDT	X	X	X	51.5 \pm 55.8	X	X
	Oxychlorane	1.7 \pm 0.2	0.5 \pm 0.2	26.6 \pm 26.4	4.2 \pm 1.8	3.8 \pm 2.2	44.7 \pm 17.7
	<i>p,p'</i> -DDD	7.2 \pm 1.3	0.5 \pm 0.2	246.9 \pm 336.4	17.2 \pm 9.9	12.3 \pm 10.7	16.6 \pm 7.8
	<i>p,p'</i> -DDE	2.3 \pm 0.2	0.5 \pm 0.2	42.5 \pm 67.5	11.4 \pm 10.3	16.7 \pm 8.0	75.1 \pm 68.2
	<i>p,p'</i> -DDT	805.5 \pm 341.5	42.2 \pm 5.7	29,839.9 \pm 34,366	1,846.9 \pm 918.1	1,392.5 \pm 1,078.2	51.6 \pm 61.4
<i>p,p'</i> -DDT	1.2 \pm 0.4	ND	25.9 \pm 24.2	31.2 \pm 3.0	1.9 \pm 0.76	9,994.3 \pm 8,529.3	
Toxaphene	X	X	13,436.1 \pm 12,672	X	X	11.0 \pm 10.7	
<i>trans</i> -Chlordane	0.3 \pm 0	0.8 \pm 0	18.3 \pm 27.5	1.6 \pm 0.5	2.3 \pm 1.5	4,862.1 \pm 4,177.0	
<i>trans</i> -Nonachlor	20.9 \pm 7.8	2.7 \pm 0.4	1,153.3 \pm 1,378.7	64.7 \pm 22.7	67.6 \pm 57.0	8.9 \pm 8.4	
Total OCP	900.3 \pm 369.7	54.9 \pm 6.8	44,650 \pm 53,230	2,140 \pm 1,024	1,610 \pm 1,226	386.7 \pm 277.7	
Griffin (8)	Aldrin	X	X	X	X	X	15,108 \pm 13,704
	α -BHC	X	X	X	X	X	X
	β -BHC	X	X	2.1 \pm 1.1	X	X	X
	<i>cis</i> -Nonachlor	4.0 \pm 2.4	0.4 \pm 0.4	74.7 \pm 74.9	7.6 \pm 4.4	9.2 \pm 10.6	14.2 \pm 7.6
	<i>cis</i> -Chlordane	1.5 \pm 0.5	0.8 \pm 0	30.3 \pm 10.8	2.1 \pm 0.7	3.1 \pm 3.4	11.3 \pm 3.7
	δ -BHC	X	X	X	X	X	X
	Dieldrin	13.1 \pm 4.9	7.4	109.3 \pm 133.4	17.1 \pm 8.0	21.8 \pm 20.8	25.6 \pm 25.7
	Endosulfan I	X	X	X	X	X	X
	Endosulfan II	X	X	X	X	X	X
	Endosulfan sulfate	X	X	X	X	X	X
	Endrin	X	X	X	X	X	X
	Endrin aldehyde	X	X	X	X	X	X
	Endrin ketone	X	X	X	X	X	X
	γ -BHC	X	X	1.5	X	X	X
Heptachlor	X	X	X	X	X	X	
Heptachlor epoxide	3.2 \pm 3.3	0.8	34.2 \pm 45.7	5.1 \pm 3.6	1.8 \pm 1.4	7.5 \pm 8.8	
Hexachlorobenzene	0.8 \pm 0	0.8	0.8 \pm 0	0.8 \pm 0	9.8 \pm 12.0	0.8 \pm 0.0	
Kepon	X	X	X	X	0.8	X	
Methoxychlor	X	X	X	X	X	1.5	
Mirex	0.3 \pm 0	0.8	4.7 \pm 3.6	1.3	1.1 \pm 0.5	1.3 \pm 0.2	
<i>o,p'</i> -DDD	X	X	X	X	X	X	
<i>o,p'</i> -DDE	X	X	X	X	X	3.4	