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ScienceDirect
Environmental Pollution 149 (2007) 18–24
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Impaired terrestrial and arboreal locomotor performance in the western fence lizard (*Sceloporus occidentalis*) after exposure to an AChE-inhibiting pesticide

Sarah E. DuRant [a,b], William A. Hopkins [a,b,*], Larry G. Talent [c]

[a] *Wildlife Ecotoxicology and Physiological Ecology Program, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, 444 Latham Hall, Blacksburg, VA 24061, USA*
[b] *University of Georgia, Savannah River Ecology Laboratory, PO Drawer E, Aiken, SC 29802, USA*
[c] *Department of Zoology, Oklahoma State University, Stillwater, OK 74078, USA*

Received 7 July 2006; received in revised form 18 December 2006; accepted 20 December 2006

Exposure to an acetylcholinesterase-inhibiting pesticide alters locomotor performance in western fence lizards.

Abstract

We examined the effects of a commonly used AChE-inhibiting pesticide on terrestrial and arboreal sprint performance, important traits for predator avoidance and prey capture, in the western fence lizard (*Sceloporus occidentalis*). Lizards were exposed to carbaryl (2.5, 25, and 250 μg/g) and were raced before and 4, 24, and 96 h after dosing. In the terrestrial setting, exposure to low concentrations of carbaryl had stimulatory effects on performance, but exposure to the highest concentration was inhibitory. No stimulatory effects of carbaryl were noted in the arboreal environment and performance in lizards was reduced after exposure to both the medium and highest dose of carbaryl. Our findings suggest that acute exposure to high concentrations of carbaryl can have important sublethal consequences on fitness-related traits in reptiles and that arboreal locomotor performance is a more sensitive indicator of AChE-inhibiting pesticide poisoning than terrestrial locomotor performance.

Keywords: Carbaryl; Cholinesterase; Reptiles; Lizards; Locomotor performance

1. Introduction

Although acetylcholinesterase (AChE)-inhibiting pesticides are among the most commonly used pesticides in the United States (Kiely et al., 2004), their impact on wildlife, especially reptiles, is not thoroughly understood. The use of AChE-inhibiting pesticides became popular because they are relatively short-lived in the environment and do not bioaccumulate (Hill, 1995). Unfortunately, the use of these pesticides does not come without costs. Numerous studies have shown that acute exposure to AChE-inhibiting pesticides can have adverse effects on non-target wildlife (Busby et al., 1990; Buerger et al., 1991; Hart, 1993; Fryday et al., 1994; Bridges, 1997; Brunet et al., 1997; Grue et al., 1997; Beauvais et al., 2000; Scholz et al., 2000; Relyea, 2005; Sandahl et al., 2005). While the majority of studies examining the effects of AChE-inhibiting pesticides have focused on birds and fish, relatively few studies have examined herpetofauna (Hopkins, 2000). Recently, the effects of AChE-inhibiting pesticides on amphibians has received attention (Boone and Bridges, 2003; Rohr et al., 2003; Boone et al., 2004; Metts et al., 2005; Relyea, 2005), but few studies have focused on effects in reptiles (Hopkins, 2000; Campbell and Campbell, 2002; but see Bain et al., 2004; Hopkins et al., 2005a; Holem et al., 2006; Hopkins and Winne, 2006). In fact, reptiles, particularly lizards and snakes, remain the least studied vertebrate taxa in ecotoxicological

* Corresponding author. Tel.: +1 540 231 7292; fax: +1 540 231 7580.
E-mail address: hopkinsw@vt.edu (W.A. Hopkins).

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doi:10.1016/j.envpol.2006.12.025

studies even though contaminants have been implicated as one factor contributing to reptile population declines (Gibbons et al., 2000). Of particular importance is understanding the effect of AChE-inhibiting pesticides on traits relevant to the individual's fitness (Hopkins, 2000, 2006; Campbell and Campbell, 2002).

In lizards and snakes, one important fitness-related trait that could be affected by exposure to AChE-inhibiting pesticides is locomotor performance. Sprint speed is a commonly measured endpoint in ecological and evolutionary studies of lizards due to its apparent importance to survival and fitness (Garland et al., 1990; Garland and Losos, 1994; Warner and Andrews, 2002; Miles, 2004; Husak, 2006; Peterson and Husak, 2006) and because it is a highly repeatable measure in a laboratory setting (Huey and Dunham, 1987; Van Berkum et al., 1989). Several studies involving reptiles and amphibians have found that exposure to AChE-inhibiting pesticides can greatly impact an individual's ability to perform (Bridges, 1997; Hopkins et al., 2005a; Hopkins and Winne, 2006). While exposure to pesticides may not directly result in death, reductions in performance could ultimately be of equal importance to the individual's fitness by altering an individual's ability to avoid predators, capture prey, and/or defend territories.

In our study we sought to examine the effects of carbaryl, an AChE-inhibiting pesticide, on sprint performance in both terrestrial and arboreal settings in *Sceloporus occidentalis* (western fence lizard). Two studies on the effects of carbaryl on swimming speed in four species of Natricine snakes documented 19–31% decreases in swimming performance during the first 24 h after exposure, but animals recovered within 96 h after exposure (Hopkins et al., 2005a; Hopkins and Winne, 2006). Exposure to carbaryl also resulted in a decrease in swimming speed and distance in leopard frog tadpoles (*Rana blairi*) (Bridges, 1997). Based on the results of these previous studies, we hypothesized that exposure to carbaryl would result in a dose-dependent decrease in sprint speed in lizards. We also predicted that sprint speed in an arboreal setting would prove to be a more sensitive endpoint to the effects of carbaryl than terrestrial performance because arboreal locomotor performance requires greater coordination and balance than running on a flat surface (Losos and Sinervo, 1989; Irschick and Losos, 1999; Mattingly and Jayne, 2005).

2. Materials and methods

2.1. Carbaryl and dose administration

The pesticide chosen for our study was carbaryl (1-naphthyl methylcarbamate). Carbaryl, is a carbamate which deactivates acetylcholinesterase through carbamylation, during which a carbamyl group binds reversibly to the active site of the enzyme (Fukuto, 1990). Carbamate-inhibited AChE is not stable, however, and the carbamyl group is hydrolyzed within minutes to days, resulting in recovery of the enzyme (O'Brien, 1976; Fukuto, 1990).

Carbaryl is one of the most widely used non-commercial insecticides. According to the US EPA's Pesticide Industry Sales and Usage 2000–2001 Market Report (Kiely et al., 2004), carbaryl was ranked as the sixth most commonly used conventional pesticide in the home and garden market. The 22.5% formulation we chose, Sevin ©, is available for non-commercial use. Carbaryl is used on a variety of agricultural crops such as oranges, apples, alfalfa, tree nuts, and turfgrass (EPA, 2004). Carbaryl can be applied between 1–8 times a season with the time between applications ranging from 7–30 days (EPA, 2004). Carbaryl is a relatively short-lived contaminant in the environment with a half-life in soil ranging between 8–18 days (Nkedi-Kizza and Brown, 1998). The short half-life of carbaryl makes studies of acute exposure ecologically relevant.

Although contaminated insects are an important route of exposure to pesticides for insectivorous vertebrates inhabiting areas that receive pesticide application, very little data exist on invertebrate pesticide residues. Therefore, it is difficult to predict actual concentrations lizards are likely to encounter in the wild. In the only study to directly quantify carbaryl residues of terrestrial invertebrates, Fair et al. (1995), showed that grasshoppers had mean residues of 17 μg/g two days following rangeland application of 0.5 kg active ingredient/ha. Using this insect residue data and carbaryl application rates, which can vary from 1.12 to 22.42 kg active ingredient/ha (EPA, 2004) we estimated that a 10 g lizard consuming 1 g of prey could ingest dose concentrations ranging between 3.9–78.5 μg/g 2 days following carbaryl application. Factoring the short half-life of carbaryl into our estimates, as well as the fact that lizards can consume meals exceeding 10% of their body mass, we selected three doses that fully encompass the range of concentrations that we believed lizards could encounter in the environment.

Carbaryl was administered to lizards via oral gavage using an Eppendorf micro-pipette (2–20 μl). The 2.5 and 25 μg/g solutions were made within one hour of administration by diluting the 22.5% Sevin © formulation with water and then vortexing the solution for one minute. Lizards in the 250 μg/g treatment group received an undiluted dose of the 22.5% Sevin © formulation, and lizards in the oral gavage treatment group received a comparable volume of water. A control group (i.e., not receiving gavage) was not used in these experiments because prior research demonstrated that lizards gavaged with water did not differ in sprint speed from unmanipulated control animals (Holem et al., 2006).

2.2. Fence lizard natural history and husbandry

Sceloporus lizards belong to the family Phrynosomatidae which accounts for more than 30% of all lizards in the United States. The species used in our study, *S. occidentalis*, ranges from Mexico to Canada between the California coast and western Utah, USA. The original parental stock of western fence lizards used in our study originated from a population in the grasslands of the San Joaquin Valley, CA, USA. Most females reach sexual maturity within one year under *ad libitum* feeding conditions in the laboratory, and lay 3–6 clutches of 8–15 eggs per year. This population of western fence lizards does especially well under laboratory conditions and has been identified as a good candidate for use as a laboratory reptile model in ecotoxicology studies (Talent et al., 2002; Hopkins et al., 2005b).

Adult western fence lizards, representing the F2 generation, were shipped to Savannah River Ecology Laboratory (SREL) from a breeding colony at Oklahoma State University. Lizards husbandry protocol was identical to that of Hopkins et al. (2005b) with the following exceptions: a 10:14 (light: dark) photoperiod, a daytime temperature gradient within each lizard's cage of ~28–40 °C, and a diet consisting of 4 crickets (~1.5 cm each) a day.

2.3. Experiment I: terrestrial sprint performance

In our first experiment we sought to determine the effects of carbaryl exposure on terrestrial sprint velocity. Lizards were fasted 48 h before the start of the experiment after which time they were assigned to one of four treatment groups: gavage, 2.5 μg/g, 25 μg/g, or 250 μg/g carbaryl ($N = 10$ males and 10 females/treatment). Sprint velocity was measured at four time intervals, before dosing, and 4 h, 24 h, and 96 h after dosing using a 2.3 m linear sprint track lined with pairs of photocells projecting infrared beams at 10 cm intervals interfaced with a laptop computer (Columbus Instruments, Columbus, Ohio, USA). Methods were similar to Holem et al. (2006). All lizards were conditioned to the sprint track before the start of the experiment by racing the lizard down the track 2 times 24 h prior to the start of the experiment. At each time interval lizards were raced successively for a total of 3 laps. Body mass of lizards used in the terrestrial sprint trials ranged between 11.0–22.1 g and dose volumes ranged between 11.3–22.6 μL. Because temperature influences sprint speed, lizards were maintained at their optimal body temperature (34 ± 1 °C)

during sprint trials (Bennett, 1980; Crowley, 1985; Huey and Bennett, 1987) and their temperature was recorded prior to each lap using a Schultheis ® cloacal thermometer. Lizards were offered five crickets after the 24 h sprint time interval and any remaining crickets were removed 24 h later.

For each lap at each time interval we calculated an individual's maximum terrestrial velocity (MTV) over each 0.2 m interval. Lizard performance was estimated using two methods. In the first method, we used the greatest MTV of the three laps, which is similar to techniques commonly used in the literature (Huey and Dunham, 1987; Van Berkum et al., 1989; Sinervo and Losos, 1991; Irschick and Losos, 1999; Holem et al., 2006). However, we observed that while some lizards performed very well on the first lap, performance declined on the second and third laps. In the second method, we monitored MTV of each lap per time interval. This allowed us to monitor how the performance of a lizard changed over the entire time interval. Similar techniques used with snakes revealed that exposure to carbaryl resulted in a decline in swimming performance with each subsequent lap (Hopkins et al., 2005a).

2.4. Experiment II: arboreal sprint performance

To better understand the effects of carbaryl on locomotion in lizards, we also examined how lizards performed in an arboreal setting (artificial branch). Several studies have indicated that sprint performance differs depending on the substrate (Losos and Sinervo, 1989; Sinervo and Losos, 1991; Mattingly and Jayne, 2004). Testing lizards in an arboreal setting examined the potential effects of carbaryl on finer motor skills (balance, ability to grasp) than might not be apparent in a terrestrial setting. To measure arboreal performance, we raced lizards for two consecutive laps at the four aforementioned time intervals on a 1.2 m wood dowel rod; 2.54 cm in diameter marked at 10 cm intervals and covered with 1 cm^2 fiberglass mesh screening. The dowel rod was horizontally suspended ~2 m above the ground and a hidebox was positioned at the finish to encourage lizards to run across the rod. Similar to the terrestrial performance experiment, lizards were fasted 48 h prior to treatment administration; pre-treatment trials occurred immediately prior to dose administration, and lizards were raced at 34 °C. Lizards used in this experiment were also offered five crickets after completion of the 24 h time interval sprint and remaining crickets were removed 24 h later.

We calculated lizard's maximum arboreal velocity (MAV) per lap per time interval over a 0.2 m interval using a frame by frame advance on a VCR (30 frames per second) (Hopkins et al., 2005a). Lizard arboreal performance was estimated similarly to terrestrial performance. Each treatment group consisted of 10 lizards per sex, except for the low dose group which contained 10 females and 11 males. Body mass of adult lizards in the arboreal sprint trials ranged from 10.5–19.2 g and dose volumes ranged from 10.8–19.7 μL.

2.5. Statistical analyses

Maximum terrestrial velocity and MAV achieved at each time interval were analyzed separately using a mixed model approach (SAS PROC MIXED) with snout vent length (SVL) as the covariate. The initial models included all interaction terms but insignificant interactions were dropped in subsequent iterations of the model. Initial models indicated there was no difference in sprint speed between males and females, and therefore sexes were combined for statistical analyses. Maximum terrestrial velocity and MAV achieved for each individual lap at each time point were analyzed separately in an identical manner. Some individuals in the arboreal performance experiment refused to run for one or both laps during a sprint trial, these individuals were not included in statistical analyses.

We also examined the number of lizards that refused to traverse or fell off of the arboreal substrate at least once during the arboreal experiment. These calculations were then compared among treatment groups using a Fisher's Exact Test.

3. Results

The dose concentrations administered to lizards in the terrestrial and arboreal experiments did not result in any mortalities. However, 58% (23/40) of lizards in the highest dose group exhibited clinical signs of exposure to carbaryl (e.g., body/limb tremors, twitching). Onset of tremors began as early as 4 h after exposure and persisted up to 48 h after exposure.

Maximum terrestrial velocity of lizards achieved at each time interval was significantly affected by treatment, but this was also dependent on time (treatment × time: $F_{9,228} = 2.07$, $p < 0.0331$). The treatment and time effects were caused by an 11–23% increase in sprint speed at the lower concentrations (2.5 and 25 μg/g) at 4 and 24 h after exposure and a 9–10% decrease in sprint speed at the highest dose concentration (250 μg/g) at 4 and 24 h after exposure (data not shown). Similarly, when we examined MTV of each lap separately we found there was a significant treatment × time interaction for each lap and this effect became more pronounced with each subsequent lap (lap 1: $F_{9,228} = 2.11$, $p < 0.0299$; lap 2: $F_{9,228} = 2.66$, $p < 0.0059$; lap 3: $F_{9,228} = 4.06$, $p < 0.0001$; see Table 1 and Fig. 1). Again, exposure to carbaryl at the two lower dose concentrations (2.5 and 25 μg/g) had a stimulatory (17–33% increase over controls) effect on sprint speed, but impaired sprint speed at the highest dose concentration (250 μg/g; see Fig. 1). The reduction in sprint speed in the highest treatment group compared to controls was more pronounced in later laps, decreasing from no difference in lap 1 to a 30% reduction in lap 3 (see Fig. 1).

Examination of MAV achieved for each time interval revealed there was a significant effect of time on MAV ($F_{3,204} = 6.35$, $p < 0.0004$) while treatment and treatment × time had marginal effects on MAV (treatment: $p = 0.0768$; treatment × time: $p = 0.0553$). This pattern appeared to be driven by a 37% and 33% decrease in sprint speed in the highest treatment group (250 μg/g) compared to control lizards at 4 and 24 h after exposure to carbaryl, respectively (data not shown). However, when we examined MAV of each lap separately we found there was a significant effect of both treatment and time for both lap 1 (treatment: $F_{3,66} = 3.75$, $p = 0.0149$; time: $F_{3,201} = 8.45$, $p < 0.0001$) and lap 2 (treatment: $F_{3,66} = 5.26$, $p = 0.0028$; time: $F_{3,201} = 3.94$,

Table 1
Results of repeated measures ANCOVA for the effects of carbaryl treatment on maximum terrestrial velocity (SVL as a covariate) per lap in *Sceloporus occidentalis* before, 4, 24 and 96 h after oral gavage with carbaryl

Variable	Effect	Num df	Den df	F	p
MTV lap 1	Treatment	3	75	1.75	0.164
	Time	3	228	7.14	0.001
	SVL	1	75	0.67	0.416
	Treatment × time	9	228	2.11	0.030
MTV lap 2	Treatment	3	75	1.11	0.351
	Time	3	228	6.52	0.003
	SVL	1	75	0.01	0.926
	Treatment × time	9	228	2.66	0.006
MTV lap 3	Treatment	3	74	3.62	0.017
	Time	3	228	13.37	<0.001
	SVL	1	74	1.69	0.198
	Treatment × time	9	228	4.06	<0.001

The mixed procedure was performed using SAS (Proc Mixed). Sample size = 10 for each treatment for each sex for all variables.

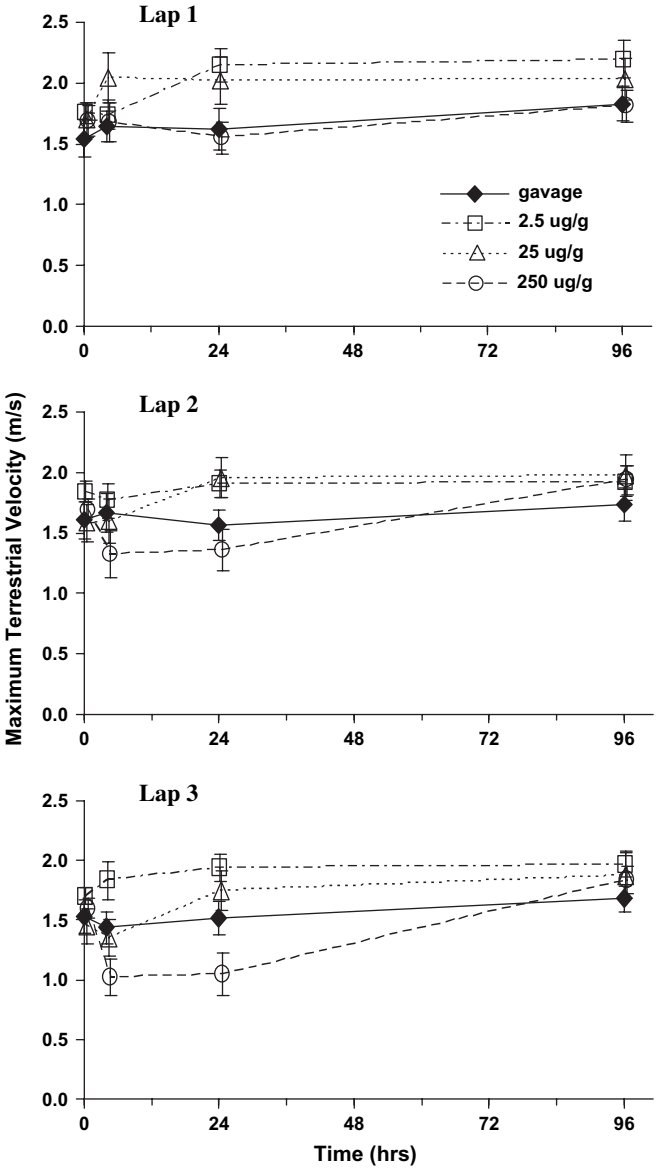

Fig. 1. Maximum terrestrial velocity achieved by *S. occidentalis* for each of three laps over a 2.3 m track before and 4, 24, and 96 h after oral administration of carbaryl. Error bars are ±1 standard error of the mean. $N = 10$ per sex per treatment group for each lap except for the highest dose group in lap 3 which includes 9 females and 10 males. Sample sizes varied for lap 3 because one female refused to sprint during the 24 h time point.

$p = 0.0095$), but no treatment by time interaction (lap 1: $p = 0.3460$; lap 2: $p = 0.3950$) (see Table 2). In both laps, treatment and time interval effects were driven by a decrease (29–55%) in MAV in the highest treatment group compared to controls at 4 and 24 h after dosing (see Fig. 2). Reductions in sprint speed were more pronounced in the later lap, from 29%–37% in lap 1 to 42%–55% in lap 2 (see Fig. 2).

Both the number of lizards who fell and refused to traverse the arboreal substrate at least once during the arboreal experiment were significantly different among treatments (Overall model; refusals: $p = 0.0035$; falls: $p < 0.0001$) (see Fig. 3). Only 10% of gavage control lizards fell or refused in the arboreal experiment compared to 35% of lizards falling in the

Table 2
Results of repeated measures ANCOVA for the effects of carbaryl treatment on maximum arboreal velocity (SVL as a covariate) per lap in *Sceloporus occidentalis* before, 4, 24 and 96 h after oral gavage with carbaryl

Variable	Effect	Num df	Den df	F	p
MAV lap 1	Treatment	3	66	3.75	0.015
	Time	3	201	8.45	<0.001
	SVL	1	66	0.13	0.722
	Treatment × time	9	201	1.13	0.346
MAV lap 2	Treatment	3	66	5.26	0.003
	Time	3	201	3.94	0.001
	SVL	1	66	1.26	0.266
	Treatment × time	9	201	1.06	0.395

The mixed procedure was performed using SAS. Individuals that refused to run were not included in statistical analyses. Sample sizes varied in statistical models. Lap 1: Sample size = gavage: 9 females, 9 males; 2.5 μg/g: 8 females, 10 males; 25 μg/g: 9 females, 10 males; 250 μg/g: 6 females, 10 males. Lap 2: Sample size = gavage: 9 females, 9 males; 2.5 μg/g: 6 females, 11 males; 25 μg/g: 9 females, 9 males; 250 μg/g: 1 female, 8 males.

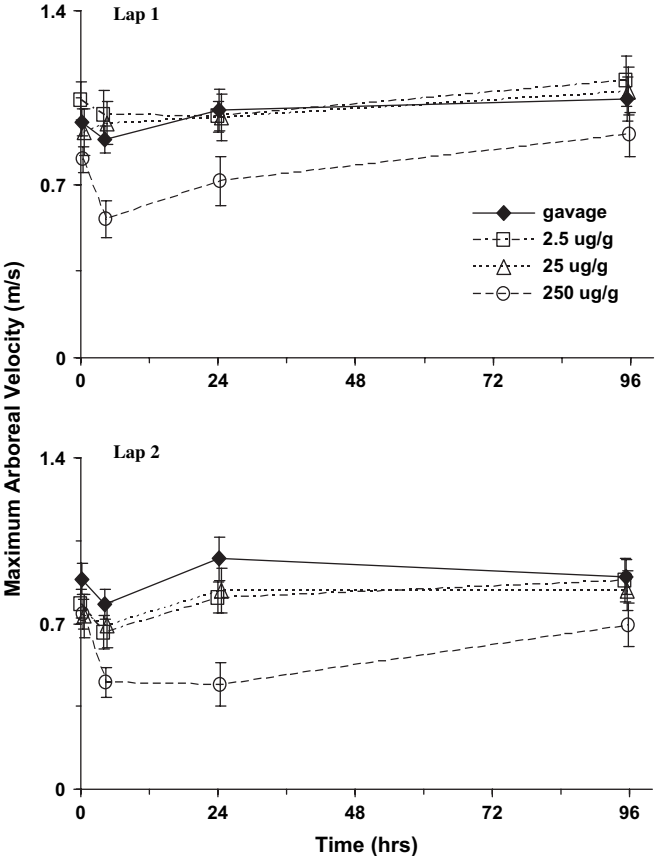

Fig. 2. Maximum arboreal velocity achieved by *S. occidentalis* for each of two laps over a 1.2 m dowel rod before and 4, 24, and 96 h after oral administration of carbaryl. Error bars are ±1 standard error of the mean. Sample sizes varied because some lizards refused to sprint during one or more time intervals. Lap 1: $N = 9$ females and 9 males for the gavage control group; 8 females and 10 males for the 2.5 μg/g group: 9 females and 10 males for the 25 μg/g group; and 6 females and 10 males for the 250 μg/g. Lap 2: $N = 9$ females and 9 males for the gavage control group; 6 females and 11 males for the 2.5 μg/g group: 9 females and 9 males for the 25 μg/g group; and 1 females and 8 males for the 250 μg/g.

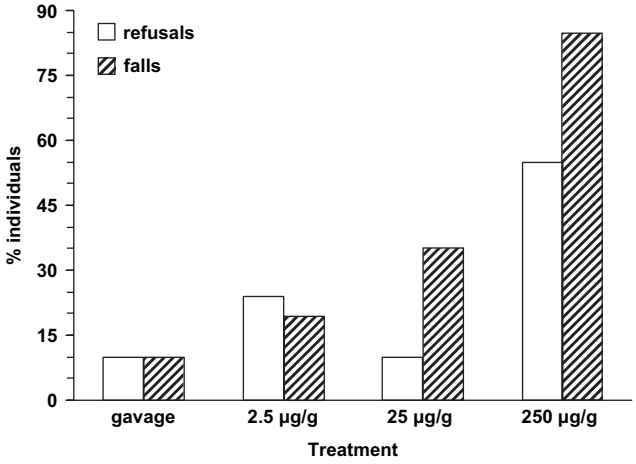

Fig. 3. Percentage of individuals that refused to sprint across, or fell off of a 1.2 m arboreal track at least once during the course of the experiment. $N = 10$ lizards per sex per treatment group for all treatments except the 2.5 µg/g group which contained 10 females and 11 males.

medium dose group and 55–85% of lizards in the highest treatment group either falling or refusing to traverse.

4. Discussion

Acute exposure to carbaryl influenced performance in lizards, but contrary to our predictions it did not inhibit sprint speed in a dose-dependent manner in either the terrestrial or arboreal setting. Instead, exposure to carbaryl at the two lower dose concentrations (2.5 and 25 µg/g) had a stimulatory effect on terrestrial sprint speed, but at the highest dose concentration (250 µg/g) carbaryl impaired sprint speed (see Fig. 1). The reduction in sprint speed in the highest treatment group compared to controls was more pronounced in later laps, suggesting that carbaryl also affected endurance of lizards (see Fig. 1). Sprint speed in the arboreal setting was reduced only in the highest dose group (250 µg/g) and was also most pronounced in the later lap, further supporting the idea that carbaryl affected lizard endurance (see Fig. 2). In addition, lizards in both the medium and high dose groups exhibited other symptoms of impairment in the arboreal tests including refusal to traverse and falling.

As predicted, performance in the arboreal setting appeared to be more challenging than terrestrial locomotion, and as a consequence, arboreal performance also proved to be a more sensitive indicator of carbaryl exposure. Regardless of treatment group, maximum velocity achieved during the arboreal sprint trials was ~50% lower than maximum velocity achieved in the terrestrial experiment. Whereas carbaryl induced reductions in sprint velocity ranged between 13–30% in the terrestrial setting, reductions in the arboreal setting were twice as pronounced (29–55%). Furthermore, we noted that lizards in the highest treatment group were 4.5× more likely to refuse to traverse the arboreal substrate, and 7.5× more likely to fall than controls during arboreal sprint trials (see Fig. 3). Interestingly, there was also a significant increase in the percentage of individuals that fell in the 25 µg/g (35%) compared to controls (10%). These effects were not captured when examining terrestrial locomotor performance, but could be of importance to *S. occidentalis* because they regularly utilize arboreal substrates for movement and prey capture (Sinervo and Losos, 1991; Schlesinger et al., 1993).

Recently, a study was conducted (Holem et al., 2006) that examined the effects of malathion, an organophosphate (OP), on sprint speed in *S. occidentalis*. Interestingly, the authors found that exposure to 200 µg/g of malathion resulted in a 23% increase in sprint speed that remained elevated for up to 13 days after dosing, even though 70% of lizards in this dose group exhibited clinical signs of AChE-inhibiting pesticide poisoning (e.g., body/limb tremors, twitching) and 20% of them died. Because carbaryl and malathion are both AChE-inhibiting pesticides (Hill, 1995), one might expect they would have comparable effects on locomotor performance in the same species. However, this was not the case. In our study, lizards in the highest carbaryl dose group exhibited not only clinical signs of exposure to an AChE-inhibiting pesticide (58%), but also a significant reduction in sprint speed. The difference in effects of these two pesticides on locomotor performance in *S. occidentalis* emphasizes that generalizations should be drawn cautiously about the effects of AChE-inhibiting pesticides on whole-animal responses.

The decrease in sprint speed in our highest dose group is consistent with two studies that reported carbaryl degraded swimming performance in several species of semi-aquatic snakes (Hopkins et al., 2005a; Hopkins and Winne, 2006). Similar to our study, the authors also noted that animals appear to recover within 96 h of exposure. Hopkins et al. (2005a) noted that the effects of carbaryl on swim speed were more pronounced as swim distance increased, similar to what was observed in the highest treatment group in our study. This effect could be of great ecological relevance to behaviors that require stamina, such as extended bouts of combat observed in male *Anolis* lizards during the breeding season (Jenssen et al., 1995, 2000). However, neither of the snake swimming performance studies observed an increase in swimming speed at the lower dose concentration examined. Several studies examining the effects of carbofuran, another carbamate, on swimming behavior in goldfish observed an increase in burst swimming speed at low concentrations (Saglio et al., 1996; Bretaud et al., 2001, 2002). Other studies have noted an increase in activity several hours after exposure to an AChE-inhibiting pesticide (Hart, 1993; Timofeeva and Gordon, 2002) and another study noted an increase in sprint speed and distance in tadpoles 24 h after exposure to carbaryl (Bridges, 1997). However, Bridges (1997) and Timofeeva and Gordon (2002) reported a subsequent decrease in activity within these same treatment groups at later time periods which was not observed in our study. A similar effect was also noted in red-winged blackbirds in which activity levels increased with low doses of dimethoate, an OP, but decreased at higher dose concentrations (Brunet et al., 1997). It is possible that an increase in fasciculation accounts for the increase in sprint speed at low dose concentrations of AChE-inhibiting pesticides (ASTDR, 2003). Taken together, the results of our study

and previous studies suggest that complex dose-response curves may exist for behavior and performance in a variety of fish and wildlife and are worthy of future study.

Our results suggest that carbaryl at high dose concentrations compromise locomotion involved with such critical processes as predator avoidance and prey capture. It also appears, based on the results of our study that sprint speed in an arboreal setting is a more sensitive indicator of acute AChE-inhibiting pesticide poisoning than terrestrial locomotor performance. Decreases in sprint speed were greater in the arboreal setting than in the terrestrial setting, and effects such as refusal to sprint and falling could be important consequences of pesticide exposure that are not apparent in the terrestrial setting. Of particular importance is the finding that similar pesticide compounds with similar modes of toxicity can produce such contrasting results on sprint performance in *S. occidentalis*, indicating the importance of future studies of multiple AChE-inhibiting pesticides on whole-organism responses.

Acknowledgements

Ryan Holem, Chris Hayes, Justin Jones, and Jamie Williams provided technical support on the project. Jerry Husak, John Willson, and Tom Jenssen provided comments on early drafts of the manuscript. Animal husbandry was in conformance with all appropriate animal care and use protocols. Financial support was provided by U.S. Department of Energy through the Financial Assistance Award # DE-FC09-96SR18546 to the University of Georgia Research Foundation, and teaching and research assistantships from the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University and from the Savannah River Ecology Laboratory Graduate Program.

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