TEMPORAL PATTERNS OF DDE IN BURROWING OWL EGGS FROM THE IMPERIAL VALLEY, CALIFORNIA

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ABSTRACT—We compared levels of DDE contamination in the eggs of burrowing owls (*Athene cunicularia*) from the Imperial Valley of California in 2002 to levels detected in eggs collected at the same site in 1996. Levels of DDE ranged from 0.10 to 3.01 μg/g and were similar between years, suggesting a persistent, local source of contaminant for this resident population of owls.

RESUMEN—Comparamos los niveles del contaminante DDE en los huevos del búho machuelo excavador (*Athene cunicularia*) provenientes del Imperial Valley de California en el 2002 con los niveles detectados en huevos colectados en el mismo lugar en 1996. Los niveles de DDE variaron de 0.10 a 3.01 μg/g y fueron similares entre años, lo que sugiere una persistente fuente local de contaminante para esta población residente de búhos.

Burrowing owls (*Athene cunicularia*) frequently live in agricultural systems throughout their range in North America (e.g., Haug and Oliphant, 1990; Desante et al., 1997; Rosenberg and Haley, 2004). Accordingly, agricultural contaminant exposure from pesticides still in widespread use might occur at levels great enough to cause reduced reproductive success or even mortality in some instances (James and Fox, 1987; Gervais et al., 2003). In addition, organochlorine pesticides, such as DDT (dichlorodiphenyltrichloroethane) and its metabolic breakdown product, *p,p'*DDE (dichlorodiphenyldichloroethylene), remained in agricultural soils of California long after the 1973 ban on DDT use in the United States (Mischke et al., 1985). DDE has long been linked to reproductive impairment and population declines in many species of birds, particularly raptors (e.g., Ratcliffe, 1967; Hickey and Anderson, 1968; Enderson and Berger, 1970; Wiemeyer and Porter, 1970). However, the effects of *p,p'*DDE are species-specific and sensitivity ranges widely (Blus, 1996; Gervais et al., 2000).

In 1996, eggs were sampled from 3 populations of burrowing owls in California, including 2 areas of intensive agriculture in the Imperial Valley and the Central Valley (Gervais et al., 2000). Although later work with radio telemetry suggested that exposure to pesticides currently used on crops does not cause significant mortality (Gervais et al., 2003; Rosenberg and Haley, 2004), both sites produced eggs with measurable quantities of *p,p'*DDE (Gervais et al., 2000). Subsequent sampling in the Central Valley population demonstrated that there was pronounced annual variation in egg contaminant loads, even from the same female, suggesting that a single sample collection was insufficient to evaluate the potential risk at the population level posed by persistent organochlorine contaminants (Gervais and Anthony, 2003).

The sample of eggs collected from the Salton Sea area of the burrowing owls in the Imperial Valley in 1996 contained low levels of the contaminant *p,p'*DDE. However, given the temporal variability in egg contaminants documented in the Central Valley (Gervais and Anthony, 2003), we submitted a second sample of eggs from the Imperial Valley for organochlorine contaminant analysis in 2002. Specifically, we wished to compare the egg contaminant concentrations between years to determine if dramatic fluctuations in DDE egg content also occurred in this population. Moreover, this population of owls has been the focus of a demographics study since 1998. Therefore, we also examined patterns of egg contaminants in relation to the age of the female owls that laid them.

The study site is on and adjacent to the Sonny Bono Salton Sea National Wildlife Refuge, located 40 km NE of the city of El Centro in the Imperial Valley of California. It is an area of intensive agriculture, where as many as 4 crops are produced on each field per year. Burrowing owls are year-round residents within the site, often remaining at the same burrows throughout the year (D. H. Catlin and D. K. Rosenberg, unpubl. data).

Eggs were collected in 2002 in conjunction with a study examining nest failure and subsequent dispersal of the adult owls. Whole clutches were taken from a total of 10 randomly selected nests, and 7 eggs, randomly chosen from 7 clutches, were submitted for toxicological analysis. These 7 clutches also were chosen randomly from all clutches collected. We selected only 1 egg from each clutch because intra-clutch variation in egg contaminant levels has been shown to be slight compared to interclutch levels (Newton and Bogan, 1978; Custer et al., 1990). The remaining eggs were sent to the Western Foundation of Vertebrate Zoology in Camarillo, California, to be added to existing collections of burrowing owl eggs from the region. All eggs were refrigerated prior to shipment or processing.

Egg contents were removed from the shells and placed in chemically clean glass jars before shipment on dry ice to the California Animal Health and Food Safety Laboratory at University of California, Davis. Details of chemical analyses scanning for 22 compounds can be found in Gervais et al. (2000); eggs collected in both 1996 and 2002 were analyzed by the same laboratory using similar techniques. Whole egg concentrations were adjusted to reflect fresh wet weight of contaminants (Gervais et al., 2000).

Female owls from each nest were identified and banded if they were not already part of the demographics study. Exact age of some of the owls could be determined by identifying which females were first captured as fledglings. In other cases, a minimum age could be determined based on the fact that an unmarked adult was at least 1 year old when first captured.

Egg contaminant levels in 1996 and in 2002 were compared using a t-test. Data were log-transformed prior to analysis and variances checked for equality using Hartley's $F\ max$ test (Dowdy and Wearden, 1991). Minimum ages were calculated for the laying females and regressed against concentrations of egg DDE. Contaminant values were log-transformed prior to regression analysis.

The only organochlorine compound detected in egg samples was *p,p′*DDE, and it was detected in all samples. Levels ranged over 2 orders of magnitude, as they did in 1996 (Gervais et al., 2000). The geometric mean in 2002 was 0.62 μg/g (range = 0.10 to 3.01 μg/g *p,p′*DDE), compared with the geometric mean in 1996 of 0.20 μg/g (range = 0.2 to 3.4 μg/g *p,p′*DDE) (Gervais et al., 2000). The years were not significantly different in contaminant levels ($t = -0.11$, $P = 0.91$, $n = 7$ each year). Clearly, the marked inter-annual variation in egg contaminants found in the Central Valley owl population was not present at the Salton Sea study area; sites in the Central Valley geometric means of DDE contamination ranged from 0.74 μg/g to 8.83 μg/g fresh weight among years (Gervais and Anthony, 2003). Furthermore, there was no relationship between minimum age and contaminant level in eggs ($F_{1,5} = 0.00$, $P = 0.99$, $r^2 = 0$, $n = 7$ in 1996, $n = 7$ in 2002). Levels found in Salton Sea eggs were generally well below those linked to any reproductive effects in burrowing owls (Gervais and Anthony, 2003).

Although organochlorine contaminant load has been related to age in other raptors (e.g., Newton et al., 1981), our results are more consistent with a low but relatively constant level of dietary exposure. Burrowing owls the Imperial Valley take a wide variety of prey, but primarily invertebrates (York et al., 2002), none of which are likely candidates for high levels of biomagnification. Body burdens reach a balance between rates of intake and excretion, after which accumulation of further organochlorine residues stops. The lack of relationship between contaminant levels and age suggests that, in the Salton Sea study area, this balance between uptake and excretion is reached rather quickly and is relatively constant through time. This explanation is consistent with the fact that burrowing owls at the Salton Sea are year-round residents and that most of the movements made by the owls as indicated by radio-telemetry were less than 5 km (Rosenberg and Haley, 2004; D. H. Catlin and D. K. Rosenberg, unpubl. data). Although the Mexican border is only 25 km distant, and DDT has been in use there after it was banned in the United States, the owls do not seem to venture across the border, where they could encounter DDE-contaminated food chains.

Studies examining sediments and biota for residual organochlorine contaminants in the Salton Sea and its tributaries have found only low levels of contaminants (Setmire et al., 1990, 1993), and most recently, none were detected at all in the sediments (Vogl and Henry, 2002). These findings are consistent with the hypothesis that low levels persist within the Salton Sea ecosystem and are available at a relatively constant rate for uptake by owls through the local food web.

The low and fairly stable level of *p,p'*DDE contamination in the Imperial Valley burrowing owl eggs does not seem to be a cause for concern in this population, as contaminant levels were below those linked to declining reproductive success when interacting with food shortages (Gervais and Anthony, 2003). In addition, the Salton Sea burrowing owl population shows no signs of reproductive impairment or reduced survival relative to other populations within the state (D. K. Rosenberg, unpubl. data). Larger sample sizes and more specific studies linking contaminant levels with demographic endpoints, such as survival rates and reproductive success, would certainly better elucidate patterns of contaminant impacts. Our findings do suggest that persistent organochlorine contaminants that are no longer in use are not likely to be a major factor in the population dynamics of burrowing owls in the Salton Sea region.

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NOCTURNAL DRINKING BY MOURNING DOVES (*ZENAIDA MACROURA*)

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Abstract—In February 2000, we recorded mourning doves (*Zenaida macroura*) congregating at and drinking from a guzzler during nocturnal hours in the Chihuahuan Desert. Mourning doves might use nocturnal hours to maintain water balance in desert environments.

Resumen—En febrero del 2000, registramos palomas huilota (*Zenaida macroura*) reuniéndose en y tomando de una fuente de agua artificial en las horas nocturnas en el desierto de Chihuahua. Las palomas huilota pueden usar las horas nocturnas para mantener el balance de agua en ambientes desérticos.

Mourning doves (*Zenaida macroura*) are an important migratory game bird in North America. Mourning doves are strictly granivorous and require freestanding water for drinking (Mirarchi, 1993). MacMillen (1962) estimated that mourning doves require 2.4 to 5.1 g (3% of body mass) of water daily to maintain physiological functions. During excessive temperatures (e.g., >39°C), mourning doves will drink 4× their normal amount (Bartholomew and Dawson, 1954). Mourning doves drink from a variety of water sources and have ben-