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Organochlorine Pesticides and Polychlorinated Biphenyl Congeners in Lanner *Falco biarmicus feldeggii* Schlegel Chicks and Lanner Prey in Sicily, Italy

This paper reports on research conducted to elucidate the risk posed to the Sicilian population of the endangered lanner falcon *Falco biarmicus feldeggii* Schlegel by organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs), as part of a wider study on contaminant risk to the lanner. Seventeen lanner nest sites were studied in northern and central Sicily. Sampling (in 2005) and analysis were carried out for selected OC pesticides and PCB congeners in lanner chick blood (15 chicks from 6 nest sites) and in two of the main lanner prey species, magpie *Pica pica* (36 individuals from 6 lanner nest sites) and rock dove *Columba livia* (10 individuals from 2 lanner nest sites). No OC and PCB residues were found in lanner chick blood above the detection limits, except for one solitary congener PCB153 (21.8 ng g^{-1} wet weight), suggesting that these contaminants do not pose a significant risk to lanner chicks in the study area. Magpie and dove appeared mostly free of contamination with OC pesticides, though contamination levels were significantly higher in magpie than in dove. The presence of exceptional DDE and HEOD values in ~8% of the *P. pica* sample, and one *P. pica* sample showing recent DDT contamination, may indicate a local OC pesticide hazard to some lanner. Future research to further elucidate the contaminant risk to lanner in Sicily is suggested.

INTRODUCTION

Pollutant Threat to Raptors in Europe

The threat posed by pollution to raptors, as a group, is well documented. Raptors were among the first species of birds known to be affected by chemicals, such as persistent organic pesticides, and the problems these birds experience with chemicals have not gone away despite bans on the most acutely poisonous chemicals and restrictions on many others (1). It is now becoming apparent that there is a widespread and growing threat to raptors in Europe from the necessary use of rodenticides to control pests such as rats and voles. Recent studies show that some raptor species contain as many as 40 unknown substances in their tissues (2). Protecting such species from past, as well as presently unidentified, pollutant threats is particularly important given that they are K-selected species (which typically invest in fewer offspring) that may take a long time to recover (3).

However, despite all the previous work, existing data on contaminants in raptors across the European Union (EU) remain patchy, and a comprehensive review of the state-of-the-art has not been carried out for some time. Certainly, most EU studies of contaminants in raptors relate to northern species and ecosystems, such as the peregrine falcon in the UK; much less work has been carried out on contaminants in raptors in southern Europe, and in particular in Italy (4–6).

Lanner Falcon *Falco biarmicus feldeggii* nestling (Photo: M. Lo Valvo).

The Lanner: Status and Conservation Needs

The lanner falcon *Falco biarmicus feldeggii* Schleg. is one of the most threatened bird species in Europe and is listed as an endangered species in Annex I of the Birds Directive (7). It is classified by BirdLife International as "endangered" at the European level and a Species of European Conservation Concern category 3 (SPEC3), experiencing rapid decline (8, 9). The lanner is also listed in Appendix II of the Bonn Convention, Appendix II of the Bern Convention, and Appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). EU policy prioritizes action for "most important species" (10) and, in particular, for those, such as the lanner, listed under the Birds Directive (7). In the Mediterranean Action Plan produced under the Barcelona Convention, the lanner is considered to be a priority species for conservation along with only 15 other species. In Europe, the species is at the edge of its global range and may therefore be particularly susceptible to ecological changes and to threats (8). Most of the EU population of the lanner (~210–245 pairs) is resident in Italy (140–172 pairs), of which over half (~70–80 pairs) reside in Sicily (11, 12); the only other member state with a resident population is Greece (8, 9).

The lanner is the subject of an International Species Action Plan (ISAP) (13) that identifies pesticide toxicity as one of the main probable causes of decline. Article 4 of the Birds Directive requires that the lanner "...shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution" and that "Member States *shall take appropriate*

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steps to avoid pollution or deterioration of habitats or any disturbance affecting the birds . . ." (author's italics).

Previous Contaminant Studies on the Lanner

The ISAP notes that "data on the relative significance of . . . the impact of pollutants (on the lanner) are very limited," citing only a limited study on the separate subspecies *F. biarmicus erlangeri* in Tunisia (14). Similarly, very few data exist on the bioavailability of contaminants in the extensive cereal and dry steppic grassland ecosystems (ecosystems which are also a priority for conservation under the Habitats Directive) in which the lanner resides. Outside Europe, a study has been made of residues in the closely related laggar falcon *Falco biarmicus jugger* in Pakistan (15).

Current Study

This paper reports on work carried out under a Marie Curie Fellowship provided by the European Community, under the name RAPTOR ECOTOX, which began in early 2005 and concluded in early 2007. The wider objectives of the project were twofold: first to establish how rare sedentary raptors, such as the lanner falcon in Sicily, Italy, can serve as sentinels of environmental health, contamination, and ecosystem change; and second, whether, through a better understanding of the lanner's ability to cope with environmental pressures, recovery plans for the species can be reinforced.

Within these wider objectives, the project had a number of specific objectives, one of which was to investigate current and historical exposure to and effects of contaminants in the lanner populations studied and the general bioavailability of pollutants by measuring residue levels of persistent organic pollutants (POPs) and other contaminants in the lanner falcon and prey species of the lanner, and in lanner feathers in museum collections. The current paper reports on the project's methods, materials, and results relating to persistent organic pollutants. Other aspects of the project will be reported elsewhere.

MATERIALS AND METHODS

Ecotoxicological research was divided into four phases—design, fieldwork, laboratory analysis, and interpretation.

Design

Activities during the design phase included: determination of types and numbers of in-nest and out-of-nest samples, taking into account ethical and statistical requirements; obtaining relevant sampling and export permits; design of field ecological studies and sampling regime and development of protocols; and logistical arrangements for export of samples from Italy to UK, including application for relevant permits.

Field Ecology and Sampling

Field observations and sampling took place in 2005 and 2006. This involved locating breeding territories and nest sites, collection of ecological data on lanner, prey, habitats, land-use, and other pressures, and collection of samples for ecotoxicological analysis.

Location of Breeding Territories and Nest Sites. The lanner in Sicily is essentially a sedentary species, although it has less fidelity to nest sites than related species such as the peregrine. It is very sparsely distributed, and nests are often several kilometers or tens of kilometers apart. Adult breeding pairs select nest sites in more-or-less remote upland locations, on craggy outcrops usually adjacent to extensive grasslands and arable lands. Nests are usually built on vertical cliff faces and, in almost all cases, may only be reached by professional climbers. The University of Palermo has been studying the lanner in Sicily for a number of years and has good knowledge of the habitual territories of breeding pairs and likely nesting sites. Occasional winter visits (January–February) preceding each breeding season (2005, 2006) were carried out to verify presence of lanner at these sites and to identify breeding pairs to be studied. The nesting sites selected for study were all located in the northern and central parts of Sicily, one of the two main centers of distribution of the lanner in Sicily (the other being in eastern Sicily, not covered in our study). Exact locations were recorded but are not reported here given the risk posed by egg collectors, the illegal falconry trade, and/or intrusive birding. More intensive fieldwork took place from the start of the breeding season (occupation of territories) in February–March each year, with the purpose of identifying a statistically significant number of pairs for intensive observation and sampling.

Collection of Ecological Data. We gathered, throughout the breeding season each year, a range of data on the lanner populations sampled, their habitats, and land use. Data were gathered using protocols designed to allow integration with contaminant data and included data on: location and cliff topology, habitat variables, past and present land uses, hunting and other human pressures, land-use policies, eco-ethological observations (preferred hunting habitat, preferred prey, perch sites, etc.), prey densities, and observation of peregrine populations to elucidate interspecific competition. Substantial data of this kind already existed for some of the lanner pairs selected for study.

Collection of Samples for Contaminant Analysis. Ethical consideration of the endangered status of the lanner required sampling methods to minimize any risk of disturbance. Contaminant studies in endangered raptors are facilitated by the availability of nondestructive sampling methods for blood, eggs, and feathers.

We determined to collect samples for contaminant analysis from lanner fledglings and from lanner prey occurring in the vicinity of the nest sites, in order to test any correlation in contaminant residue levels between lanner chicks and prey.

Whilst the resident (or locally migrant) status of the lanner in Sicily makes it probable that residue burdens in adults largely reflect contamination in the general localities in which the birds are sampled, contamination in fledglings is all the more likely to reflect intake of contaminants from local food sources. Others have also observed that nestling blood plasma better reflects local conditions than egg samples or adult plasma (16). Fledgling contaminant levels can therefore be used as an indicator of local pollution (17).

In order to achieve a statistically significant number of samples from lanner chicks, we aimed to sample from ~15 nest sites each year. Sampling was carried out by qualified ornithologists and climbers holding relevant permits from the competent regional authorities (Regional Government of Sicily, and Istituto Nazionale per la Fauna Selvatica), in the course of an annual ringing program. Eggs are laid in February–March, and fledging occurs around late April to mid-May. Care was taken to time climbs to nests such that chicks were large enough (500–850 g) to bear sampling, yet not so old (2–3 wk) as to risk their jumping from the nest.

For collection of lanner chick blood samples, chicks were lowered to the ground, where they were weighed, aged, and ringed. A blood sample was taken from the brachial vein (previously cleaned with 70% alcohol to avoid contamination) using a clean 2.5 mL heparinized syringe fitted with a 25-guage needle. Blood was centrifuged within 6 hr of collection. Plasma was drawn off, transferred to chemically cleaned glass vials, and

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Table 1. Limits of detection (LoD) (ng g^{-1} wet weight) for OC pesticides and PCB congeners (IUPAC numbers).

OC	HCB	a-HCCH	g-HCCH	HEOD	DDE	DDT	TDE
LoD	0.034	0.075	0.060	0.136	0.129	0.149	0.221
PCB	**8**	**18**	**28**	**29**	**31**	**52**	**77**
LoD	0.104	0.134	0.286	0.053	0.148	0.163	0.180
PCB	**81**	**101**	**105**	**114**	**118**	**123**	**126**
LoD	0.181	0.181	0.186	0.194	0.150	0.169	0.210
PCB	**128**	**138**	**141**	**149**	**153**	**156**	**157**
LoD	0.181	0.202	0.163	0.192	0.207	0.217	0.223
PCB	**163**	**167**	**169**	**170**	**171**	**180**	**183**
LoD	0.208	0.212	0.227	0.206	0.221	0.218	0.228
PCB	**187**	**189**	**194**	**199**	**201**	**205**	**206**
LoD	0.212	0.209	0.223	0.223	0.230	0.211	0.217
PCB	**209**						
LoD	0.225						

frozen at −20°C (18). The loss of the volume of blood required from each chick (1.5–2 mL) has no negative effect on the chicks.

We also collected breast feathers from each chick found in each nest. Feathers can be collected from live birds, which is particularly appropriate for rare and declining species (19). Breast feathers (2–3 from each chick) can be collected without undue harm to the chick, can be removed without affecting thermoregulation or flight, and rapidly regrow.

In addition to samples from lanner chicks, we collected samples of lanner prey. Birds make up some two-thirds of the lanner's prey in Sicily, the remainder consisting of arthropods, in particular, Imenopteri formicids of the genus *Camponotus* (20).

We collected samples of two of the most important prey species, magpie *Pica pica*, and dove *Columba livia*, in order to allow investigation of possible routes of contamination, bioaccumulation of contaminants through the food chain, and general bioavailability of contaminants in the ecosystem.

We also collected any molted adult lanner feathers, pellets, prey remains, unhatched eggs, and/or eggshell fragments found in or around the lanner nests. We also collected any available adult lanner carcasses received at the Ficuzza Recovery Centre in northern Sicily. While we obtained only two such carcasses, they provided the opportunity to analyze a range of body tissues, including muscle, liver, bone, and adipose tissues, for a range of contaminants. Finally, we sampled from collections of lanner feathers from the Museo Regionale di Storia Naturale, Terrasini, Sicily, in order to analyze historical residue levels (particularly for the period 1945–1970 following extensive DDT use in Italy at the end of the Second World War).

Samples were exported to the UK Centre for Ecology and Hydrology, Monks Wood, for laboratory analysis. Samples (other than feathers) were stored frozen pending analysis.

Overview of Samples Collected for Ecotoxicological Analysis. The following lanner samples were collected from the field in 2005: samples of blood and feathers from chicks from six nests (total 15 chicks), a few other nest-site samples (unhatched eggs from two nests, eggshell fragments from one nest, prey remains from two nests, pellets from five nests, adult feathers from one nest), and two adult carcasses from the Ficuzza Wild Fauna Recovery Centre.

The following prey samples were collected in 2005: 10 *C. livia* and 36 *P. pica* individuals. Feathers of these prey samples were stored separately from the carcasses. The availability of samples of these two species—the former a seed eater, the latter a carrion eater—allowed for examination of two possible contaminant routes into the lanner.

Adult lanner feathers were collected from 17 museum skins dating from between 1907 and 1976 (mostly from 1920s and 1930s) allowing—for some residues found in feathers—comparison of contemporary residue levels with historical levels.

The following lanner samples were collected from the field in 2006: samples of blood and feathers from chicks from seven nests (total 17 chicks) and a few other nest-site samples (prey remains from six nests, unhatched egg from one nest).

Laboratory Analysis

Here, we present the methods relating to analysis of lanner chick blood and lanner prey tissue samples collected in 2005 for organochlorine (OC) pesticides and for polychlorinated biphenyls (PCB) congeners. Analyses of other types of samples collected in 2005, and of samples collected in 2006, for OC pesticides and PCBs and/or other contaminants, will be reported elsewhere.

The procedure for extraction and cleanup of OC pesticides and PCBs from blood and from prey tissues was as described by Pereira et al. (21). Prey tissues were homogenized prior to cleanup.

OC pesticides and PCBs were determined by gas chromatography with electron-capture-detection (GC-ECD) using the methods described by Shore et al. (22). We tested lanner chick blood and lanner prey tissues for the following OC pesticides (International Union of Pure and Applied Chemistry [IUPAC] names): Hexachlorobenzene (HCB), 1a,2a,3,4a,5b,6b-hexachlorocyclohexane (a-HCH), 1a,2a,3b,4a,5a,6b-hexachlorocyclohexane (g-HCH), (1R,4S,4aS,5R,6R,7S,8S,8aR)-1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphthalene (HEOD), 1,1′-(dichloroethenylidene)bis[4-chlorobenzene] (DDE), 1,1,1-trichloro-2,2-bis(4-chlorophenyl)-ethane (DDT), 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane (TDE).

We tested for the following PCB congeners: 8, 18, 28, 29, 31, 52, 77, 81, 101, 105, 114, 118, 123, 126, 128, 138, 141, 149, 153, 156, 157, 163, 167, 169, 170, 171, 180, 183, 187, 189, 194, 199, 201, 205, 206, 209 (numbered according to Ballschmiter et al. [23]). The analysis was run in four batches: three batches of 15 samples for prey tissues, and one batch of 15 samples for lanner chick blood (plus one final prey tissue sample). For quality assurance purposes, a sample blank, control (chicken liver), and spiked control (chicken liver spiked with a known concentration of each congener) were run with each batch. Concentrations of OC pesticides or PCB congeners in the sample were expressed as wet weight and as lipid weight in ng g^{-1} corrected for limits of detection (which varied between 0.034 ng g^{-1} and 0.221 ng g^{-1} for OC pesticides and between 0.053 and 0.286 ng g^{-1} for PCB congeners; see Table 1) with the method blank subtracted from the results. All results quoted here are expressed as wet weight and arithmetic means.

Arithmetic means and standard deviations were calculated on untransformed data, setting below detection level values as half the detection value. A Kruskal-Wallis test was used to compare DDE values in *P. pica* and *C. livia*.

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RESULTS AND DISCUSSION

Field Ecological Data

A full report on field ecological data collected will be provided elsewhere, but a brief overview is provided here.

Nest sites were all on cliff faces (15–50 m high) in upland areas (300–600 m amsl) surrounded by largely arable agriculture. As this suggests that agrochemicals were a possible source of contaminants in the lanner diet, information was collected on chemicals in use and their active ingredients. There is also a variety of possible sources of industrial contaminants in Sicily, including refineries and power stations, mineral plants, metal processing plants, chemical plants, waste treatment plants, and surface treatment plants. These emit pollutants to air and water, including carbon, nitrogen, and sulfur gases, non-methane VOCs (volatile organic compounds), metals such as nickel, zinc, chromium, lead, etc., polycyclic aromatic hydrocarbons, and other organic carbon, particulates, etc. Any hazard to lanner from these pollutants might depend on factors including prevailing winds, and "occult deposition" in mountainous areas linked to condensation.

Prey species present included rock dove *C. livia*, magpie *P. pica*, and a variety of smaller bird species, including *Galerida cristata*, *Sturnus unicolor*, *Passer hispaniolensis*, *Carduelis carduelis*, *Sylvia melanocepalus*, *Hirundo rustica*, *Cisticola juncidis*, *Merops apiaster*, *Saxicola torquata*, *Miliaria calandra*, *Coturnix coturnix*, *Corvus corone cornix*, and *Turdus merula*.

Number of Samples

Obtaining a statistically significant number of samples of the lanner falcon was particularly challenging. The first challenge related to locating nest sites. The lanner population in Sicily is very sparsely distributed, and adult breeding pairs select nest sites in more-or-less remote upland locations, not all accessible by road. Given these constraints, we were able to locate, observe, and record data for a total of 17 nest sites. Second, little more than half of these 17 nest sites produced chicks. The remainder was abandoned (24%), occupied by second-year couples or a single lanner (12%), or taken over by peregrines (12%). Third, of those nests with chicks, almost a third (18% of the total) could not be sampled because they were inaccessible, even to professional climbers. In total, we were able to sample lanner chicks at 6 of the 17 nest sites under observation. Extrapolating from these figures, one would need to locate and follow ~28 nests to obtain samples from 10 nests. Sampling from such a large number of nest sites is constrained by two factors. First, the sites are widely distributed across thousands of square kilometers of remote upland terrain. Second, most egg laying occurs within a 1–2 wk period, and as already noted, samples must be collected when chicks are aged 3–5 wk; consequently, there is at most a 3–4 wk period available for all sampling to be carried out. Thus, to sample from more than the 17 sites we identified would have required a larger team of field ornithologists and climbers than the three-man, part-time team at our disposal.

Laboratory Analyses

In this paper, we present the results relating to analysis of lanner chick and lanner prey samples for OC pesticides and for PCB congeners. To date, analyses have been carried out on all lanner chick blood samples collected in 2005 and on all lanner prey samples collected in 2005. Analyses of other types of samples collected in 2005 and samples collected in 2006, for OC pesticides and PCBs and/or other contaminants, will be reported elsewhere.

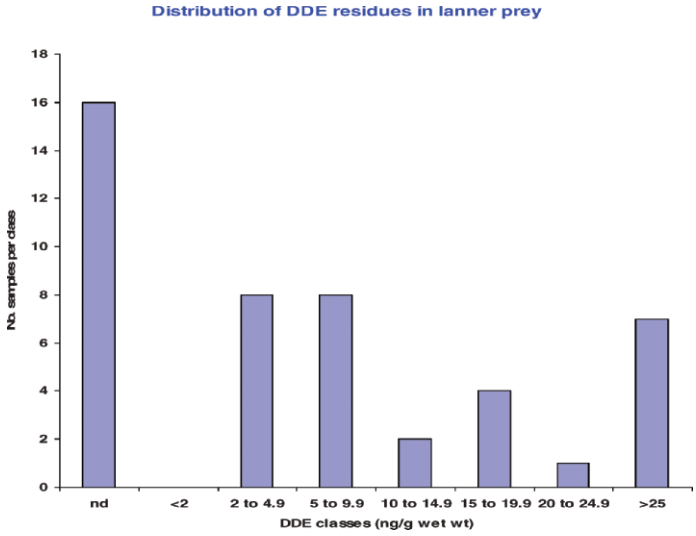

Figure 1. Distribution of DDE residues in lanner prey.

Lanner Chick Blood. No OC pesticide or PCB residues were found in lanner chick blood above the detection limits, except for one solitary sample PCB153 (21.8 ng g^{-1} wet weight [ww]). Lanner chick blood appears to be free of OC pesticide residues above the detection limits. This may suggest that there is no or very limited exposure of lanner chicks to OC pesticide contaminants in the study sites and that OC pesticides therefore do not present a significant threat to the lanner chick population in the study area of northern and central Sicily. However, caution is required in reaching such a conclusion as our chick blood was necessarily sampled from live chicks, *ergo* from successful nests; it may be that unsuccessful nests exhibit higher levels of contaminants. Moreover, the chicks sampled were only a few weeks old and so had not had much time to accumulate contaminants.

Lanner Prey Tissues: OC Pesticides. DDE (metabolite of DDT) was detected in 30 of the 46 samples (range 3.29 to 9189.83 ng g^{-1} ww). DDE was found in 4 of 10 (40%) *C. livia* samples (range 3.74 to 17.60 ng g^{-1} ww, arithmetic mean [SD] 3.81 [6.22] ng g^{-1} ww) and in 26 of 36 (72%) *P. pica* samples (range 3.29 to 9189.83 ng g^{-1} ww, mean [SD] 287.12 [1530.17] ng g^{-1} ww). The distribution of DDE in lanner prey (Fig. 1) shows a more classical skewed distribution of values, where the majority of samples contain low concentrations, though with a substantial elongated tail (samples >25 ng g^{-1}). DDE was more frequently found in *P. pica* (72% of samples) than in *C. livia* (40%) and at mean concentrations some 100 times higher, though the *P. pica* mean is skewed by three samples with relatively high—in one case very high—concentrations (162, 654, and 9190 ng g^{-1} ww). Excluding these three samples, the *P. pica* mean (SD) falls to 10.00 (14.71) ng g^{-1} ww. A Kruskal-Wallis test for all prey samples suggests that DDE levels in *P. pica* may be higher than in *C. livia* ($P = 0.06$). The lower DDE values for *C. livia* may reflect the fact that it is a seed eater, while *P. pica* feeds predominantly on live prey and carrion. The few exceptional values for *P. pica* suggest that some 10% of the magpie population may have exceptional levels of DDE residues. For the peregrine *Falco peregrinus* (which is closely related to the lanner), the critical DDE concentration in total prey (i.e., the threshold above which DDE residues result in eggshell thinning and associated problems in peregrine) has been variously estimated to be between 0.5 and 3 μg g^{-1} (24–26). Only our most contaminated magpie exceeded 3 μg g^{-1}, but two magpies exceeded 0.5 μg g^{-1}. These two *P. pica* samples were probably exposed to high DDE sources in their diet, probably accumulated in the fat of prey/carrion that was itself exposed to

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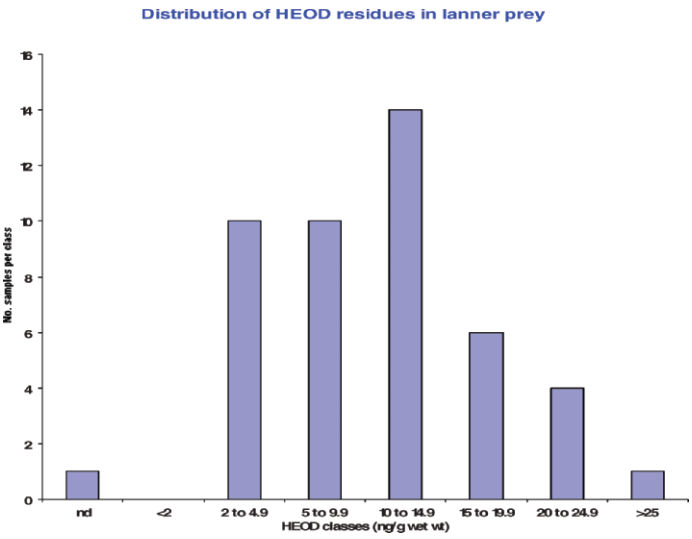

Figure 2. Distribution of HEOD residues in lanner prey.

DDE or its precursor DDT. The relatively small proportion of these exceptional values suggests that the sources might be infrequent or isolated (but at high levels), so that only a few magpies are eating them. Nonetheless, the occurrence of such values may indicate *P. pica* as a potentially important route of critical levels of DDT/DDE into local lanner populations. In Australia, Olsen et al. (27) found that DDE concentrations in prey were reflected in concentrations in peregrine egg contents and in measures of productivity and nest-site occupancy. Further, the hazard to lanner reproduction from DDE in its prey may be increased by biomagnification of contaminants from prey to raptor egg; DDE has been calculated to biomagnify by a factor of 87-fold on a wet weight basis from prey to egg in osprey, and by a factor of 70 in peregrine (28, 29).

DDT and TDE were detected in only one *P. pica* sample; this was the same sample with exceptionally high values for DDE and HEOD. The exceptional values for DDT and TDE in one *P. pica* sample indicate recent exposure (but not necessarily recent *use*). However, we cannot speculate on the possible locality of this source.

HEOD (dieldrin) was detected in 45 of the 46 samples (range 2.5 to 175.5 ng g^{-1} ww). HEOD was detected in 9 of 10 (90%) *C. livia* samples (range 3.05 to 24.45 ng g^{-1} ww, mean [SD] 13.17 [8.43] ng g^{-1}) and in all *P. pica* samples (range 2.52 to 175.48 ng g^{-1} ww, mean [SD] 14.78 [28.04] ng g^{-1} ww). The distribution of the HEOD levels in lanner prey (Fig. 2) shows an almost normal distribution. HEOD was detected in more-or-less all samples of both species and at more-or-less the same relatively low mean concentrations for each species. These results suggest that neither species is particularly important as a potential source of HEOD to lanners. However, there was one *P. pica* sample with an exceptional value for HEOD (175.5 ng g^{-1} ww), the same sample having by far the most exceptional DDE concentration (9.1 μg g^{-1} ww; see below). The distribution of DDE and HEOD residues (Figs. 1 and 2) differs to a degree, and this may indicate that the exposure pattern to these two contaminants is different. (Note: the >25 class in Figure 2 includes the exceptional value of 175.48 ng g^{-1}.)

Table 2 shows mean HEOD, DDE, and HCB values by nest site and prey species.

HCB (fungicide) was detected in only 3 of the 46 samples (range nd to 1.41 ng g^{-1} ww). HCB was not detected in *C. livia* samples and was detected at low levels in 3 of 36 (8%) *P. pica* samples (range nd to 1.41 ng g^{-1} ww, mean 0.09 ng g^{-1} ww). HCH, the main constituent of lindane, was not detected in any of the prey samples.

Differences in OC Pesticide Values Between Sites and Between Prey Species. Regarding differences in OC pesticide values between lanner nest sites, *P. pica* samples were collected from six nest sites (from four of which we also collected lanner chick blood). We compared between sites the values of HEOD, DDE, and HCB in *P. pica* samples to examine whether lanner chicks might be more exposed to these OCs via *P. pica* prey at one or another site. However, we found no significant difference between sites, whether log transformed or not (all $P > 0.58$). *C. livia* samples were collected from only two lanner nest sites (neither of which had lanner chicks). Again, we compared between sites the levels of HEOD, DDE, and HCB in *C. livia* samples to examine whether lanner chicks might be more exposed to these OCs via *C. livia* prey at one or another site. However, we again found no significant difference between sites, whether log transformed or not (all $P > 0.30$). Thus, there appear to be no significant differences in levels of HCB, HEOD, or DDE between nest sites, either for magpies or for doves.

Regarding differences in OC pesticide values between the two prey species (*P. pica*, *C. livia*), we could compare OC pesticide values for only one nest site (we collected both prey species only at this one site). Here, the mean values for HEOD at this nest site were 11.62 ± 4.4 ng g^{-1} for *C. livia* and 7.4 ± 1.4 ng g^{-1} for *P. pica*. The mean values for DDE at this nest site were 3.6 ± 2.9 ng g^{-1} for *C. livia* and 8.7 ± 6.4 ng g^{-1} for *P. pica*. Thus, for this one site, we found no significant difference between *C. livia* and *P. pica* for either HEOD or DDE residue levels.

Correlation of OC Pesticide Values within Each Prey Species. We found no correlation between DDE and HEOD residue concentrations in *P. pica*, and similarly no correlation in *C. livia*. This suggests that these residues may derive from separate sources in the diet for each species.

Table 2. Arithmetic mean (SD in parenthesis) for HCB, HEOD, and DDE values by nest site and prey species (ng g^{-1} wet weight).

		Nest site						
Species	**OC**	**1**	**2**	**3**	**4**	**5**	**6**	**13**
C. livia	HCB	<0.034	<0.034					
	HEOD	15.5 (3.3)	11.6 (10.7)					
	DDE	4.06 (5.82)	3.64 (7.02)					
P. pica	HCB		<0.034	<0.034	<0.034	0.216 (0.444)	<0.034	0.231 (0.486)
	HEOD		7.4 (3.1)	11.1 (4.2)	13.3 (6.2)	8.8 (5.5)	8.4 (3.1)	26.1 (50.0)
	DDE		8.73 (14.22)	12.23 (9.96)	50.43 (65.94)	8.65 (8.06)	132.16 (291.78)	843.22 (2768.30)

Note: for *C. livia*: nest site 1, n = 4; nest site 2, n = 6. For *P. pica*: nest site 2, n = 5; nest site 3, n = 5; nest site 4, n = 5; nest site 5, n = 5; nest site 6, n = 5, nest site 13, n = 11.

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Table 3. PCB congener concentrations (ng g^{-1} wet weight) in homogenized body tissues of *Pica pica* (Pp) specimens collected from the environs of lanner falcon nest sites.

	PCB congener										
Bird	**101**	**118**	**128**	**138**	**153**	**156**	**170**	**180**	**183**	**187**	**201**
Pp15	ND	ND	ND	ND	9.367	ND	ND	ND	ND	ND	ND
Pp18	ND	ND	ND	ND	ND	ND	ND	6.470	ND	ND	ND
Pp20	ND	ND	ND	ND	5.483	ND	ND	ND	ND	ND	ND
Pp26	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.671	ND
Pp28	28.40	19.14	4.610	24.80	91.63	6.933	11.92	39.60	7.102	20.59	6.701

ND indicates values were below the limit of detection.

Overall Conclusion Concerning OC Pesticides in Lanner Prey. In general, magpie and dove, two of the principal prey of the lanner, seem largely free of significant contamination with OC pesticides. This finding appears compatible with our finding of no detectable residues of OC pesticides in lanner chick blood. However, the presence of relatively high levels of DDE and HEOD in ~8% of the *P. pica* sample and one *P. pica* sample showing recent DDT contamination may indicate a local OC pesticide hazard to some lanner.

Lanner Prey Tissues: PCBs. PCB congeners were detected in very few samples (Table 3). No PCBs were detected in *C. livia*, whereas we found one contaminated *P. pica* (Pp28, Table 3; the same individual having exceptional DDE, HEOD, DDT, and TDE values) and a few other isolated low values. A possible explanation of the exceptional values of a wide range of contaminants in this bird may be that it is an old bird—corvids are known to be long-lived—though as already noted, the relatively high DDT concentration indicates recent exposure. As with OC pesticides, the fact that no such exceptional PCB values were found in *C. livia* may reflect the fact that it is a seed eater, while *P. pica* feeds predominantly on live prey and carrion. The *P. pica* sample with exceptional PCB residues was probably exposed to high PCB sources in its diet, probably accumulated in its prey/carrion, which was itself exposed to PCBs. The fact that we found only one bird with these exceptional values suggests that the sources might be infrequent or isolated (but at high level), so that very few magpies are exposed to significant levels of PCBs. However, the one exceptional value may indicate *P. pica* as a potentially important route of PCBs into local lanner populations.

CONCLUSIONS AND PRIORITIES FOR FURTHER RESEARCH

Our chick blood results appear to indicate that there is no or very little risk of OC pesticide or PCB contamination to lanner from *P. pica* and *C. livia* prey at chick life stage. However, there appears to be a possible risk to lanner at later life stages from HEOD (dieldrin) in *P. pica*. Lanner may also be exposed to DDT and its metabolites in *P. pica*, though it is not clear whether this would be enough to cause eggshell thinning. Similarly, lanner may be exposed to PCBs in *P. pica*, though the risk of PCB exposure appears to be lower than that of OC pesticide exposure.

Our results suggest that it may well be worth examining OC pesticide and PCB residues in adult lanner carcasses from Sicily (the authors have already collected a small number of such carcasses from the Ficuzza Recovery Centre) on the basis that we now know that at least one species of lanner prey is somewhat contaminated, especially given the rare and declining status of the lanner. Sicilian Peregrine *Falco peregrinus* carcasses might also be analyzed for OC pesticides and PCBs for comparative purposes and to compare with other European peregrine data (the authors have already collected 15 *F. peregrinus* carcasses from the Ficuzza Recovery Centre). If any residue problems are found in Sicilian peregrine, this may to some extent imply similar risks for the lanner, though the peregrine occupies a wider range of habitat types.

Future studies to elucidate contaminant hazard to lanner chicks should also investigate contaminant levels in other prey species, such as smaller birds and arthropods, which may make up an important part of lanner chick diet.

Our findings indicate that the lanner may serve as a useful biomonitor of OC pesticide and PCB contaminants, and they show the need for further studies to inform management and recovery for this rare species.

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