EVALUATION OF ORGANOCHLORINE COMPOUNDS IN PEREGRINE FALCON (FALCO PEREGRINUS) AND THEIR MAIN PREY (COLUMBA LIVIA) INHABITING CENTRAL SPAIN

RUBÉN MERINO,† LUISA R. BORDAJANDI,‡ ESTEBAN ABAJ,‡ JOSEP RIVERA,§ and BEGOÑA JIMÉNEZ*†
†Department of Instrumental Analysis and Environmental Chemistry, Institute of Organic Chemistry, CSIC, Juan de la Cierva 3, 28006, Madrid, Spain
‡Department of Ecotechnologies, Research and Development Centre, CSIC, Jordi Girona, 18-26, 08034, Barcelona, Spain

(Received 14 January 2004; Accepted 21 February 2005)

Abstract—The population of peregrine falcon (Falco peregrinus sbs. brookei) inhabiting the Regional Park of southeastern Madrid (RPSM), Spain, has experienced an increase of unsuccessful pairs (from 15% among a total of 20 pairs in 1995 to 55% among a total of 18 pairs in 2001). Traditionally, this area has been known to be contaminated with organochlorine compounds and toxic metals, which are known to be deleterious to the reproductive system of birds. During the breeding seasons of 2000 and 2001, contaminant residues were measured in unhatched eggs of peregrine falcons and liver of their main prey, to determine if they could be affecting the survival of the population. The most abundant contaminants were ortho–polychlorinated biphenyls (ortho–PCBs), ranging from 202.56 to 3,335.16 ng/g (wet wt) in falcon eggs and from 10.25 to 53.51 ng/g (wet wt) in pigeon livers. In all samples, the 2,3,7,8-substituted polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were detected, although these levels never exceeded 20 pg/g (wet wt). The major contributor to total toxic equivalent quantities (TEQs) were non–ortho–PCBs. Organochlorine levels found in this study may contribute to the entire suite of stressors that are negatively affecting the peregrine population.

Keywords—Peregrine falcon Organochlorines Polychlorinated biphenyls Polychlorinated dibenzo-p-dioxins Toxic equivalents

INTRODUCTION

Adverse effects of organochlorine compounds such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and organochlorine insecticides in wildlife have been documented widely in the literature in the past decades [1,2]. It is also well-documented that peregrine falcon (Falco peregrinus) represents a species particularly sensitive to these contaminants [3,4].

The peregrine falcon population (Falco peregrinus sbs. brookei) inhabiting the Regional Park of southeastern Madrid (RPSM), Spain, has experienced an increase of unsuccessful pairs (from 15% among a total of 20 pairs in 1995 to 55% among a total of 18 pairs in 2001) [5]. This phenomenon could have its origin in the bioaccumulation by adult individuals of toxic chemicals detected in the area. Fernández et al. reported relatively high concentrations of organochlorine residues such as PCBs and dichlorodiphenyltrichloroethanes (DDTs) in soil and water from this area [6]. Also, heavy metals were detected in blood from a black kite population nesting in our study area [7]. Because these chemicals are known to have deleterious effects, such as decrease of eggshell quality, embryo mortality, genetic modifications or behavior alterations, and feminization of males [8–10], their influence on the increasing number of unsuccessful pairs had to be investigated. This study constitutes, to our knowledge, the first evaluation of the presence of persistent organic contaminants in F. peregrinus inhabiting central Spain.

Some studies link the decline of bird populations to the increase in the use of chemical pollutants. These may cause direct toxicity [1] or indirect effects through the prey species [11]. Other studies suggest that reproductive effects are induced following PCB exposure during prenatal and early postnatal periods, which may compromise future reproduction or survival [12]. Due to the importance of food as the route of exposure of falcons to contaminants, it is important to determine such levels in their prey species. In our study area, pigeons (Columba livia) represent about 80% of these raptors’ total diet.

The purpose of this study was to make the first evaluation of the status of organochlorine residues (PCDDs, PCDFs, PCBs, and DDTs) in peregrine falcon eggs and in their main avian prey species, pigeons, in the RPSM, with the aim of evaluating their possible negative influence on the peregrine falcon. We discuss the potential significance of those contaminants to the peregrine falcon population based on comparisons with a reference population of peregrines from a close area relatively unaffected by agricultural or industrial activities.

MATERIALS AND METHODS

Study area

The present study was conducted in a protected area in the province of Madrid, Spain. This area encompasses the RPSM, which was declared a protected zone by the Madrid Regional Government in 1994. In spite of being a protected area, it receives contaminant inputs from industrial and agricultural activities around the Park. Peregrine falcons nesting in a relatively unpolluted area were selected as our reference population. The reference area, with similar geomorphic charac-
teristics to the RPSM, is in the province of Guadalajara (G), east of Madrid province, and has not suffered declines of the peregrine falcons over the five past years [13]. Low contaminant levels were expected, as industrial and agricultural activities are not developed in the reference area.

**Samples**

During the breeding seasons of 2000 and 2001, the territories of the peregrine falcons in the RPSM were observed closely; 19 pairs were detected in 2000, and 18 pairs were detected in 2001. At least 7 d after the expected hatch date, failed eggs were collected. A total of seven unhatched peregrine eggs were collected in 2000, four from the RPSM and three from the reference area. In 2001, only one egg was found in the RPSM and collected for residue analysis. No eggs were found in the reference area during 2001. Due to this limitation, statistical comparisons could not be done.

In all cases, no more than one egg per nest was collected. Eggs were transported to the laboratory and stored at −80°C until analysis. It was assumed that all eggs had the same water loss. Before residue analysis, eggs were examined, and none of them were embryonated.

Pigeons, the main prey of the peregrine falcons, were trapped for contaminant analysis in the falcon’s hunting territories during 2001. The pigeons were euthanized following general ethical guidelines for animal welfare; the livers were removed and frozen at −20°C. The livers were examined, and none of them were embryonated.

**Residue analysis**

The following organochlorine compounds were analyzed: All the 2,3,7,8-substituted PCDDs and PCDFs; PCB congeners including ortho-PCBs (28, 52, 95, 101, 123, 149, 118, 114, 153, 132, 105, 138, 167, 156, 157, 180, 179, 189, 194) and non-ortho-PCBs (77, 126, 169); and DDTs. Sample treatment involved three steps. First, the extraction step was carried out using a solid-phase matrix dispersion procedure. Then, a clean-up step based on neutral silica, silica modified with sulphuric acid, and silica modified with potassium hydroxide was carried out. The final fractionation step was achieved using Supelclean® Supelco ENVII-Carb tubes (Bellefonte, PA, USA) as described elsewhere [14]. Three fractions were collected: The first fraction contained the bulk of PCBs and DDTs; the second and third fractions contained non-ortho-substituted PCBs and PCDD/Fs, respectively.

Resolution and quantification of ortho-PCBs and DDTs were carried out by high-resolution gas chromatography using a Hewlett-Packard 6890 gas chromatograph (GC) equipped with a △Ni electron capture detector (Palo Alto, CA, USA). A DB-5 (J&W Scientific, Folsom, CA, USA) fused silica capillary column (60 m × 250 μm and 0.25-μm film thickness) was used. The carrier gas was nitrogen at a head pressure of 192.2 KPa. Detector and injector temperatures were 300 and 270°C, respectively. Resolution and quantification of PCDDs, PCDFs, and non-ortho-PCBs were performed by high-resolution gas chromatography–high-resolution mass spectrometry on a GC 8000 series gas chromatograph (Carlo Erba Instruments, Milan, Italy) equipped with a CTC A 200S autosampler (Water Instruments, Manchester, UK) and coupled to an Autospec Ultima mass spectrometer (Micromass, Manchester, UK), using a positive electron ionization source and operating in the selected ion-monitoring mode at 10,000 resolving power (10% valley definition). The current trap was 600 μA, the ionization energy was 31 eV, and the acceleration voltage was 8,000 V. Ion source temperature was 250°C. The two most abundant ions in the [M-CI]+ cluster were monitored between 50 and 80 ms dwell time and a delay time of 20 ms as described in U.S. Environmental Protection Agency method 1613 [15]. Chromatographic separation was achieved with a DB-5 (J&W Scientific) fused-silica capillary column (60 m × 0.25 mm ID, 0.25-μm film thickness) with helium as carrier gas in the splitless injection mode (1–2 μl). Chromatographic windows for each group of PCDD/PCDF homologues, from tetra- to octachlorinated, were defined on the DB-5 capillary column. Injector temperature was 280°C for the DB-5 column. The interface temperature was 280°C. The temperature program was 140°C (1 min) to 200°C (1 min) at 20°C/min, then at 3°C/min to 300°C and held isothermally for 20 min at 300°C. Quantification was carried out by the isotopic dilution method [15].

Quality assurance criteria were based on the applications of the quality control and quality assurance measures as described elsewhere [16]. Such measures included the analysis of blank samples covering the complete analytical procedure. Other performance checks taken into account were accurate isomer specific separation, sensitivity check, and 10,000 resolution power of mass spectrometer, and sufficient recovery. Additional evaluation for ensuring good quality data were obtained by the analysis of certified reference materials and the participation in interlaboratory studies covering both biotic and nonbiotic matrices.

**RESULTS**

Levels of all the organochlorine compounds analyzed in the unhatched peregrine eggs and pigeon livers are presented in Table 1 and are expressed on a wet weight basis.

**PCDDs, PCDFs, PCBs, and DDTs levels in unhatched eggs of peregrine falcons**

Total PCDD/F levels in peregrine falcon eggs were 7.79 ± 0.98 pg/g (wt wt) in the reference area (G). These compounds were almost two times higher, 16.11 ± 2.14 pg/g (wt wt) in the study area (RPSM). Figure 1 shows the profile of the 2,3,7,8-substituted PCDDs and PCDFs. All 17 of the 2,3,7,8-substituted PCDDs and PCDFs were detected, 2,3,4,7,8-PeCDF being the most abundant congener, with percentages ranging from 19 to 40%, followed by 1,2,3,6,7,8-HxCDD, 1,2,3,7,8-PeCDD, and 2,3,7,8-TCDF.

Non-ortho-PCBs were detected in all the eggs analyzed. In the reference area, non-ortho-PCBs concentration was 147.39 ± 22.22 pg/g (wt wt), congener 126 being the most abundant, followed by PCB 77 and PCB 169. In the RPSM, non-ortho-PCB levels were 519.47 ± 194.89 pg/g (wt wt), which were higher than those found in the reference area.

In the case of ortho-PCBs, total levels in the reference area were 242.07 ± 43.32 ng/g (wt wt) and, in the RPSM area, ortho-PCB levels were 1,492.51 ± 1,090.08 ng/g (wt wt). In all falcon eggs, the most abundant PCB congeners were 180 and 153, accounting for 60% of the total, as can be seen in Figure 2.

The 2,3,7,8-TCDD equivalents were estimated for PCDD/F congeners and dioxin-like PCBs with an assigned toxic equivalency factor value, based on the bird toxic equivalency factors reported in 1998 by the World Health Organization [17]. Total toxic equivalent quantity (TEQ) levels were 13.28
Table 1. Concentrations on a wet weight basis of dichlorodiphenyltrichloroethanes (DDTs), polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs), polychlorinated dibenzo-p-dioxins (PCDDs), and total toxic equivalent quantities (TEQs) in peregrine falcon eggs from the study area Regional Park of southeastern Madrid (F-RPSM), Spain and from the reference area Guadalajara (F-G), Spain; and liver of falcon preys from the study area Regional Park of southeastern Madrid (Prey-RPSM), Spain.

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Σ DDTs ng/g</th>
<th>ortho-PCBs ng/g</th>
<th>Non-ortho-PCBs pg/g</th>
<th>PCDFs pg/g</th>
<th>PCDDs pg/g</th>
<th>Total TEQs pg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-RPSM-1</td>
<td>332.34</td>
<td>429.76</td>
<td>246.50</td>
<td>5.86</td>
<td>7.36</td>
<td>20.84</td>
</tr>
<tr>
<td>F-RPSM-2</td>
<td>359.48</td>
<td>1,339.48</td>
<td>591.71</td>
<td>13.00</td>
<td>6.18</td>
<td>51.32</td>
</tr>
<tr>
<td>F-RPSM-3</td>
<td>716.17</td>
<td>3,335.16</td>
<td>676.24</td>
<td>7.85</td>
<td>7.75</td>
<td>50.10</td>
</tr>
<tr>
<td>F-RPSM-4</td>
<td>226.79</td>
<td>1,243.77</td>
<td>694.18</td>
<td>11.66</td>
<td>4.24</td>
<td>54.13</td>
</tr>
<tr>
<td>F-RPSM-5</td>
<td>1,915.47</td>
<td>1,114.36</td>
<td>388.74</td>
<td>7.42</td>
<td>9.25</td>
<td>36.98</td>
</tr>
<tr>
<td>F-G-1</td>
<td>270.99</td>
<td>202.56</td>
<td>429.76</td>
<td>3.41</td>
<td>3.25</td>
<td>3.48</td>
</tr>
<tr>
<td>F-G-2</td>
<td>255.12</td>
<td>288.40</td>
<td>163.10</td>
<td>4.51</td>
<td>3.88</td>
<td>14.42</td>
</tr>
<tr>
<td>F-G-3</td>
<td>264.76</td>
<td>235.25</td>
<td>131.68</td>
<td>4.33</td>
<td>3.99</td>
<td>12.15</td>
</tr>
<tr>
<td>Prey-RPSM-1</td>
<td>4.02</td>
<td>53.51</td>
<td>92.20</td>
<td>3.33</td>
<td>7.16</td>
<td>6.38</td>
</tr>
<tr>
<td>Prey-RPSM-2</td>
<td>1.49</td>
<td>22.10</td>
<td>39.32</td>
<td>4.10</td>
<td>5.84</td>
<td>3.55</td>
</tr>
<tr>
<td>Prey-RPSM-3</td>
<td>1.73</td>
<td>34.90</td>
<td>51.66</td>
<td>2.93</td>
<td>8.30</td>
<td>4.37</td>
</tr>
<tr>
<td>Prey-RPSM-4</td>
<td>0.74</td>
<td>13.74</td>
<td>31.50</td>
<td>2.68</td>
<td>3.72</td>
<td>3.11</td>
</tr>
<tr>
<td>Prey-RPSM-5</td>
<td>1.84</td>
<td>17.34</td>
<td>32.41</td>
<td>2.59</td>
<td>4.11</td>
<td>3.15</td>
</tr>
<tr>
<td>Prey-RPSM-6</td>
<td>2.27</td>
<td>13.77</td>
<td>26.55</td>
<td>2.21</td>
<td>2.87</td>
<td>2.55</td>
</tr>
<tr>
<td>Prey-RPSM-7</td>
<td>3.43</td>
<td>20.20</td>
<td>29.58</td>
<td>3.87</td>
<td>5.74</td>
<td>3.32</td>
</tr>
<tr>
<td>Prey-RPSM-8</td>
<td>1.89</td>
<td>10.25</td>
<td>22.82</td>
<td>2.87</td>
<td>5.08</td>
<td>2.54</td>
</tr>
<tr>
<td>Prey-RPSM-9</td>
<td>10.21</td>
<td>17.10</td>
<td>26.59</td>
<td>2.84</td>
<td>5.17</td>
<td>3.27</td>
</tr>
</tbody>
</table>

* NQ = not quantified.
* TEQs corresponding to the sum of PCDDs, PCDFs, and ortho-PCBs with an assigned toxic equivalency factor.

± 1.61 pg/g (wet wt) in the reference area and 46.67 ± 13.88 pg/g (wet wt) in the RPSM. In all falcon eggs, the highest contribution to the total TEQs corresponded to non-ortho-PCBs, mainly PCB 126, with a contribution between 63 and 78%, followed by the PCDFs, mainly 2,3,4,7,8-PeCDF, ranging from 10 to 22% (Fig. 3).

Dichlorodiphenyltrichloroethane and its main metabolite, DDE, were found in all falcon eggs. The DDT levels were relatively low in both areas studied. In the reference area, DDT concentrations were 0.99 ± 0.10 ng/g (wet wt) and, in the RPSM concentrations were slightly higher at 3.77 ± 0.68 ng/g (wet wt). However, this difference was more remarkable for DDE concentration, which was 262.63 ± 8.10 ng/g (wet wt) in the reference area and 705.88 ± 698.86 ng/g (wet wt) in the RPSM.

PCDDs, PCDFs, PCBs, and DDTs levels in pigeon livers from the RPSM

In pigeon livers, total PCDD/F levels ranged from 5.08 to 11.23 pg/g (wet wt). In all samples examined, the most abundant congener was OCDD, accounting for about 35% of total PCDD/F levels (Fig. 1), followed by 1,2,3,4,6,7,8-HpCDD, which represented up to 15%. In all cases, the levels of PCDDs were higher than those of PCDFs.

Non-ortho-PCBs were detected in all pigeon livers, ranging...
Organochlorine compounds in peregrine falcon

Environ. Toxicol. Chem. 24, 2005 2091

Fig. 2. Relative contribution of individual congeners of ortho−polychlorinated biphenyls (ortho-PCBs) to total ortho-PCB levels in falcon eggs from the study area Regional Park of southeastern Madrid (F-RPSM), and the reference area Guadalajara (F-G); and liver of falcon prey from the study area Regional Park of southeastern Madrid (Prey-RPSM), Spain.

from 22.82 to 92.20 pg/g (wet wt). The most abundant congener was PCB 77, followed by PCB 126 and PCB 169.

Total ortho-PCBs concentration ranged from 10.25 to 53.51 ng/g (wet wt). Among these, the most abundant PCBs were those with a low chlorination degree, such as PCBs 28, 52, 95, 101, 118, 123, and 149, accounting for total PCB levels up to 52%. This congener pattern is quite different from those observed in eggs from peregrine falcon, which exhibited PCBs 153 and 180 as the most abundant (Fig. 2).

Total calculated TEQs ranged from 2.54 to 6.38 pg/g (wet wt). The major contribution to the total TEQs (Fig. 3) came from non−ortho-PCBs, mainly PCB 77, ranging from 42.5 to 75.0%, and PCDFs and mainly 2,3,4,7,8-PnCDF, contributed between 13.3 and 32.1% to total TEQs.

Regarding DDT, levels ranged from 0.22 to 1.59 ng/g (wet wt) and, in the case of DDE, this range was between 0.37 and 9.74 ng/g (wet wt).

DISCUSSION

Total PCDD/F concentrations found in falcon eggs were lower than those found by Jarman et al. [18] in peregrine falcon eggs from California, USA (134.1 ng/kg wet wt), where the peregrine population is now recovering. Data suggest that, at present, PCDDs and PCDFs do not represent a threat for the peregrines being studied in the RPSM. It is remarkable that the most abundant congener found in our study (2,3,4,7,8-PnCDF) differs from the most abundant congeners (1,2,3,7,8-TeCDD and 1,2,3,6,7,8-HxCDD) reported in the study on peregrines from California. The different profiles found in the present study could be due to different sources of contamination.

In all eggs, non−ortho-PCB levels were lower than the doses found to be toxic to chicken embryos [19]. The toxic dose for peregrine falcons is not established, and sensitivity to toxic compounds can vary greatly between species [20]. Because there are no toxicity data for these compounds in peregrine falcons and these levels are the first ones reported on eggs from Spain, it is difficult to assess the actual impact that these chemicals may have on the peregrines.

Concentrations of total ortho-PCBs in all falcon eggs analyzed here were lower than levels (>4,000 ng/g) shown to cause reduced hatchability, embryo mortality, and deformities in birds [21]. Also, a lowest-observed-adverse-effect level of 3 to 5 ppm PCBs has been estimated for egg concentrations in free-ranging birds by Giesy et al. [22]. Because some of the eggs analyzed in the present study had concentrations near to these values, the PCBs could be a cause of concern in the Park in the future due to the bioaccumulation process. In addition, Fernie et al. demonstrated in American kestrels that reproductive effects are seen with both direct and in ovo PCB exposure [12]. Similarly, the study from Brouwer et al. [23]

Fig. 3. Relative contribution of the sum of ortho−polychlorinated biphenyls (ortho-PCBs), non−ortho−polychlorinated biphenyls (non−ortho-PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) to total toxic equivalent quantities in peregrine falcon eggs from the study area Regional Park of southeastern Madrid (F-RPSM), and from the reference area Guadalajara (F-G); and liver of falcon prey from the study area Regional Park of southeastern Madrid (Prey-RPSM), Spain.
concludes that reproductive problems are induced following PCB exposure during prenatal as well as early postnatal periods.

Total TEQs measured in falcon eggs were lower than those reported to produce reproductive dysfunction in double-crested cormorant [24] and are also lower than the lowest-observed-effect level of 210 pg/g (wet wt) of TEQs on whole egg for cytochrome P450 1A (CYP1A) induction in bald eagles reported by Elliot et al. [25].

None of the eggs from the RPSM exceeded the DDE levels associated with reproductive impairment [21] or decline of peregrine falcon populations [3]. However, it is remarkable that the falcon egg collected in 2001 exhibited a total DDT (DDT + DDE) concentration 10-fold higher than levels found in the reference area. Because peregrine falcon is known to be particularly sensitive to DDE effects [26], our findings do not allow us to discard a possible negative effect of this compound on the peregrines.

The PCDD/PCDF levels found in pigeons are low as reported in similar species located low in the trophic web [27]. These results are in good agreement with those found by Olaf-sötir et al. [28] in their study about organochlorine levels in prey species of gyrfalcon (Falco rusticolus) from Iceland. They found that the most abundant PCB congeners in species lowest in the food web (such as pigeons) were the lower chlorinated PCB, increasing chlorination substitution through moving up the food web, PCB 153 and 180 being the most abundant in top predators.

The DDE in pigeons is well below the amount of 1 μg/g (wet wt) described by Enderson et al. [29] as the amount of DDE known to cause thin-shelled eggs and reduced reproductive success in the prey of peregrine falcons.

The DDE levels found here are lower than those reported in a recent study by Mora et al. [11] in the prey carcasses (180–5,140 ng/g wet wt) of peregrine falcons from Texas, USA. Mora et al. concluded that only rough-winged swallows, with DDE levels over 5,000 ng/g (wet wt), could be implicated in the reduced reproductive success of peregrine falcon observed in the area. Our results suggest that DDE levels found in the main falcon’s prey do not seem to compromise directly the survival of the peregrine falcon population at present. However, due to the bioaccumulation and biomagnification process through the food web, the recalcitrant characteristics of these contaminants, and the sensibility of falcon species to DDE, deleterious effects cannot be discounted in the future.

The levels of organochlorine compounds (PCDDs, PCDFs, PCBs, DDTs) analyzed in falcon eggs and pigeon liver from the Regional Park of southeastern Madrid, Spain, are lower than those associated with reproductive failure in falcons. However, it should be noted that, in some eggs, ortho-PCBs exhibited levels close to those associated with reproductive impairment.

An important observation is the difference in residue levels between eggs from the reference area and contaminated sites. Considering the wide interspecies variation demonstrated for the toxicity of dioxins and PCBs, and with no data available on the effect on raptors about the interaction between compounds, we cannot discard a negative effect on the reproductive health of peregrine falcons, which could compromise the stability of this population.

The presence of organochlorine compounds in the unhatched eggs, as well as in pigeons, the main prey of the peregrine falcon, suggest that the young falcons born during the breeding seasons of 2000 and 2001 could have been exposed to pollutants in ovo, as well as during their early postnatal periods. Due to their high sensitivity to these compounds, they could be suffering from alterations in reproductive and general development. We do not know what other contaminants simultaneously are challenging the peregrine population in the RPSM, but we feel that further investigation is important. Heavy-metal levels (Cu, Cd, Zn, Pb, As) were measured in eggs and found to be within the range reported in other studies [30]. We cannot dismiss their possible negative effects in falcons, because no one has reported the minimum concentrations of toxic metals (cadmium, arsenic, lead) in peregrine eggs that affect embryonic development; interactions with other contaminants are not known; and it is well described that metal exposure in ovo is known to affect the immune system [31], brain development [32], and hatchability [33], compromising chick development and population stability. Hazards described in the area, such as electrical support, recreational climbing, robbing of nests, other human disturbance, habitat change, and interspecific competition with eagle owls, could compromise the survival of this falcon population. Even though Augspurger and Boynton [34] concluded in their study that factors limiting falcon productivity in North Carolina were nest predation, inclement weather, poor food supply, and human disturbance, but not contaminants such as DDE. It is important to consider all the factors when the stability of a population is being evaluated, especially taking into account that no previous studies have been performed in this area.

Organochlorine levels found in this study may contribute to the entire suite of stressors that negatively are affecting the peregrine population in our study area. The minimization of these hazards is necessary to ensure the survival of the peregrine falcon population in the RPSM.

Acknowledgement—Financial support for this research was provided by the project 186/RN-38 Consejería de Agricultura y Medio Ambiente de la Junta de Comunidades de Castilla-La Mancha. Sociedad Española de Ornitología Birdlife helped to finance this research. The authors would like to acknowledge J. Carlos del Moral y for his participation in the peregrine falcon project and to thank M.A. Nieto and J. de Lucas for their fieldwork and J. Smits for her valuable comments. Rubén Merino is the recipient of a PhD fellowship from the Regional Government of Madrid (Consejería de Educación y Ciencia).

REFERENCES
7. Blanco G, Frias Ó, Jiménez B, Gómez G. 2003. Factors influencing variability and potential uptake routes of heavy metals in...