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EFFECTS OF METHYL PARATHION ON RED-WINGED BLACKBIRD (*AGELAIUS PHOENICEUS*) INCUBATION BEHAVIOR AND NESTING SUCCESS

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Abstract – Free-living female red-winged blackbirds (*Agelaius phoeniceus*) were captured on their nests and given oral doses of 0, 2.37 or 4.21 mg/kg methyl parathion in a propylene glycol carrier during incubation. Birds were released immediately after dosing and observed for 5 h to document behavioral effects, amount of time spent off the nest after dosing and time spent incubating. Each nest was monitored until nestlings fledged or until all nestlings died or disappeared. For each nest, the time of abandonment, hatching success and fledging success were determined. In addition, prefledging weights were obtained for all nestlings in nests at 8 d after hatch. Although methyl parathion caused ataxia, lacrimation and lethargy and significantly depressed cholinesterase activity (>35%) at 4.21 mg/kg, there were no apparent adverse effects on reproduction. Females receiving 4.21 mg/kg methyl parathion were able to return to their nests, resume incubation, successfully hatch their clutch and rear their young. Nestlings of poisoned females did not have significantly different body weights at 8 d compared to controls, indicating that methyl parathion did not disrupt the females' ability to forage and deliver adequate food to nestlings. Band returns from the following year indicated that treatment birds returned and nested in nearly the same proportion as did controls and other red-winged blackbirds occupying the ponds. There was no indication that a single oral dose of methyl parathion (2.37 or 4.21 mg/kg) decreased over-winter survival.

Keywords – Red-winged blackbirds *Agelaius phoeniceus* Methyl parathion Organophosphorus Reproductive effects

INTRODUCTION

Behavioral changes [1,2], alteration in the ability to thermoregulate [3–6], reproductive impairment [7] and mortality [8] have been attributed to organophosphorus (OP) insecticide exposure in birds. Exposure may result from direct spray, contact with sprayed vegetation or from ingesting contaminated food items [9]. This exposure may occur more than once during a typical breeding season. It is common for birds exposed to an OP to survive an exposure event with brain cholinesterase (ChE) depressions of between 20 and 50% [9–11]. Depressed ChE activity may be associated with disruption in behavior [12,13]. In addition, hormones may be affected by OPs. Note that plasma concentrations of luteinizing hormone, progesterone, corticosterone and prolactin were affected by OP ingestion in birds and mammals [14–16]. Alteration of these hormones may have profound effects on avian reproductive activities such as egg laying and incubation.

The objective of this study was to investigate the behavioral response, reproductive effects and long-term survival of female red-winged blackbird (*Agelaius phoeniceus*, redwing) exposed to a single sublethal gavage of an organophosphorus insecticide. With an estimated population of nearly 200

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million, the redwing is probably the most abundant bird species in North America [17]. Redwings use a wide variety of habitats for nesting, feeding and roosting, ranging from wetlands to upland grasslands and agricultural crops [18–20]. Their close association with agricultural crops enhances the redwing's potential for exposure to pesticides. In addition, the redwing appears to be more sensitive to some pesticides than other avian species for which comparative data exist [21–23].

METHODS

Study area

This study was conducted at the U.S. Environmental Protection Agency's (EPA) Western Fish Research Station, Corvallis, Oregon. This facility includes a complex of six 0.1-ha ponds. The pond facility is completely enclosed by a 3-m cyclone fence and encompasses approximately 1.0 ha. The ponds range in depth from 3 to 5 m. Surrounding each pond is a 4- to 6-m band of emergent vegetation, primarily cattails (*Typha* sp.) and lesser amounts of bulrush (*Scirpus* sp.) and willow (*Salix* sp.). Centrally located among the ponds is a 1.8 × 1.8 × 3.0-m tower with an enclosed observation platform. From this tower observations of nests in all six ponds were possible.

For the last five years, as vegetative cover has developed, breeding redwings have increasingly used these ponds for nesting. The reproductive population consisted of 20 territorial males and approximately 100 nesting females. Birds have been censused and banded annually since 1985 to establish life history data for this system and for identification of individuals used in tests.

Dose determination

We selected a dose of methyl parathion (*O,O*-dimethyl (*O-p*-nitrophenyl) phosphorothioate) that would produce overt signs of poisoning without mortality and would produce depression of brain ChE between 20 and 50%. Crystalline methyl parathion (purity, 98%) was prepared for gavage by dissolving in propylene glycol. Propylene glycol was also used to gavage control birds. The reported LD50 value for a single oral dose of methyl parathion for red-winged blackbirds was 10 mg per kg of body weight [23]. Three test doses, 2.37, 4.21 and 7.5 mg/kg, were arranged geometrically below this value. All chemically treated birds received a gavage of 1 μl methyl parathion–carrier solution per g of body weight. Control birds received 1 μl carrier per g of body weight.

Female (n = 30) red-winged blackbirds were captured and gavaged into the proventriculus using a 100-μl syringe with a 16 gauge × 5 cm IV catheter. After dosing, individuals were placed in cloth-covered wire cages (25 × 50 × 30 cm^3) and provided water. Observations were made through small openings in the cloth covers. Signs of intoxication (e.g., ataxia, lacrimation) were noted and time to apparent recovery was recorded.

After 3 h, all birds were sacrificed (CO_2 asphyxiation) and brains were removed and stored in liquid nitrogen until analyzed for total cholinesterase activity using a modified Ellman method [24]. Whole brains were homogenized in pH 7.4 Tris buffer at ratios of 35 mg/ml with a Virtis "45"® homogenizer at 30% speed for 15 sec. The entire homogenate was centrifuged for 20 min at 12,500 *g* under refrigeration (2–5°C) and the supernatant was refrigerated (0–5°C) until assayed (within 5 h). The supernatant was analyzed for ChE activity using a calibrated Gilford SBA300 automated selective batching clinical chemistry analyzer (wavelength, 405 nm). Acetylthiocholine iodide (ACTI) was used as the substrate. Final volumes of reagents in the analysis were 2.9 μl 0.075 M ACTI and 14.7 μl 0.1 M 5,5-dithio-bis(2-nitrobenzoic acid) in 382.4 μl pH 8.0 phosphate buffer. The sample volume was 60 μl brain supernatant. ChE activity was expressed as μmol of ACTI per min per g tissue. One-way analysis of variance was used to compare mean ChE activity between treatments and control [25].

Pond study

Monitoring of redwings began with the establishment of male territories in early March 1987. At this time, trapping of all breeding birds using the ponds was attempted using three-celled potter traps [26]. All captured birds were fitted with U.S. Fish and Wildlife Service aluminum leg bands and color-coded plastic bands for future identification.

In April, female behavior was observed to determine when and where nest building occurred. Nest searches began shortly after mating and nest building were observed. Nests were located by searching the vegetation from the shoreline at least twice a week and by boat once a week. As nests were located, each was marked with numbered yellow-green flagging tape attached below the nest rim on the nest or in close proximity to the nest. Hatch dates were determined by adding 11 d for incubation to the date the third or last egg was laid if less than three were laid [20]. Although it was recognized that any stage of reproduction (nest building through fledging) can be affected by exposure to OPs, the incubation through fledging period was selected for observation in this study to minimize nest abandonment caused by handling females during nest building and early incubation.

Dosing began when four to six females completed laying and were in mid to late incubation (5–9 d). This provided enough birds from which birds were selected to create a test block. A complete test block included four birds: a high dose, a low dose, a control (propylene glycol) and a control–control (not captured). The control–control bird in each block controlled for effects of capture and handling. Treatments were randomly assigned within blocks. If only three birds were available for capture the low dose was eliminated from the block. Females were trapped on their nests using a single-celled potter trap placed over the nest. Trapping began at 0600 and continued until 0800 or until three or four females were captured. All birds were gavaged in the same manner as in the dose determination test.

Mirrors (10 × 15 cm) attached to 3-m metal conduit were placed next to the nest and adjusted such that the nest could be seen from the observation tower using either 10 power binoculars or a 15–45 power spotting scope. Once a female was captured, she was taken to the work station, where she was weighed and dosed. The dosed female was then released from the work station. The maximum distance any female had to fly to her nest was approximately 100 m. Testing procedures continued in this manner from 12 May to 19 June 1987.

After a female was released, observers in the tower visually followed the bird when possible and watched the nest to determine when the female returned. Data were recorded every 5 min after release to determine the female's location, time until first return to nest and activity at nest. Observations were continued until 1200 and again from 1500 to 1600 of the same day. Females were monitored periodically thereafter to determine if abandonment had occurred. This provided a sampling of posttreatment incubation behavior and an opportunity to observe other aberrant behaviors. The length of time between dosing and when a female first returned to her nest was compared among treatments using a Krushal–Wallis Test [25]. The number of times the female was on the nest at every 5-min check was ultimately determined. These data were analyzed as percent of each time period ($\bar{x} = n/12$). To take into account the correlation among measurements on the same experimental unit (female), a repeated-measures analysis of variance was performed [27] where test block, incubation stage between 5 and 9 d and dose were used as independent variables to determine if treatments differed significantly ($p < 0.05$, unless stated differently) from controls. Separation of significantly different means was determined using Studentized Maximum Modulus (GT2) Test [25].

As hatch date approached, nests were visited daily to determine exact hatch day. Nests were checked approximately every other day after hatching to determine mortality of nestlings. To limit disturbance, nests were checked by extending a mirror from a wooden handle through the vegetation and over the nest. This was done from boat and from shore. Nests of each test bird were monitored until fledging. Blackbird nestlings may leave their nest on the tenth or eleventh day after hatching (hatch day = day 0) or on the ninth day if disturbed [19]. Therefore, nestlings found in the nest on the eighth day were considered successfully fledged. Using the eighth day avoided missing birds that fledged early and avoided causing birds to fledge early.

Measures of reproductive success for each nest were determined as percent hatched ((number eggs hatched/number eggs laid) × 100) and percent fledged ((number birds fledged/number eggs laid) × 100) [28]. An arcsine transformation was performed on percent data [29]. Analysis of variance [25] was performed on the above measures using test block, incubation stage (between 5 and 9 d) and dose as independent variables to determine if significant differences ($p < 0.05$) among treatment groups existed.

Nestling weights and sex [30] were determined at day 8 after hatch. An analysis of variance [25] was performed on nestling weight for each sex using block, number of nestlings per nest and dose as independent variables. Mean nestling weight per nest (without regards to sex) was also used to determine if significant differences ($p < 0.05$) in nestling weights existed among treatments.

RESULTS

Dose determination study

Results of the range finder demonstrated that 4.21 and 7.5 mg/kg methyl parathion produced a sublethal response (ataxia, lacrimation, lethargy) and fell within the desired range of ChE activity depression of 20 and 50% compared to controls. Calculated depression was 42% for 4.21 mg/kg and 35% for 7.5 mg/kg. Birds treated 4.21 and 7.5 mg/kg methyl parathion appeared recovered and capable of flight in less than or equal to 105 min (range 60–105 min). Birds receiving 2.37 mg/kg methyl parathion showed no signs of toxicity and had cholinesterase activity similar to controls ($p > 0.05$). Because 7.5 mg/kg was close to the reported LD50 value and there was not a significant difference between 4.21 and 7.5 mg/kg in ChE depression, as a measure of safety, the smaller of the two was selected. To determine if reproductive effects could be observed in birds that did not show significantly depressed ChE in the lab but received a dose of methyl parathion, 2.37 mg/kg was used as the low dose.

Pond study

A total of 11 partial blocks consisting of one control–control, one high-dosed (4.21 mg/kg) and one control bird were completed. Six blocks were complete using all four treatments. One additional partial block contained one control–control and one high-dosed bird. Therefore, 12 control–control, 11 control, 6 low-dose and 12 high-dose birds were captured for this study.

Block effects and incubation stage were not significant among treatments for any of the parameters measured. Time to return to the nest after dosing was significantly longer for high-dosed birds than either low-dosed or control–control ($p < 0.0001$). Fifty percent of the high-dosed birds took 158.0 min (114–274 min) or longer to return to their nests. The median time for low-dosed and control–control birds to return to their nests was 75.5 min (30–130 min) and 27.0 min (7–99 min), respectively. Birds that received 2.37 mg/kg methyl parathion were not off their nest significantly longer than controls.

Significant treatment differences in incubation time (time on the nest) were detected at the 0800 ($p < 0.0003$) and 0900 ($p < 0.0022$) observation periods. Comparisons among treatment means indicated that for the first 2 h of observation high-dosed birds were off their nests a significantly longer percent of time than control–control or control birds (Table 1). Low-dosed birds were observed off their nests significantly longer than controls during the first hour only and were not significantly different than high-dosed birds for that period.

In contrast to observed short-term effects of methyl parathion, there were no significant differences found among treatment groups in percent hatched and percent fledged (Table 2). Although nest abandonment was expected, only three nests failed to produce one or more nestlings: one control–control, one control and one high dosed. The high-dosed bird was the only one known to abandon after treatment. This bird did not return to the nest during this study, but returned to the study area to nest successfully the following year. Nestlings from one control–control bird were lost after the nest was toppled by growing vegetation. Cause of the remaining failure (control) was unknown. Only one of the four nestlings from this control was found dead in the nest after 6 or 7 d of growth.

Mean nestling weights for both sexes were not significantly different among treatments, regardless of the number of nestlings in the nest (one to three at 8 d). The number of nestlings per nest significantly affected mean nestling weight for female nestlings, but not males. Mean nestling weights on

Table 1. Mean percent ± SE of observations of incubating red-winged blackbirds observed on nests after treatment with methyl parathion, 1987

		Observation hour[b,c]					
Treatment[a]	*n*	0800	0900	1000	1100	Morn	1500
C–C	12	73 ± 4	74 ± 5	66 ± 4	64 ± 3	69 ± 2	72 ± 4
Cont	11	55 ± 11	63 ± 6	75 ± 3	77 ± 5	68 ± 5	71 ± 4
Low	6	25 ± 15*	51 ± 16	74 ± 6	74 ± 6	56 ± 7	59 ± 6
High	12	0 ± 0*	14 ± 6	43 ± 10	55 ± 9	28 ± 5*	51 ± 6

[a]C–C, control birds that were not handled and were only observed; cont, control birds that received gavage of propylene glycol; low, birds that received 2.37 mg/kg of body weight (b.w.) methyl parathion in propylene glycol solution; high, birds that received gavage of 4.21 mg/kg b.w. methyl parathion in propylene glycol solution.
[b]Each observation period began on the hour for 4 h (observations were made every 5 min) in the morning of the day of dosing and for 1 h in the afternoon of the same day. Morn, mean percent of observations of birds on their nest for the entire morning of the first day.
[c]Values, mean percent ± SE of 12 observations that females were observed on the nest. Asterisk indicates values significantly different ($p < 0.05$) than control.

Table 2. Reproductive measures for red-winged blackbirds treated with a single gavage of methyl parathion, 1987

Treatment[a]	n[d]	Average clutch size ($\bar{x}$ ± SE)	Average no. eggs hatched ($\bar{x}$ ± SE)	Average % hatched[b] ($\bar{x}$ ± SE)	Average no. young fledged ($\bar{x}$ ± SE)	Average % fledged[c] ($\bar{x}$ ± SE)
C–C	12	3.2 ± 0.2	2.7 ± 0.1	85.4 ± 4.5	1.9 ± 0.2	61.8 ± 7.8
Cont	11	4.0 ± 0.3	3.2 ± 0.3	81.5 ± 7.7	1.8 ± 0.3	48.8 ± 9.2
Low	6	3.3 ± 0.2	2.5 ± 0.3	76.4 ± 11.9	2.0 ± 0.4	59.7 ± 10.6
High	13	3.7 ± 0.2	2.6 ± 0.3	73.1 ± 8.9	1.7 ± 0.2	47.4 ± 5.7

[a]C–C, control birds that were not handled, only observed; cont, control birds that received gavage of propylene glycol only; low, birds that received 2.37 mg/kg b.w. methyl parathion in propylene glycol solution; high, birds that received gavage of 4.21 mg/kg b.w. methyl parathion in propylene glycol solution.

[b]Average percent hatched = $100 \times 1/n \times \sum$ (number of eggs hatched/clutch size for nest x).

[c]Average percent fledged = $100 \times 1/n \times \sum$ (number of nestlings alive at day 9/clutch size for nest x).

[d]n, number of nests.

a per-nest basis was not significantly different among treatments.

There were no apparent long-lasting effects to female redwings that received a single oral exposure to methyl parathion. Band return for experimental birds (Table 3) demonstrated that dosed birds over-wintered with equal success as control birds or other nonexperimental redwings using the ponds. Of all study birds that returned the following year ($n = 30$), only one control was not subsequently found nesting at the study site.

DISCUSSION

No apparent adverse effects were observed in adult redwing females that received 2.37 or 4.21 mg/kg methyl parathion by oral gavage. Brain ChE activity was assumed to be depressed at least 35% 3 h postdose in birds given the higher dose based on information from a dose determination test. Actual ChE depression may have been much greater later in the day. Evidence from other researchers indicated that maximum depression of ChE in birds probably occurs between 4 and 24 h [1,2,9,31]. Redwings receiving an oral dose of 4.21 or 7.5 mg/kg methyl parathion showed definite signs of intoxication (ataxia, lacrimation, lethargy). White et al. [2] reported that laughing gulls (*Larus atricilla*) gavaged with 6 mg ethyl parathion/kg body weight had approximately 50% ChE depression in 20 h. In contrast to redwings, laughing gulls showed no signs of intoxication at this dose and level of ChE depression. Similarly, starlings with ChE activity depressed 50% were not incapacitated [1]. Differing results among these cited studies and the one presented here suggest that the amount of ChE depression and overt signs of toxicity are not clearly related and appear to be species specific.

Table 3. Band return data for methyl parathion-treated red-winged blackbirds at EPA, Corvallis, Oregon (1987 to 1988)

Treatment[a]	No. banded	No. returned	% Returned
Cont	11	5	45
Low	6	6	100
High	12	6	50
General population[b]			
Females	77	34	44
Males	25	14	56

[a]Cont, control birds that received gavage of propylene glycol only; low, birds that received 2.37 mg/kg b.w. methyl parathion in propylene glycol solution; high, birds that received gavage of 4.21 mg/kg b.w. methyl parathion in propylene glycol solution.

[b]All birds except treated or control females.

Although dosed females took longer to return to their nests after release than controls and consequently spent significantly less time on their nests for the first 2 h after dosing, hatching and fledging success were not adversely affected. Similarly, Powell [32] did not observe disruption in breeding activities or behavior when nesting redwings were exposed to an aerial application of the OP fenthion. In his study, frequency of nest abandonment, clutch size, hatching success and fledging success were monitored. Powell [32] reported that nestling weights were lower than controls within one of his two treatment areas. White et al. [2] found that incubation behavior was temporarily altered in laughing gulls receiving 6 mg/kg (oral) ethyl parathion but could not demonstrate significant reproductive effects.

Grue et al. [1] reported significant decreases in starling nestling weights resulting from a decrease in feeding efforts of females affected by dicrotophos. The consequence of reduced body weight at the time birds fledge may be reduced survival of fledglings [1,33–35]. Nestling weights were not significantly different in the study presented here. However, these data may have been confounded by inaccurate sex determination of nestlings, number of nestlings present in each nest or small sample size of subgroups (sex, nestlings per nest) combined with relatively high between-nest variability.

Nesting female redwings took an average of 177 min to return to their nests following dosing with 4.21 mg/kg methyl parathion. This was longer than the 60 to 105 min to recovery of captive redwings and suggests that the laboratory birds may not have fully recovered.

Predation of nesting birds in this study did not occur but the prolonged period of absence following dosing may have increased the risk of predation to both the adult females and nestlings. In situations where predators are in high concentration, cover is not available or observers are not present, the situation could have been quite different, resulting in the loss of exposed females. During and after uncontrolled exposures such as agricultural spraying for insect pests, redwings may be at risk of predation.

In addition to short-term and reproductive effects, this study, through band return data, was able to determine long-term survival of females exposed to methyl parathion. There were no differences in the number of birds that returned and nested the following year between treated, control or other redwings using the ponds. To our knowledge this type of return data has not previously been reported for redwings exposed to an OP.

The red-winged blackbird has proven a valuable subject for behavioral, physiological and ecological research. The species is easy to observe, tolerant of human disturbance and can be found in relatively high concentrations. This species could provide valuable research opportunities in avian toxicology.

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