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Effects of Carbaryl-Treated Bait on Maternal Behavior and Sprint Performance in the Meadow Jumping Mouse, *Zapus hudsonius*

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Poisoned baits have been used to control insects such as grasshoppers and locusts on rangelands since the 1870s (Coe 1878). The introduction of synthetic organic insecticides combined with low-volume aerial application procedures caused a significant decrease in the use of such baits. However, more recent discoveries that low concentrations of wheat-bran bait treated with carbaryl can be effective as a control strategy for rangeland grasshoppers have led to a renewal of interest in the use of baits in integrated pest management (Krupovage et al. 1990). Studies have shown that 2 - 20% carbaryl bait at 1.7 kg/ha and 0.17 kg/ha, respectively, can effectively control these insects (Smith 1987). Carbaryl (Sevin®), like other carbamates, is a potent cholinesterase inhibitor and can cause a variety of symptoms including respiratory difficulty, impairment of thermoregulation and reproduction, reduction in food consumption, and muscle spasms (Matsumura 1985; Grue et al. 1997), as well as affecting a wide range of behavior (Mineau 1991). Since wheat bran has nutritional value and is consumed by small mammals (Barrett 1988), carbaryl-treated baits may represent an important risk factor for these animals.

Most of the research on the toxicological effects of carbamates on rodents was conducted on laboratory-reared gerbils (Collins et al. 1971), house mice (Thomas et al. 1974), and Norway rats (Shtenberg and Rybakova 1968). Few data are available for wild rodents (Krupovage et al. 1990) and none are available for the meadow jumping mouse, *Zapus hudsonius,* a locally abundant species which is found in areas where carbaryl-treated baits are employed in insect control.

Zapus hudsonius ranges from southern Alaska and across most of the southern Canadian provinces, south through eastern Wyoming to Oklahoma, and eastward through the northeastern U.S. (Mathews 1980; Whitaker 1996). It prefers brushy fields, dense grassy or sedge covered areas along marshes or streams, or woods with thick vegetation (Foresman 2001). It feeds on a variety of foods including the seeds of grasses and other plants as well as insects (Quimby 1951; Muchlinski 1988). The purpose of this study was to assess the effects of carbaryl on maternal behavior and sprint performance in *Z. hudsonius.*

MATERIALS AND METHODS

The animals used in these experiments were adult males and females (7.5 - 8 months old; 23 - 24 g) obtained from a captive breeding colony established in 1997 from adults collected from Big Horn County in southeastern Montana. Animals were housed in plastic rodent cages in a room where temperature, humidiy, and photoperiod were controlled (21-22^{o}C, 60-65% RH, 10L:14D). They were provided with distilled water at all times from a tubelick water bottle, and fed on a diet consisting of Purina chicken scratch grain and commercial cat chow (Complete Diet Mix, Ralston Purina, St. Louis, MO).

Bait concentrations were prepared by incorporating carbaryl (Sevin® 4 oil, Rhone-Poulene Ag Co., Research Triangle Park, NC, 20% carbaryl by weight) insecticide on wheat-bran flakes as described by Gaines (1960). The flakes were spread in a thin layer on a glass plate and carbaryl was applied using an atomizer. Three bait concentrations (treatment groups) were used: 0 (control), 2, and 20% (AI) by weight.

Experiments were conducted to determine the effects of consumption of carbaryl-treated baits on running speed in *Z. hudsonius.* Tests were conducted on animals selected at random from the breeding colony. Mice were deprived of food for 24 hr prior to testing. Eight different males and 8 non-pregnant females were fed bran flakes containing either 0 (controls), 2, or 20% carbaryl as described above (a total of 24 males and 24 females). Mice were placed individually in plastic rodent cages provided with tubelick water bottles and a sand substrate, and fed a preweighed amount (5 g) of bait during each of 7 successive, 12-hr diurnal feeding periods, followed by food deprivation. Test subjects were apportioned in such a way as to obtain 8 replications for each sex at each of the bait concentrations. After 7 days on this feeding regime, the animals were placed back into their individual housing cages and running speed experiments were started on the next day.

Maximal running speeds (sprint performance) were determined by timing the animals as they ran along a microprocessor-controlled rectangular racetrack fitted with photocells and timers. A detailed description of the track and protocol used in the present study can be found in Djawdan and Garland (1988). To summarize, the track was 2 m in length and 10 cm in width. It was constructed of plywood and had walls 20 cm in height. Starting at the beginning of the track (start-end), nine sets of vertically-aligned photocells were placed at 0.1 m-intervals along the base of the floor to allow for the determination of running speed. The floor was covered with artificial turf to provide for traction. The end of the track contained a darkened box that provided a refuge for the subject.

To allow the animals to habituate to conditions inside the track, each mouse was chased slowly back and forth along the runway 4 - 5 times before actual testing began. At the start of each trial, one mouse was placed at the start-end of the track and coaxed to run by gently prodding it with a padded wooden dowel. After each trial, the animal was returned to the start area for the next trial. Multiple trials were run for each animal (4 - 7) until no increase in speed was observed for subsequent trials. The fastest time was defined as the maximal running speed in km/hr (Djawdan and Garland 1988). Log-transformed data were analyzed for differences in sprint performance of male and female mice in the 3 treatment groups using a two-way ANOVA (sex [male and female] and bait concentration [0, 2, and 20%]) as described by Sokal and Rohlf (1995). Differences between the treatment groups were tested for significance using Scheffe F tests.

Another series of experiments were done to assess the effects of carbaryl on maternal behavior. One treatment group consisted of 10 sperm-positive females, that were fed as described above, on bran containing 2% carbaryl until parturition; another group of 10 were fed on non-carbaryl containing bran (0%). Following birth, observations were made on behavioral interactions between mothers and their pups including grooming and cannibalism.

RESULTS AND DISCUSSION

These experiments showed that *Z. hudsonius* will feed on baits treated with carbaryl. Animals exposed to 2 or 20% carbaryl exhibited more random, jerky movements within the racetrack and would frequently bump against the walls. The control animals, on the other hand, ran a more direct route along one side of the track. The effects of carbaryl on sprint performance is shown in Table 1. There were no differences between males and females ($F_{2,42} = 1.61$, $P > 0.50$). However, there was a significant overall effect of carbaryl concentration on running speeds ($F_{2,42} = 8.92$, $P < 0.01$). Control subjects exhibited the fastest running speed, followed in decreasing order by the 2% and 20% groups.

Exposure to carbaryl in the diet reduced running speed in this species which may have a significant impact on overall fitness. Impairment of sprint performance would make these animals more vulnerable to cursorial mammalian predators as well as raptors. Predators reported to feed on *Z. hudsonius* include foxes, badgers, coyotes, bobcats, skunks, weasels, owls, and hawks (Quimby 1951; Alder et al. 1984; Foresman 2001).

No apparent differences in the grooming of pups by females were observed. Females from both treatment groups exhibited 3 - 4 licking bouts / hr that lasted about 3 - 7 min. With respect to cannibalism, only one out of 10 (10%) of the control mice giving birth consumed their young (2 pups out of 6, on the 2nd day after birth). In contrast, a significantly higher number (N =7; 70%) of the mice fed on bran containing 2% carbaryl ate their young ($X^2 = 7.3$, $P < 0.01$). These results suggest that

Table 1. Running speeds of *Zapus hudsonius* feeding on carbaryl-treated baits containing 0 (control), 2, or 20% carbaryl by weight. Data expressed as means ± S.E. Data in columns with different letters are significantly different (Scheffe F tests, $P < 0.05$, Sokal and Rohlf 1995).

	Number		Running speed (km/hr)	
Carbaryl conc.	Males	Females	Males	Females
0 %	8	8	13.5 ± 3.1a	12.9 ± 2.6a
2 %	8	8	8.4 ± 1.5b	7.9 ± 1.2b
20 %	8	8	5.2 ± 1.8c	5.7 ± 0.7c

carbaryl-induced cannibalism will also result in higher mortality rates in these mice.

To my knowledge, these experiments represent the first data on the effects of carbaryl-treated baits on any aspect of the biology or behavior of *Z. hudsonius.* This species is clearly susceptible to carbaryl poisoning as indicated by reduced running speed and increased rate of cannibalism, and the use of insecticide-containing baits should be expected to increase mortality and reduce population densities in this small mammal. In addition, a reduction in its numbers will result in a decrease in food for predators that feed on *Z. hudsonius.*

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