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Luring Small Mammals: A Levels-of-organization Perspective

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Abstract - We compared prebaiting versus non-prebaiting of small mammal live traps during autumn (i.e., when food resources were abundant) and during spring (i.e., when food resources were scarce). Trapping was conducted within 10 experimental grids (0.21-ha each) located in upland and bottomland (5 each) habitats. Four species of small mammals were captured 10 or more times during this study: *Peromyscus leucopus* (White-footed Mouse; 543 captures), *Glaucomys volans* (Southern Flying Squirrel; 94 captures), *Tamias striatus* (Eastern Chipmunk; 53 captures), and *Ochrotomys nuttalli* (Golden Mouse; 12 captures). The White-footed Mouse, because of its abundance during both seasons, was the primary species of analysis. White-footed Mice had a significantly higher probability of capture (1.29 times [or 29 percent]) in the prebaiting treatment than in the non-prebaited treatment. Prebaiting did not have a significantly different effect on males compared to females or on juveniles versus adult White-footed Mice. The practice of prebaiting, or luring small mammals, is discussed across levels of organization .

Introduction

Baiting is defined as a food, or some substitute, used to lure or entice animals for entrapment or to stop for food during a journey (*Webster's Unabridged Dictionary of the English Language* 2001). Baits are used as a lure in fishing, game management, and integrative pest management to increase harvest, rates of capture, or for pest control. Prebaiting is the early placement of food at a site of potential capture (e.g., live trap) or spread across an area (e.g., grain or food distributed across a field or forest) to lure or acclimate animals to this site or landscape patch to increase rate of capture or removal once live-trapping techniques are used. The practice of prebaiting live traps to increase the frequency of capturing small mammals by conditioning them to trap presence goes back well over 70 yrs. Prebaiting was described as a fruitful technique for increasing trapping efficiency, both for research (Moore 1936) and pest eradication (Chitty 1942). Prebaiting has also been used as a means to ensure equal probability of capture of new and marked individuals within a study population (Chitty and Kempson 1949), as a technique to increase rates of capture (Gentry et al. 1971), and to more accurately estimate population densities (Tanton 1969). Chitty and Kempson (1949) remarked that when a study demands a random catch of marked and unmarked animals on any one day, it is essential that prebaiting be used. They suggest that certain small mammals tend to avoid entering an unfamiliar object (e.g., a live trap); hence, an increased rate of capture is predicted if the traps have been prebaited. They observed higher capture success of *Microtus agrestis* L. (Field Vole) following

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prebaiting with oats. Moore (1936) also found that *Microtus pennsylvanicus* Ord (Meadow Vole) was more efficiently captured if traps were baited, then propped open for a day before being set for capture. The efficacy of prebaiting or luring small mammals to live traps, however, awaits critical analysis.

Several early studies focused on how prebaiting affected population estimates (Grodzinski et al. 1966, Tanaka and Kanamori 1969, Zejda and Holisova 1971). Earlier mark-recapture studies assumed that prebaiting would increase the rate of capture and provide a more robust estimate of population abundance. Grodzinski et al. (1966), however, found that prebaiting failed to homogenize removal rates between marked and unmarked individuals, a result that skews regression estimates. Further, Buchalczyk and Pucek (1968) found no evidence that prebaiting increased the rates of removal of *Microtus oeconomus* Pallas (Tundra Vole), though total captures were twice as high. Their finding was partially clarified by Zedja and Holisova (1971) who showed that prebaiting within a grid lures animals whose home ranges are not fully within the grid of study. Thus, prebaiting affects spatial distribution and can contribute to inflating density estimates.

The practice of luring small mammals to specifically established habitat sites has also been used for decades at the ecosystem and landscape levels to: (1) attract and poison, or remove, small mammals considered to be crop depredators or vectors of disease to humans (Chitty 1942), (2) insure that mark-recapture methods of estimating population densities are valid and accurate (Smith et al. 1975), and (3) increase frequency of capture (Gentry et al. 1971). The question remains unanswered, however, whether or not the prebaiting or luring practices are worthy of the time and resources necessary to continue this practice, or if prebaiting efficacy is species specific. To test these questions, we designed a replicated, seasonal (fall and spring) study to quantify the effects of prebaiting at the population and community levels. Though other species were frequently captured in prebaited traps, we selected *P. leucopus* Rafinesque (White-footed Mouse) as the primary focus of our analysis because of its abundance and frequency of capture. Specifically, we addressed questions, such as whether behavioral response of *P. leucopus* to prebaiting changes with season and whether prebaiting affects the probability of recapture of marked individuals.

Methods

Study area and research design

The study site was the HorseShoe Bend Ecological Research Site (HSB) located in Clarke County near Athens, GA (33º57'N, 83º23'W). HSB is located in a 14.2-ha riverine peninsula formed by a meander of the North Oconee River. Upland and bottomland deciduous forest characterize the peninsula. Though the bottomland is susceptible to flooding, no flooding occurred during our investigation. Both habitats are dominated by *Smilax* spp. (greenbrier), *Lonicera mackii* (Rupr.) Herder (Honeysuckle), *Ligustrum sinense* Lour. (Chinese Privet), *Quercus nigra* L. (Water Oak), and *Liquidambar styraciflua* L. (Sweet Gum). *Quercus alba* L. (White

Oak) and *Fagus grandifolia* Ehrh. (American Beech) are also abundant in the upland, whereas *Betula nigra* L. (River Birch) and *Liriodendron tulipifera* L. (Tulip Poplar) are common in the bottomland (Christopher and Barrett 2006, Klee et al. 2004).

We established five experimental grids in each of the bottomland and upland habitats. Each grid was approximately 0.21 ha, including a 10-m border around each grid, consisted of 12 trapping stations spaced approximately 10 m apart along two parallel transects of six stations each (see Christopher and Barrett [2006] for an aerial photograph of the research site including a design of trapping stations). Each station consisted of one Sherman live trap (7.6 x 7.6 x 25.4 cm; H.B. Sherman Traps, Tallahassee, FL) situated on a wooden platform 1.5 m high on the trunk of a tree. Thus, we used a total of 120 live traps for this study.

The possibility that newly-situated live traps might serve as novel stimuli, thus decreasing initial rates of capture of small mammals, can be eliminated (1) by using a continuous or daily trapping regime, including use of a population abundance estimator, such as the Schnabel method (Schnabel 1938), or (2) by maintaining live traps in the same place on a seasonal or yearly basis (Boonstra and Krebs 2006). To eliminate the foreign stimulus concern, we followed a research design that maintained Sherman live traps left in place on wooden platforms for six consecutive years (see Christopher and Barrett [2006] and Klee et al. [2004] for details regarding research design).

Live trapping was conducted weekly from 4 September–22 November 2005, and from 21 February–9 May 2006. We randomly selected one of the two transects within each grid to be prebaited. Prebaiting consisted of placing black oil sunflower seeds in open traps during a 24-hr prebaiting period; nonprebaited traps within each grid were left open, but not baited. At the end of the 24-hr prebaiting period, all traps were baited with black oil sunflower seeds, set overnight, and checked the following morning. Seeds from both prebaited and non-prebaited traps were removed from each trap when we checked for captured individuals. Date, location of capture, and species of small mammal livetrapped were recorded. Each captured individual was marked with a sequentially numbered ear tag (Scott Roestenburg, Neway Products, Murray, Utah) for identification. We determined sex, weight to the nearest gram, reproductive condition (open or closed vaginal orifice, abdominal or scrotal testes, pregnant, and/or lactating), and examined for general health of each captured animal. Captured individuals were released at the site of capture immediately following examination. Animals were handled in accordance with the guidelines provided by the American Society of Mammalogists (ASM Animal Care and Use Committee 1998) and approved by The University of Georgia Animal Care and Use Committee (AUP #A2007-10220).

Statistical methods

We considered as categorical measurements taken on each of 120 traps, half (60 traps) of which were prebaited and half (60 traps) not prebaited.

Measurements were taken weekly over 12 weeks during each of two seasons (Fall 2005 and Spring 2006). Each measurement corresponded to a trapping outcome that was categorical, with possible values: female, male, juvenile, or empty. The response can be treated as a multinomial random variable; we used a multinomial regression model as the basis of statistical analysis. A generalized logit model (Agresti 1990) was used in which the log odds (or logit) of a capture of a particular sex type (female, male, or juvenile) versus no capture (empty) was modeled as a linear function of explanatory variables including whether or not the trap was prebaited, the season, and time of capture within each season. The model involved three log odds specifications as follows:

$$\log\left(\frac{\pi_{Fijkl}}{\pi_{Eijkl}}\right) = \mu_{Fij} + \gamma_{Fj}\,\text{week}_k + \delta_{Fj}\,\text{week}_k^2$$

$$\log\left(\frac{\pi_{Mijkl}}{\pi_{Eijkl}}\right) = \mu_{Mij} + \gamma_{Mj}\,\text{week}_k + \delta_{Mj}\,\text{week}_k^2$$

$$\log\left(\frac{\pi_{Jijkl}}{\pi_{Eijkl}}\right) = \begin{cases} \mu_{J\bullet 1} & \text{if } j = 1 \text{ (fall)} \\ \mu_{Ji2} + \gamma_{J2}\,\text{week}_k + \delta_{J2}\,\text{week}_k^2 & \text{if } j = 2 \text{ (spring)} \end{cases} \qquad (1.1)$$

Here π_{Fijkl} represents the probability of capturing a female in the *l*th trap (l = 1…60), during the *k*th week (k = 1…12), during the *j*th season (j = 1,2, corresponding to Fall 2005 and Spring 2006, respectively), under the *i*th treatment (i = 1,2, corresponding to no prebaiting and prebaiting, respectively). Probabilities π_{Mijkl}, π_{Jijkl}, π_{Eijkl} of capturing, respectively, a male, juvenile, or no animal (E = empty trap) are defined similarly.

The three lines in model (1.1) represent sub-models for the log odds of a female capture versus no capture, male capture versus no capture, and juvenile capture versus no capture, respectively. The first two of these logits (for female and male capture odds) were each modeled in terms of a linear predictor involving constant terms (means on the log odds scale) for each treatment by seasons combination (the μ_{*ij} terms), and quadratic functions of time (γ_{*j} week$_k^2$ + δ_{*j} week$_k$) that differed across seasons. Because only one juvenile animal was captured in fall 2005, it was necessary to assume a much simpler constant log odds model for juvenile captures in season 1 (j = 1). In season 2 (spring 2006), the log odds of a juvenile capture were modeled similarly to those of females and males. Model parameters were allowed to differ across the three logits (F = female, M = male, and J = juvenile) subscripts to allow a comparison of the treatment effect of the odds of female capture to differ from the treatment effect of the odds of a male being captured. A quadratic effect of time was chosen based upon initial plots of capture, which indicated non-constant rates of capture over time. Note that week$_k$ in (1.1) has been centered in the *i*th treatment, *j*th season after averaging over each 12-week time period.

Model (1.1) allows tests to be conducted to detect treatment effects (i) for any particular animal type (female, male, or juvenile); (ii) for at least one of the three animal types; or (iii) for all animal types (aggregated). Season and time effects were similarly investigated.

We tested the following hypotheses:

A. There was no treatment (prebaiting) effect for any mouse type. This hypothesis states that the odds of capturing a female, male, or juvenile versus capturing no animal are equal between the two treatments for all three animal types.
B. Assuming that treatment effects were equal for all three mouse types, there was no effect on the overall capture rate of mice regardless of gender/maturity. This hypothesis states that the odds of captures across all three animal types are the same across treatments.
C. The treatment effect on the capture rate for females was no different than that for males. This hypothesis specifies that the odds of a female versus male capture are the same in the prebaiting condition as in the non-prebaiting condition.
D. During spring 2005, the treatment effect on the capture rate for juveniles was no different from that of adults. This hypothesis specifies that the odds of a juvenile capture versus adult capture are the same in the prebaiting condition as in the non-prebaiting condition.

In addition, to justify averaging across seasons and animal types when assessing treatment effects, we tested for a two-way interaction between treatment and season and a three-way interaction between treatment, season, and animal type.

Model (1.1) was fit using maximum likelihood estimation with the SAS procedure NLMIXED (Version 9.1 of the SAS System for Windows, Copyright © 2002–2003 by SAS Institute, Cary, NC). All hypotheses were tested using Wald test statistics, which have asymptotic Chi-square distributions (Agresti 1990, section 4.2.4). The goodness-of-fit of model (1.1) to these data were assessed via a deviance goodness-of-fit test (Agresti 1990, section 4.1.4) to insure the validity of inferences derived from the model.

Results

We captured four species of small mammals at least 10 times during this study: *Peromyscus leucopus* Rafinesque (White-footed Mouse; 543 captures), *Glaucomys volans* L. (Southern Flying Squirrel; 94 captures), *Tamias striatus* L. (Eastern Chipmunk; 53 captures), and *Ochrotomys nuttalli* Harlan (Golden Mouse; 12 captures). *P. leucopus* was selected for detailed analysis because of their abundance during both the fall and spring trapping sessions.

We conducted a deviance goodness-of-fit test to support the use of model (1.1) as the basis of inference. The resulting test statistic $\chi^2_{123} = 129.6$, $P = 0.32$ confirmed that there was no significant evidence for lack of fit. Test statistics for hypotheses A–D are summarized in Table 1. The three-way interaction between treatment, season, and animal type, the two-way interaction between treatment and season, and the two-way interaction between

Table 1. Primary hypotheses A-D showing odds ratio (ORs) estimates for significant effects. F = females, M = males, and J = juveniles.

	Hypothesis description	Test statistic	*P*-value	Odds ratio (95% confidence interval)	Interpretation
A	No prebaiting effect for any mouse type.	$\chi_3^2 = 7.92$	<0.05	F: 1.46 (0.90, 2.02); M: 1.35 (0.97, 1.73); J: 1.08 (0.80, 1.37)	Odds of capture are significantly higher under prebaiting treatment than control treatment for at least one mouse type (gender/maturity level).*
B	No treatment effect for all mouse types combined.	$\chi_1^2 = 6.92$	<0.01	1.29 (1.05, 1.53)	Odds of capture (all mice) are significantly higher in the prebaiting treatment than in the control condition.
C	No gender by treatment interaction.	$\chi_1^2 = 0.11$	0.74		Insufficient evidence to conclude that prebaiting has different effects on males than on females.
D	No juvenile/adult by treatment interaction in Spring, 2005.	$\chi_1^2 = 0.06$	0.81		Insufficient evidence to conclude that prebaiting has different effects on juveniles than on matures.

*Note that 95 percent confidence intervals on the odds ratios (ORs) are separate intervals for individual ORs, and are not based on a simultaneous confidence region for all three ORs. This explains why no intervals cover 1, but the result that at least one OR is different than 1 is significant at $P = 0.05$.

treatment and animal type were nonsignificant (χ^2_2 = 1.46, *P* = 0.48; χ^2_1 = 0.24, *P* = 0.62; χ^2_2 = 2.14, *P* = 0.34; respectively), justifying the inferences presented in Table 1.

Prebaiting resulted in significantly higher odds of capture for White-footed Mice than the nonprebaiting treatment. Because the treatment by mouse-type interaction was nonsignificant, the test and corresponding odds ratio (ORs) for all mice types combined provided the most appropriate summary of this result. White-footed Mice had odds of capture 1.29 times (or 29%) higher in the prebaiting treatment than in the control treatment. Prebaiting had no significantly different effect on males compared to females or on juveniles compared to mature animals. Our finding suggests that prebaiting does increase frequency of capture of the White-footed Mouse. Therefore, this practice may be viewed as an efficacious methodology for this species.

Discussion

Perhaps the main reason for prebaiting is to increase the initial probability of capture by conditioning animals to the trapping station. Prebaiting techniques have been practiced for decades to lure animals to a site or area for termination by poisoning (Chitty 1942), and to increase probability of capture (Gentry et al. 1971). There is a paucity of information, however, with which to evaluate this technique where prebaited and nonprebaited treatments are established in a replicated research design. There also exists the need to discuss how baiting and prebaiting practices relate to potential changes in abundance across levels of organization.

Procedures used when live-trapping small mammals vary with the length of the trapping regime. For example, some investigators prebait small mammal live traps for a 2-day (Getz et al. 2006, Suazo and DeLong 2007) or even a 1-week period of time (Boonstra and Krebs 2006). Some researchers place closed live traps on grids a minimum of 3 days before sampling to allow small mammals to acclimatize to their presence before trapping begins (e.g., Wiewel et al. 2007), whereas more typically, traps are set in a particular grid pattern, baited with peanut butter, oats, cracked corn, or sunflower seeds, then checked the following morning. Trapping is frequently conducted for 2–3 consecutive days (e.g., Christopher and Barrett 2006, Pauli et al. 2006).

Prebaiting procedures and acclimation practices are typically affiliated with mark-recapture estimates of small-mammal population abundance and related parameters (e.g., Hammond and Anthony 2006, Wiewel et al. 2007). Numerous factors may affect capture probabilities. These include social status, sex, age, patterns of activity, and location of traps in relation to centers of animal activity; quality of habitat; live traps previously occupied by other species (Boonstra et al. 1982, Hammond and Anthony 2006); or traps previously occupied by conspecifics, especially those of the opposite sex (Christopher and Barrett 2007, Drickamer 1984, Mazdzer et al. 1976).

Disadvantages of prebaiting include the probable attraction of animals on the edge of the sampling area resulting in inflated density estimates

(Zedja and Holisova 1971), including a disruption of the spatial and social organization of the small-mammal populations (Gentry et al. 1971). It is recommended to avoid prebaiting in studies investigating social organizaton based on live-trapping results, unless these data are needed for calculation of edge effect. Summerlin and Wolfe (1973), for example, have shown that older and higher social ranking *Sigmodon hispidus* Say and Ord (Hispid Cotton Rat) tend to be caught first and more frequently than younger, lower ranking individuals. Further, prebaiting adds additional food resources that may affect population dynamics. Additional time and monetary expenses are also associated with prebaiting. To date, the behavioral and economic effects of prebaiting on White-footed Mice have not been quantified.

We next provide a perspective on the effects of prebaiting and luring on small-mammal dynamics across levels of organization (population, community, ecosystem, and landscape).

Population level

In our study, we found significantly greater probability of capture of White-footed Mice in prebaited traps compared to those traps that were baited once a trapping regime was initiated. Prebaiting had no significant effect on males compared to females or on juveniles when compared to adults. We suggest that prebaiting is species specific at the population level and likely related to the type of bait used, quality of habitat, and season when prebaiting was used. For example, Grodzinski et al. (1966) suggest that food availability would influence trap response of small mammals. To test this hypothesis, Smith and Blessing (1969) demonstrated that food availability reduced the number of live trap captures of *Peromyscus polionotus* Wagner (Old-field Mouse) when wild birdseed was dispersed to one-half of an old-field community. We suggest that addition of grain, such as wild birdseed, is a form of prebaiting at the population level if the type of bait used is targeted at a particular species, such as Old-field Mice.

Community level

Although we focused on White-footed Mice in the current study based on a robust sample size (n = 543 captures), numerous other small mammals likely will be attracted to the baiting site, thus providing valuable information at the community level. For example, four species of small mammals (Old-field Mouse, Southern Flying Squirrel, Eastern Chipmunk, and Golden Mouse) were captured at least ten (10) times during our prebaiting/baiting comparative study.

Prebaiting may alter food availability, and should decrease movement of small mammals near the supplemental food, thus invalidating any comparisons of home-range size. It may also shift the focal point of species activity into the grid or site from the surrounding border zone. Thus, species or individuals responding to the site of prebaiting would appear to be part of the resident population (Zejda and Holisova 1971). This response to prebaiting would alter not only home-range size but, perhaps, small-mammal species interactions at the community level. These interactions, plus factors such as bait used, weather, and habitat quality must be taken into account when deciding to prebait traps or add bait to a particular community type.

Ecosystem level

Whereas, prebaiting and baiting studies involving small mammals traditionally have focused on specific species and feeding sites (e.g., live traps or feeding stations; Chitty and Kempson 1949, Grodzinski et al. 1966, Gurnell 1980), several approaches have focused on the ecosystem level, such as grain addition or food enrichment (Bendell 1959, Cole and Batzli 1978, Fordham 1971, Hansen and Batzli 1979). For example, supplemental food has been added to old-field and riparian ecosystems to quantify the population dynamics response of Old-field Mice (Smith and Blessing 1969), Meadow Vole (Desy and Thompson 1983), Hispid Cotton Rat (Doonan and Slade 1995), *Microtus ochrogaster* Wagner (Prairie Vole) (Slade et al. 1997), and *Zapus hudsonius* Zimmermann (Jumping Mouse) (Trainor et al. 2007). See reviews by Boutin (1990) and Adams (2001) regarding the response of small mammals to supplemental food resources.

Landscape level

Landscape ecology focuses on elements such as patches, corridors, and matrices. At the landscape scale, patches and corridors are frequently managed for conservation purposes. Plant communities, agroecosystems, and landscapes are frequently modified or structured by special plantings or corridors to lure or effect movement of select species of small mammals to and within these patch types (Danielson and Hubbard 2000, Mabry and Barrett 2002, Mabry et al. 2003). High-quality corridors are frequently used to lure or funnel small mammals to other patches of high-quality habitat (LaPolla and Barrett 1993, Mabry and Barrett 2002). Small mammals frequently benefit from this landscape conservation and management strategy (Mech and Hallett 2001, Wolff and Barrett 2008). However, there are exceptions to this strategy (e.g., Bowne et al. 1999, Haddad et al. 2003). Small mammals lured into, or making use of, landscape corridors frequently are preyed upon by an array of predators. For example, Barrett et al. (2001) documented five events of predation on the Hispid Cotton Rat by snakes and owls in an experimental landscape investigation at the Savannah River Site (SRS) in Aiken County, SC.

This luring/patch-quality management strategy has been practiced for well over 70 years. For example, Stoddard (1931) described feed patches, established to attract and provide grain-producing plant species for *Colinus virgianus* L. (Bobwhite Quail). Plant species, such as *Lespedeza striata* Thunb. (Japanese Clover), *Panicum ramosum* L. (Brown-top Millet), and *Panicum miliaceum* L. (German Millet) are planted as food for quail. These plant species are also excellent food sources for small mammals (Barrett 1968, Miller and Miller 1999). Stoddard (1931) describes how high-quality landscape patches are beneficial to hunters in locating coveys of quail, as well as in increasing population growth and survivorship of this game species. Interestingly small mammals, such as cotton rats, also benefit from this increased food source and vegetative cover. Consequently, population densities of cotton rats were frequently controlled on these established landscape patches by poisoned baits and prescribed burning (Stoddard 1931:428).

In summary, we suggest the practice of prebaiting or luring small mammals occurs across levels of organization and at differing temporal/spatial scales. Responses to prebaiting likely differ at increased temporal/spatial scales, responses are species specific depending on habitat quality and the nature of the bait or lure used, and effects on abundance or biodiversity differ depending on trophic-level dynamics (Haddad et al. 2003). Future investigations need to be designed at the ecosystem or landscape scales to better understand small-mammal population and community dynamics in an integrative manner when prebaiting is an experimental component of the research design. Currently, luring and prebaiting are recognized as management and conservation practices. Much as Seddon et al. (2007) describe the science of "reintroduction biology," we suggest there exists the need to develop the science of "luring biology" across levels of integration.

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