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PRODUCTIVITY AND SURVIVAL OF GREAT HORNED OWLS EXPOSED TO DIELDRIN[1]

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Abstract. We investigated the influence of dieldrin, a persistent organochlorine, on a top trophic level raptor, by comparing productivity and survival of Great Horned Owls (*Bubo virginianus*) using contaminated and uncontaminated areas. Between 1994–1996, we worked on a Superfund hazardous waste site, the Rocky Mountain Arsenal National Wildlife Refuge in Colorado. Productivity of owls did not differ between those using the contaminated and uncontaminated areas. Adults in the uncontaminated area had nominally higher survival from 15 January–15 August. Mortalities related to dieldrin in adults were most likely the result of mobilization of dieldrin from other tissues due to nutritional stress associated with reproduction. Interval survival of juveniles in contaminated and uncontaminated areas was similar, however, dieldrin residue in plasma at nine weeks of age was strongly and negatively related to survival; juveniles with higher dieldrin residues died during dispersal. Plasma dieldrin concentrations in juveniles correlated with dieldrin levels in soil and prey within parental home ranges. Consequently, sampling dieldrin in juvenile plasma is a more reliable method for monitoring the impact of dieldrin than counting number of young fledged per nest.

Key words: biomonitoring, Bubo virginianus, *dieldrin, Great Horned Owls, organochlorines, survival.*

INTRODUCTION

Organochlorine pesticides, like dieldrin, are chlorinated hydrocarbons used primarily as insecticides, rodenticides, fungicides, and herbicides. Chlorinated hydrocarbons produce neurotoxicity characterized by motor, sensory, cognitive, or autonomic nervous system dysfunction (Anger and Johnson 1985, Evangelista de Duffard and Duffard 1996). Dieldrin decreases biogenic amines with chronic exposure (Sharma 1973). Biogenic amines, including serotonin, norepinephrine, and dopamine, act as neurotransmitters, hormones, and stimulators. Animals chronically exposed to dieldrin could exhibit poor cognitive and motor skill development. Such impairments and deficiencies of the nervous system might put an animal at greater risk of mortality due to starvation, predation, accidents, and disease. Thus, nonlethal, chronic exposure has potential to influence productivity and survival in wildlife populations (Sharma et al. 1976). Top trophic level animals, like the Great Horned Owl (*Bubo virginianus*), are vulnerable to bioaccumulation of these pesticides.

Dieldrin is one of seven organochlorines found in soil and biota at Rocky Mountain Arsenal National Wildlife Refuge (USFWS 1996). Great Horned Owls occupying the Refuge provided a unique opportunity to document the effects of chronic exposure to dieldrin under field conditions. From 1942–1987, industrial activities at the Rocky Mountain Arsenal included production of chemical weapons, pesticides, herbicides, and caustic adhesives. Waste disposal practices over the 40-year period of production resulted in extensive soil and ground water contamination. Portions of the Refuge are severely contaminated, whereas other areas are relatively free of organochlorines (Frank 1997). The objectives of our study were to: (1) evaluate the productivity of Great Horned Owls at the Refuge in contaminated and uncontaminated areas, (2) investigate the relationship between dieldrin tissue burdens and survival in juvenile and adult Great Horned Owls, and (3) use our results to help design future biomonitoring approaches.

METHODS

STUDY AREA

The 69 km^2 Refuge is located in south-central Adams County, Colorado. Frank (1997) describes the history of the Refuge and current biomonitoring efforts in detail. The climate is

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semi-arid; average annual precipitation is approximately 38 cm. Elevation on the Refuge ranged from 1,534 m to 1,625 m.

Historically a short grass prairie, five major communities currently dominate the vegetation on the Refuge: cheatgrass (*Bromus* spp.)/perennial grassland, weedy forbs, cheatgrass/weedy forbs, crested wheatgrass (*Agropyron cristatum*), and native perennial grassland (Environmental Science and Engineering 1989). Trees, such as plains cottonwood (*Populus sargenttii*), New Mexican locust (*Robinia neomexicana*), peachleaf willow (*Salix amygdaloides*), and Russian olive (*Elaeagnus angustifolia*) occur in localized stands (Robinette et al. 1995).

OWL SURVEYS

We searched the Refuge from vehicles and on foot (December–February), and conducted hooting call surveys to determine Great Horned Owl numbers and locate potential nests. Our hooting surveys consisted of broadcasting adult male and female Great Horned Owl calls between 18:00 and 22:00 at the edges of woodlots on the Refuge. We divided the sampling time period into three parts, following the method described by McGarigal and Fraser (1984). When owls were encountered, woodlots were searched for white wash and castings to locate roosts and nests. Since the late 1980s, a resident population of approximately 10–12 breeding pairs have occupied territories and nested on the Refuge (D. Matiatos, pers. comm.).

We assigned adult pairs and their nests to contaminated and uncontaminated areas based on geographic location. The interior six sections (1.6 km^2) of the Refuge had a history of industrial and waste disposal activities; we classified nests in this area as contaminated. We included nests along the borders of these sections as contaminated if radiomarked adults foraged in contaminated sections. Nests in all other sections were classified as uncontaminated. We used $P \leq 0.05$ as statistically significant for all comparisons between contaminated and uncontaminated areas.

We considered a nest to be active after we observed the female incubating, and monitored the status of each nest daily using a spotting scope to count the number of young in the nest until they fledged at about 9 weeks. We compared the number of fledglings produced per nest attempt between contaminated and uncontaminated areas within each year using Student's *t*-test.

CAPTURE TECHNIQUES

From 1994–1996, we captured adult owls using bal-chatri traps (Berger and Mueller 1959) with rodent and avian lures, using pigeons (*Columba livia*) outfitted with nylon noose harnesses, and dho gaza traps (Hamerstrom 1963). We captured juveniles by hand at 9 to 10 weeks of age as they fledged from their nests. We banded captured birds and outfitted them with radiotelemetry transmitters. The radio transmitters (30–35 g) permitted identification of individual birds and allowed us to collect home range, foraging area, and survival data.

PLASMA AND TISSUE COLLECTION

We collected blood samples (3.0 ml) from the brachialis or tibialis vein. We immediately (< 30 min) separated blood samples in a centrifuge at 2,500 rpm for 15 min, and then the separated plasma was frozen at −20°C until analyzed.

Plasma was analyzed for organochlorines by the U.S. Geological Survey's (USGS) Denver Wildlife Research Center, Denver, Colorado, using gas chromatography with electron capture detection. The method reporting limit (MRL) for dieldrin was 112 $\mu g\ L^{-1}$ for a 1 ml sample. For plasma dieldrin samples with concentrations below the MRL, calibration data (for 25, 50, 75, 100, 250, and 500 $\mu g\ L^{-1}$ standards) and regression formulas were used to estimate dieldrin concentration (E. Petty, pers. comm.).

We obtained tissue samples from dead owls found fortuitously on the Refuge and shipped carcasses to the USGS's National Wildlife Health Center (NWHC) in Madison, Wisconsin for necropsy. After NWHC pathologists collected tissues, they returned tissues to the U.S. Fish and Wildlife Service (USFWS) at the Refuge, and then tissues were sent to a contract laboratory (Environmental Science and Engineering in Denver, Colorado; Post, Buckley, Shuh, and Jernigan Laboratories in Orlando, Florida; and E. A. Engineering Science and Technology in Sparks, Maryland) for residue analysis. All laboratory work met Quality Assurance standards and was evaluated using Quality Control protocol established by the U.S. Army, USFWS, and the Environmental Protection Agency. Gas chromatography/electron capture detection was used to quantify organochlorine levels in brain, liver,

muscle, and fat tissues. Detection limits (wet weight) for organochlorine analytes at each laboratory were 15 ppb (parts per billion) with a minimum 8-g sample, 10 ppb with a minimum 5-g sample, and 2 ppb with a minimum 2-g sample. Results were reported by all laboratories as ppm (parts per million) on wet weight basis. Unlike plasma, we had no calibration data from tissues so could not estimate concentrations below the MRL. In prey tissue samples, we assumed the concentration of samples below the MRL to be 50% of the MRL for use in statistical analyses (Rattner et al. 1996).

We assigned a cause of death, when possible, based on field observations, pathologists' findings, and tissue analysis data. The NWHC considers residue levels of 4 to 5 ppm of dieldrin in the brain (wet weight) to be the lower threshold of toxicity (Stickel et al. 1969). The USFW at the Refuge considers residues $\geq$ 9 ppm (wet weight) or greater in the brain to be an indication of dieldrin poisoning. Residue concentrations between 4 and 9 ppm (wet weight) with supporting necropsy results and/or clinical signs also indicate dieldrin poisoning.

RADIOTELEMETRY

We fitted each owl with a backpack radio transmitter harness (Advanced Telemetry Systems, Isanti, Minnesota) that contained an activity sensor, and used a harness attachment method that was a modification of a design described by Smith and Gilbert (1981). We attached transmitters with 5.5 mm Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania) with straps running over each shoulder, threaded through a small (1 cm) piece of copper tubing at the breast, continuing down between the legs, and threaded in opposite directions through a hole at the base of the transmitter near the antenna. We secured the Teflon straps with cotton sutures and epoxy. The transmitter and harness weighed $< 3\%$ of the owl's body weight, and we did not radio tag owls weighing ≤ 800 g. We released owls in the same woodlots where captured.

We collected nocturnal location estimates between 18:00 and 04:00 for adult owls using two simultaneous bearings obtained with vehicle mounted null-peak telemetry systems between February 1995 and August 1996. We collected location estimates in both contaminated and uncontaminated areas up to five nights per week, assuring that each radiotagged owl was located 3 to 5 times per week. We conducted an accuracy assessment of the telemetry system each season using the test procedures outlined by Lee et al. (1985).

We used LOCATE2 (Nams 1990) to estimate point locations and error polygons. We retained location estimates if the 95% error ellipse was $< 2\%$ of the owl's home range. We excluded location estimates from analysis if the signal strength was weak, if the bird flew while bearings were being taken, or the crossing angles of simultaneous fixes were not between 60 and 120 degrees. We used CALHOME (Kie et al. 1994) to estimate 50%, 80%, and 95% adaptive kernel home-range contours (Worton 1989) for owls with ≥ 30 location estimates.

SURVIVAL

Juveniles. Three times per week, we monitored juvenile owls using daytime visual locations and/or nocturnal triangulations. We estimated survival from their fledging date (approximately 1 May) through 15 August of each year. We censored birds from survival analysis if they left the Refuge or could not be relocated, the transmitters fell off or quit operating, or if they were alive at the end of the monitoring period. We calculated survival rates for the monitoring period using the methods of Heisey and Fuller (1985), and compared rates among years and between contaminated and uncontaminated areas using chi-squared statistics from program CONTRAST (Sauer and Williams 1989). We calculated Kaplan-Meier (Kaplan and Meier 1958) survival estimates for juvenile owls to investigate the effects of time (days post-fledge) on survival. We used the fledging date for each bird as day zero and pooled across years. We used a proportional hazards model (Cox and Oakes 1984) to test for relationships between juvenile survival and dieldrin in plasma, and the proportion of relocations in the core area. To further investigate the effects of dieldrin plasma burdens and juvenile survival, we visually inspected the distribution of dieldrin in plasma and found three general categories (< 50 $\mu g\ L^{-1}$, 50–100 $\mu g\ L^{-1}$, and > 100 $\mu g\ L^{-1}$). We grouped the juvenile birds into these three categories based on their dieldrin plasma concentrations at time of fledge, and calculated daily and interval (1 May–15 August) survival estimates for each dieldrin category (Heisey and Fuller 1985); we

used chi-square analysis to detect differences in survival rates among the three categories.

Adults. We relocated adults at daytime roosts three to six times per week from 15 January–15 August using a hand held yagi antenna. To monitor survival, we also recorded activity detected during nightly telemetry. We calculated daily and interval (15 January–15 August) survival rates for adult owls (Heisey and Fuller 1985), and tested for differences in daily and interval survival rates among years and between adults in contaminated and uncontaminated areas using chi-square analysis (Sauer and Williams 1989).

Mortality. To assess causes of mortality and collect tissues for contaminant analyses, we retrieved dead owls as soon as possible. When an owl did not move between consecutive telemetry locations taken on a single night, we would attempt to flush the owl to trigger the activity sensor in the transmitter. If we could not verify that the owl was alive, we visually relocated the animal the following day.

DIELDRIN IN SOIL, PREY, PLASMA, AND TISSUE SAMPLES

Soil concentrations. To investigate the relationship between levels of dieldrin in soils and dieldrin concentrations in owls, we used soil samples (n = 1,097) taken on and around the Refuge between 1990 and 1995 (Frank 1997). We only used soil samples from $\leq$ 0.30 m in depth. Because samples were not uniformly distributed over the Refuge, we used ordinary kriging (Cressie 1993) to predict soil concentrations onto a grid with 50-m intervals. We used ARCVIEW GIS software (Environmental Systems Research Institute 1992) to find the mean of the grid points within each owl's 50%, 80%, and 95% adaptive kernel home range.

We used simple linear regression to investigate the relationship between dieldrin in soil within each adult home range contour and dieldrin concentrations in plasma of adult and juvenile owls. For juvenile owls, we used the mean (n = 2–4) concentration of dieldrin in plasma for all the chicks from each nest and regressed it against the mean soil concentration within the parents' home range contours. We had seven nests where our data were complete (adult home ranges, adult and juvenile plasma samples taken that year).

Casting analysis and prey sample collection. From castings analysis, we determined that the top three prey genera were *Peromyscus, Geomys,* and *Sylvilagus* (Frank 1997). We attempted to collect 10 individuals of each prey genera from foraging areas within home ranges where our data were complete (adult home range estimates, adult and juvenile plasma, and juvenile tissue samples).

At each site, we set 30 Sherman live traps for two nights to collect *Peromyscus* spp. We trapped gophers (*Geomys* spp.) by placing gopher traps in active mounds and tunnels. We collected cottontail rabbits (*Sylvilagus* spp.) in foraging areas by using a shotgun. We placed collected prey items on ice until they could be frozen, and sent frozen whole-body samples to the contract laboratories where they were homogenized before contaminant analyzes.

We used simple linear regression to investigate the relationship between dieldrin concentrations in prey and concentrations in adult and juvenile owl plasma in these foraging areas. For prey tissues, we assumed the concentration of samples below the MRL to be 50% of the MRL. For juveniles, we regressed the mean plasma concentration from all chicks (n = 3 or 4) in a nest against dieldrin concentrations in *Peromyscus* and *Sylvilagus* collected within the parents' home range.

Plasma, brain, and liver samples. We collected plasma from owls when they were initially captured and tissues if they were found dead. We used simple linear regression to investigate the relationship between dieldrin concentrations in the plasma, and dieldrin concentrations in the brains and livers of adult and juvenile owls.

RESULTS

CAPTURE

We trapped 20 adult and 59 juvenile Great Horned Owls, and obtained 79 blood samples for dieldrin analysis.

NESTING SUCCESS AND PRODUCTIVITY

Twenty-eight Great Horned Owl pairs nested on the Refuge over three years (Table 1). Four nesting sites were used in two or more years. In three cases, the same nest structure was used in multiple years. Young produced per nest attempt did not vary between contaminated and uncontaminated areas in 1994 ($t_{10} = -1.34$) or in 1996 ($t_9 = 0.88$) (Table 1).

We monitored four nest failures. All failures occurred during the incubation stage. In all cas-

TABLE 1. Reproductive parameters of Great Horned Owls in contaminated and uncontaminated areas on the Rocky Mountain Arsenal National Wildlife Refuge, Colorado, 1994–1996.

Parameter	1994		1995		1996	
	Contaminated	Uncontaminated	Contaminated	Uncontaminated	Contaminated	Uncontaminated
Pairs	4	11	0	11	4	8
Nesting	3	9	0	5	4	7
Hatched (%)	0.66	1.00	—	0.60	1.00	0.86
Successful (%)	0.66	1.00	—	0.60	1.00	0.86
Mean (SD) young/attempt	1.33 (0.88)	2.11 (0.20)	—	1.20 (0.49)	3.00 (0.00)	2.43 (0.48)

es, the adults survived and remained near the nest site after the failure. The first documented failure occurred at a nest in the contaminated area in 1994. Two nests in the contaminated area failed in 1995 and one nest in the uncontaminated area failed in 1996. In three cases, we found small egg-shell fragments in the nest structure. However, we were unable to determine if the eggs were depredated or scavenged after being abandoned. We did not document any loss of chicks before fledging.

SURVIVAL

Juvenile. We monitored the fates of 14 radiotagged juvenile owls from the contaminated area and 41 from the uncontaminated area. Accidents, including electrocution, were the most common cause of death for juvenile owls during the three years. We witnessed one juvenile death directly attributable to dieldrin. The remaining mortalities occurred throughout the post-fledgling period and tended to increase after about 80 days posthatch (Fig. 1).

Daily ($\chi^2_1 = 1.89$) and interval ($\chi^2_1 = 2.75$) survival estimates did not differ between juveniles from nests in the contaminated and uncontaminated areas (Table 2). Dieldrin concentrations in the plasma of juvenile Great Horned Owls did not differ among years ($F_{1,50} = 3.08$, $P = 0.09$), so we pooled across years. Dieldrin concentrations in plasma were related to juvenile survival ($B \pm \text{SE} = 0.0086 \pm 0.0035$, $z = 2.48$, $P < 0.05$). Proportion of relocations in the contaminated area ($B \pm \text{SE} = 0.0003 \pm 0.0002$, $z = 1.37$, $P > 0.05$) were not related to juvenile survival. Daily survival did not differ ($\chi^2_2 = 3.78$, $P = 0.16$) among the three categories of plasma levels. However, interval survival rates differed among categories ($\chi^2_1 = 11.81$, $P < 0.01$). Interval survival of owls ($f_s = 0.24$) in the high plasma concentration category was lower than survival ($f_s = 0.79$) in the low plasma concentration category ($\chi^2_1 = 8.77$, $P < 0.01$).

Adult. We monitored the fates of 9 radiomarked adults in the contaminated area, and 11 in the uncontaminated area. In general, mortalities of adults were due to the same factors as juvenile mortalities; however, dieldrin poisoning was potentially a greater risk for breeding adults (10%) than for juveniles (2%).

We observed the deaths of two breeding adults in 1996 that we attributed to dieldrin poi-

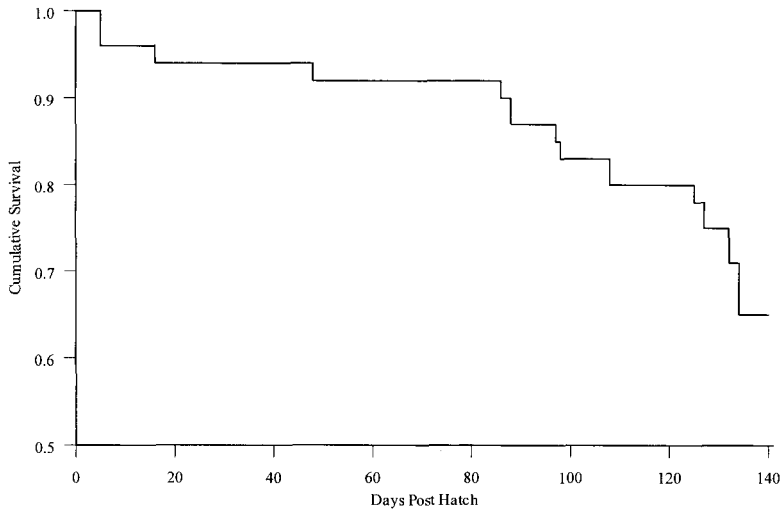

FIGURE 1. Kaplan-Meier survival estimates of juvenile Great Horned Owls (n = 53) at the Rocky Mountain Arsenal National Wildlife Refuge, 1994–1996. Time zero represents fledging date.

soning; both birds convulsed prior to death. After the final convulsion, both owls displayed posturing characteristic of dieldrin poisoning (M. Hopper, pers. comm.). The wings were folded in and over the chest, the legs were completely extended, and the talons were clenched tightly. Dieldrin residues in tissues of the adult male were 8.6 ppm (brain), 12.7 ppm (liver), and 3 ppm (plasma), and in tissues of the adult female were 8.8 ppm (brain), 10.7 ppm (liver), and 4.4 ppm (plasma).

Daily survival rates of adult owls did not differ between 1995 and 1996 (χ^2_1 = 0.62), so we pooled them for analysis. Because of low sample size (n = 2 contaminated and 2 uncontaminated), we did not compare survival in 1994. Daily survival rates did not differ between adult owls in contaminated and uncontaminated areas (Table 2). However, adults in uncontaminated areas showed nominally higher (P = 0.06) interval (January 15–August 15) survival rates than adults in contaminated areas (Table 2).

We found six dead, unmarked adult owls on the Refuge. Based on tissue analysis, we attributed two of these deaths to dieldrin poisoning. Concentrations of dieldrin in these brains ranged between (0.06–8.75 ppm), and in livers ranged between (0.01–13.6 ppm).

DIELDRIN IN SOIL, PREY, PLASMA, AND TISSUE SAMPLES

Soil concentrations. Juvenile plasma concentrations were related to soil concentrations within the 95% and 80% contours of parental home ranges, and approached significance (P = 0.06) within the 50% contour (Table 3). Plasma concentrations of adults were marginally related (P = 0.07) to soil concentrations within only the 95% contour.

Prey samples. We captured 10 *Peromyscus* and 10 *Sylvilagus* from each of four nesting territories and trapped 29 *Geomys* from three nesting territories. We found reportable levels of dieldrin in 1 (3.4%) *Geomys* ($\bar{x}$ = 0.009), 9 (22.5%) *Peromyscus* samples ($\bar{x}$ = 0.031), and 10 (25%) *Sylvilagus* samples ($\bar{x}$ = 0.051). These mean values for dieldrin in prey are from total prey captured and include 50% MRL for prey with no detectable dieldrin. Because we could not detect dieldrin in the majority of prey samples, we conducted no statistical tests. No reportable dieldrin concentrations were found in prey samples from the nests in the uncontaminated area.

Plasma concentrations in juvenile owls were related to dieldrin concentrations in *Peromyscus,* but not to concentrations in *Sylvilagus.* Conversely, dieldrin concentrations in adult plasma were related to concentrations in *Sylvilagus,* but not to concentrations in *Peromyscus.*

Plasma, brain, and liver. We had plasma and tissue samples from three adult owls that died within the year they were initially captured. For these birds, brain and liver tissue samples were collected 10, 60, and 129 days after the plasma

TABLE 2. Survival estimates (Heisey and Fuller 1985) of radiotagged adult and juvenile Great Horned Owls in contaminated and uncontaminated areas on the Rocky Mountain Arsenal National Wildlife Refuge, Colorado, 1994–1996. Adult survival rates are based on the interval January 15–August 15. Juvenile survival rates are based on the interval May 1–August 15.

Survival estimate	Adults			Juveniles		
	Contaminated	Uncontaminated	P^a	Contaminated	Uncontaminated	P^a
Daily survival	0.996	0.999	0.23	0.994	0.998	0.17
Interval survival	0.435	0.864	0.06	0.425	0.703	0.10
n	9	11		14	41	

[a] χ^2 tests.

samples. Dieldrin concentrations in adult plasma were weakly ($P > 0.05$) related to dieldrin concentrations in their brain ($r^2 = 0.984$) and liver ($r^2 = 0.840$) tissues. Dieldrin concentrations in juvenile plasma were not related to dieldrin concentrations in the brain or the liver of 16 juvenile owls that died within the year they were captured.

DISCUSSION

Although it is believed that top-level predators are particularly vulnerable to organochlorines, it is often difficult to identify concrete cause and effect relationships. Limited samples sizes due to small populations and difficulties in replicating contaminated areas make it difficult to use a rigorous experimental approach. Our results are based only on the Great Horned Owl population at the Refuge and rely heavily on correlations. Although we believe the relationships observed provide important insights, we urge readers to use caution in interpreting our results.

We have no evidence that owls on the Refuge suffer any direct dieldrin related reproductive impairment. Our results agree with those of Fowler et al. (1971) on Common and Purple Gallinules (*Gallinula chlorpus* and *Porphyrula martinica,* respectively) and Mendenhall et al. (1983) on Barn Owls (*Tyto alba*) who reported that reproductive processes of birds were not notably sensitive to dieldrin.

Our data support the idea that the major effect of dieldrin on raptor populations is through direct adult mortality (Ratcliffe 1973, Newton et al. 1991). Because owls are year-round residents and remain in their breeding territory throughout the year, they likely accumulate dieldrin over a long period of time. During the breeding season, adult owls must produce eggs, defend their territory, and feed young. Given these nutritional demands, it is likely that owls mobilize fat reserves with an accompanying increase in chemical availability of dieldrin to the brain (Stickel et al. 1969).

Juvenile Great Horned Owls that fledged with high dieldrin concentrations in their plasma had reduced survival. We found no differences in body weights between juvenile owls from the contaminated and uncontaminated areas (Frank 1997), suggesting that prey availability and parental care were similar between areas. Whereas accidents, such as collisions or electrocutions, may be the cause of death, our analyses suggest

TABLE 3. Dieldrin concentrations in adult and juvenile Great Horned Owl plasma, the three most common genera taken by Great Horned Owls, and soil concentrations within adult owl home ranges at the Rocky Mountain Arsenal National Wildlife Refuge, Colorado, 1995–1996.

	Contaminated			Uncontaminated		
Dieldrin sample	Mean	SE	*n*	Mean	SE	*n*
Owl plasma (ppm)						
Adult	0.34	0.21	2	0.07	0.03	5
Juvenile	0.22	0.03	6	0.01	0.003	10
Prey genus (ppm)						
Peromyscus	0.04	0.01	20	0.02	0.00	20
Geomys	0.06	0.02	20	0.02	0.00	20
Sylvilagus	0.02	0.00	10	0.02	0.00	19
Soil in adult home range (ppm log transformed)						
50% contour	1.15	0.57	2	0.18	0.09	5
80% contour	1.03	0.11	2	0.15	0.08	5
95% contour	0.81	0.11	2	0.12	0.06	5

that tissue burdens of dieldrin may be a contributing factor to reduced survival. Newton et al. (1991) suggest that Barn Owls in poor condition might suffer a higher rate of accidents because they may have to spend more time hunting, or may be less likely to avoid collisions.

We believe differences between juvenile and adult dieldrin plasma concentrations and the mean concentration of dieldrin in soil within the adults' home range are the result of differences in diet and our sampling scheme. We sampled adults at the time of initial capture rather than at a standard time in the breeding season. Stickel et al. (1969) and Friend et al. (1979) demonstrated that birds fed intermittently (subject to periodic starvation) had higher residues of organochlorines in sera than birds fed continuously. Thus, dieldrin levels in the plasma of adult Great Horned Owls in the wild might be quite variable due to fluctuation in environmental conditions and availability of *Sylvilagus*. Perhaps plasma levels in juveniles prior to fledging were more closely related to soil concentrations due to more consistent food intake (*Peromyscus*) provided by both parents during the nestling period.

The intent of the USFWS biomonitoring program at the Refuge is to monitor changes in the availability of contaminants to wildlife species. Currently, USFWS monitors the availability of contaminants to Great Horned Owls by counting the number of chicks fledged from a nest. This monitoring approach could be misleading for two reasons: (1) the number of young fledged/nest was not different between contaminated and uncontaminated areas, and (2) the effects of dieldrin acquired in the nest do not influence survival until months later. Plasma from juveniles may be a useful tool for the USFWS in monitoring contaminants in owls. Juvenile owl plasma burdens were related to prey items and soil concentrations within home ranges. Therefore, sampling juvenile owl plasma as they leave the nest will give an indication of contaminant availability in the soil and prey.

Because Great Horned Owls are an important component of the food web on the Refuge, nonlethal (plasma) samples are the most appropriate choice as a biomonitoring tool. Monitoring juvenile Great Horned Owls will be more effective and efficient than monitoring adults. We found that adult Great Horned Owls were difficult to sample, and that dieldrin concentrations in their plasma were not related to dieldrin concentrations in soils within their home ranges. Also, because the number of adult owls that utilize the contaminated area is small, the ability of statistical tests to distinguish true differences (power) is low.

Collecting plasma from fledgling Great Horned Owls is probably the best way to monitor the availability of dieldrin in soil and prey within Great Horned Owls' home ranges. Owls at this age are relatively easy to capture and sample. It may be more efficient and cost effective to collect plasma from young owls than to collect soil samples over large areas to monitor dieldrin availability to owls. Also, because owls tend to re-use nest sites and woodlots, it may be possible to monitor changes in owl exposure from year to year.

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