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IMPACT OF CAPTURE AND TRANSPORTATION METHODS ON SURVIVAL OF SMALL RODENTS DURING RELOCATION EVENTS

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Abstract—Capture and transportation of wild rodents is needed to supply study animals for laboratory or enclosure studies and for translocation of threatened and endangered species. Stress of captured rodents must be minimized to maximize survival. Methods to limit stress include minimizing capture and transportation durations, providing sufficiently sized housing with adequate nesting materials and foods, and ensuring that animals are maintained in comfortable environmental conditions. We utilized these techniques to capture and transport California voles (*Microtus californicus*) and pocket gophers (*Thomomys bottae*) from California to Colorado to determine their rate of survival during this process. We captured pocket gophers through live-trapping; burrow excavation substantially reduced capture and holding times for voles. All 50 voles and 88 of 91 pocket gophers were still alive and in good condition 2 weeks postarrival. The techniques and materials described should provide a useful framework for other wild rodents as well.

Resumen—Se necesitan la captura y el transporte de roedores silvestres para proveer animales para estudios del laboratorio o de encierros, y para la translocación de especies amenazadas y en peligro de extinción. El estrés en roedores capturados debe ser el mínimo para maximizar la sobrevivencia . Métodos para limitar el estrés incluyen minimizar la duración de tiempo en cautiverio asociado con la captura y el transporte, proporcionar jaulas de tamaño suficiente más alimentos y materiales adecuados para la anidación, y asegurar que los animales sean mantenidos en condiciones ambientales cómodas. Utilizamos estas técnicas para capturar y transportar meteoro de California (*Microtus californicus*) y tuzas (*Thomomys bottae*) de California a Colorado para determinar su tasa de sobrevivencia durante este proceso. Las tuzas se capturaron con trampas

de vida; la excavación de la madriguera redujo sustancialmente el tiempo de la captura y manipulaciones de meteoros. Todos los 50 meteoros y 88 de 91 tuzas llegaron vivos y en buen estado y siguieron así 2 semanas después. Las técnicas y los materiales descritos deben proporcionar información útil para otros roedores silvestres también.

Small rodents are often removed from the wild for use in a variety of studies ranging from behavioral investigations (e.g., Sterner, 2000) to studies assessing the efficacy of repellents (e.g., Sterner et al., 1999) and rodenticides (e.g., Witmer et al., 2010). Additionally, small rodents are sometimes captured and translocated to bolster small populations of threatened or endangered species (e.g., Gelling et al., 2010). Maximizing survival associated with these capture and subsequent transportation events is necessary to efficiently utilize limited resources while ensuring that animal welfare requirements are met. High survival rate is even more paramount for translocation of threatened or endangered species. For example, a recent attempt at bolstering endangered Amargosa vole (*Microtus californicus scirpensis*) populations was seriously affected by very high mortality rates that occurred during a translocation event (26 of 29 died; J. Foley, University of California, Davis, pers. comm.).

Survival of rodents during transportation events is directly influenced by stress levels associated with this event (Morgan and Tromborg, 2007; Gelling et al., 2010); minimizing stress should be a key concern when developing transportation protocols. One potential method to reduce stress levels of captured animals is to minimize the time spent in captivity and subsequent transportation. If populations of the target species are low in number, or if animals are unresponsive to traps, live-trapping efforts might be protracted out over several to many days to capture sufficient numbers. Subsequent longer holding times of housed animals could create chronic stress in the captive animals (Morgan and Tromborg, 2007). Therefore, if live-trapping cannot yield sufficient captures in the desired time frame, an alternative approach will be needed. A method involving the hand capture of voles through excavation of burrow systems could provide a viable alternative.

Other factors that might reduce stress of wild-caught captive rodents include larger housing, sufficient nesting material and foods, and comfortable environmental conditions. It seems logical that our ability to closely approximate nesting chambers would reduce stress and increase survival of captive animals. Likewise, appropriate nesting materials are required to imitate the natural nest of rodents (Hess et al., 2008). Dry grasses and alternative forages (e.g., timothy hay) are good natural options, but are not always available. Shredded paper strips (hereafter, crinkle paper) are high-quality alternatives and provide the means for proper nest construction in lab mice (Hess et al., 2008). Similar use for wild rodents could be equally effective.

The availability of highly preferred foods (e.g., fruits, seeds, succulent vegetation, etc.) and foods rodents normally consume should also help reduce stress by maximizing food intake. Because many rodents are able to obtain sufficient moisture from succulent foods (e.g., apples, carrots, potatoes, etc.), the use of these foods should address their water needs for short-term transportation events. Maintaining proper environmental conditions during housing and transportation is also important for reducing stress in small rodents (Gaskill et al., 2009), with extreme high or low temperatures resulting in direct mortality. Transportation in climate-controlled vehicles could alleviate this problem. Collectively, minimizing the time that rodents are in transit, providing sufficiently sized housing containers with proper nesting materials and foods, and maintaining proper environmental conditions during transportation should result in high survival rates of transported animals even if the distance required for transportation is great. To assess the collective impact of these factors, we captured and transported California voles (*M. californicus*) and Botta's pocket gophers (*Thomomys bottae*) from several locations in California to the National Wildlife Research Center in Fort Collins, Colorado, for use in separate laboratory studies.

We captured California voles in artichoke fields in the Castroville area, Monterey County, California, during 26–27 April 2012. Initial live-trapping efforts 2 weeks prior to capture and transportation dates indicated very low capture success (1 vole in approx. 2,000 trap-nights). As such, it was not practical to assume that we would be able to capture our target of 50 individuals using live-trapping. In a related study, we used farm laborers to capture voles by hand by excavating them out of tunnels with a shovel. The artichoke growers in this area use this technique to monitor reproductive output of the vole population. Farm laborers locate fresh vole burrows, dig into the burrows to look for voles, and back-track the tunnels until they find a vole or determine that a vole is not present. This approach allows for the rapid capture of a large number of voles. Therefore, we used this hand-capture approach to collect voles for transportation.

Once captured, we dusted voles with 0.25% Permethrin (Hi-Yield Garden, Pet & Livestock Dust, Voluntary Purchasing Groups, Inc., Bonham, Texas) to remove potential ectoparasites. We then placed voles into 33.0 × 19.0 × 10.8-cm clear plastic shoe boxes (The Container Store, Coppell, Texas) with 0.16-cm holes drilled every 2.5 cm along the top (2.5 cm from the top) of the container to provide ventilation. California vole nests are reported up to 25 cm in diameter (Stark, 1963), so we

expected this size to provide a good approximation for their nests while still providing a practical size for transport. We lined the containers with 5.0–7.5 cm of crinkle paper (FiberCore, LLC, Cleveland, Ohio) to serve as bedding. We added a handful of timothy hay to provide additional bedding and food. We also added 2–3 artichoke bracts, 2 apple slices, 2 mini carrots, and 2 tablespoons of All Living Things™ Mouse & Rat Daily Diet (Pacific Coast Distributing, Inc., Phoenix, Arizona) to serve as food and water sources for the voles during transport.

We captured pocket gophers in two separate locations. One site was located in a pasture on the Pala Indian Reservation in San Diego County, California. We trapped this site during 15–24 February 2014. The other site was located in a vineyard 8 km west of Santa Rosa, California. We trapped this site during 16–21 March 2014. For capture, we used Tomahawk Model 2000 Gopher Tunnel Traps (Tomahawk Live Trap Company, Tomahawk, Wisconsin). Traps were checked multiple times daily.

Upon capture, we dusted pocket gophers with 0.25% Permethrin to remove potential ectoparasites. We then placed pocket gophers into 29.8 × 19.7 × 20.3-cm clear plastic rectangular terrariums (HerpHaven®; Lee's Aquarium and Pet Products, San Marcos, California). We lined these containers with pet bedding (Carefresh®; Ferndale, Washington), and we provided a handful of crinkle paper (Carefresh®) to provide nesting material. We added a handful of timothy hay to provide additional bedding and food. For food, we provided three mini carrots, a small potato, and two apple slices when initially introducing pocket gophers to their terrarium. We provided additional carrots, potatoes, and apple slices as needed. The voles and pocket gophers were inspected by veterinary staff before cross-state travel to ensure health during travel.

We transported the voles from Castroville to Fort Collins on 27–28 April 2012. We transported pocket gophers in three separate events: 19–20 February 2014, 24–25 February 2014, and 21–22 March 2014. For transportation, we used a minivan with a folding back seat. The back seat was folded to create a large flat space in the back. We placed transportation containers on a thick tarp to reduce the potential of heat coming up from the floor and overheating the rodents during transportation.

Travel occurred during late winter and spring, and ambient temperatures were relatively mild at the time of transportation. Nonetheless, we maintained a constant air temperature of 20–22°C to reduce the potential for heat stress on the rodents. We checked voles and pocket gophers every 3–4 h to make sure they still looked healthy and had sufficient food. We made no overnight rest stops so as to reduce the timeframe that rodents were in transit.

After arrival in Fort Collins, we quarantined the rodents for a 2-week period. During this quarantine period, we housed rodents in individual plastic cages (voles: 28 × 18 × 14 cm; pocket gophers: 42 × 22 × 20 cm) with a wire mesh top. The maintenance diet consisted of LabDiet 5001 Rodent Diet (PMI Nutrition International, Inc., Brentwood, Missouri) and a daily apple slice (for voles) or piece of carrot (for pocket gophers). Each cage had a water bottle, a den tube, cotton balls as nesting material, and corncob bedding material (Harlan Laboratories, Inc., Madison, Wisconsin) on the floor of the cages. We also provided pocket gophers a wooden block for chewing. We again assessed survival at the end of the 2-week period. All capture, handling, and transportation protocols were consistent with guidelines provided by the American Society of Mammalogists for use of wild mammals for research and were approved by University of California-Davis (Protocol 15732) and U.S. Department of Agriculture/Animal and Plant Health Inspection Service/Wildlife Services-National Wildlife Research Center (Protocols QA-1941 and QA-2146) Institutional Animal Care and Use Committees.

Burrow excavation combined with hand capture of voles was quite efficient and effective for capturing large numbers of voles in a short period of time (50 voles captured in 14 h split between 2 days). Attempts at live-trapping voles in the 2 weeks prior to burrow excavation had been largely unsuccessful (1 capture in approx. 2,000 trap-nights). Reasons for low capture success are unclear but were likely influenced by low vole densities in the artichoke fields. Burrow excavation allowed us to actively pursue voles whenever burrow systems were located. This greatly increased our odds of success, while dramatically decreasing the time required to capture a sufficient number of voles.

In addition to short capture periods, we kept transportation times to a minimum (approx. 20 h). We observed no noticeable injuries or mortalities during the capture or transportation of voles, and all appeared to be healthy and in good condition upon arrival at the laboratory facility. After the 2-week quarantine period, all 50 voles were still alive and in good condition. By keeping capture and subsequent holding times to a minimum, we were able to reduce this potential stressor, which likely had a positive impact on the survival rates of transported voles. A similar impact was noted in deer mice (*Peromyscus maniculatus*), where mice that were housed for a shorter period of time (27 h) during transportation survived at a higher rate (100% survival) than those that experienced a longer transportation period (36 h, 83% survival; Haywssen, 1998). As such, efforts that minimize the duration of time that rodents are in transit likely have a positive impact on survival of the captive animals.

An added benefit of burrow excavation is that it can reduce the number of nontarget captures of many species

by focusing capture efforts only on the target species. This could be particularly beneficial when attempting to avoid disturbing threatened or endangered species or species that could transmit zoonotic diseases (e.g., deer mouse carrying Sin Nombre virus). As such, burrow excavation could be considered in other studies where capture of voles via standard live-trapping is overly difficult, when it is imperative that large numbers of voles be captured in short time-frames, or when reducing or elimination of nontarget captures is highly desirable.

Because we used live-trapping for pocket gopher capture, capture duration was necessarily longer than what we experienced with voles. At the Pala site, we trapped for 8 days (4 days for each travel period), resulting in 53 total captures. We transported 35 pocket gophers during the first transportation event; we transported 18 during the second trip. At the Santa Rosa site, we trapped for 5 days, resulting in 38 captures. Transit time for all three transportation events was approximately 20 h.

Similar to voles, all pocket gophers appeared to be in relatively good health upon arrival from the first two trips, although one individual from the third group died during transit. During the 2-week quarantine period, we observed two additional mortalities, both from the first transportation event. Collectively, we observed 97% ($SE = 2$) survival for all transportation events (first trip = 94%, second trip = 100%, third trip = 97%).

Not surprisingly, transportation of small rodents over long distances can result in high mortality rates given the added stress of a new environment combined with environmental conditions that might be more extreme than what they are accustomed to (Gelling et al., 2010). For example, a previous attempt to transport voles from California to Colorado resulted in the mortality of all captured voles (T. Primus, USDA-National Wildlife Research Center, pers. comm.). The exact cause of mortality for these voles was not determined, but likely stemmed from some combination of longer travel times (voles were live-trapped over several days and the transportation event was divided up into 2 days), smaller housing structures (housed in live traps for trip), less variety of food sources (only artichoke bracts were provided), and no climate control. Likewise, 8 of 48 deer mice died in a flight from the United States to England (Hayssen, 1998). In contrast, we observed 100% survival of voles and 97% survival of pocket gophers transported during this study, even after a 2-week quarantine period following arrival in the laboratory. This high rate of survival was replicated four times, indicating robust results from our transportation protocols.

That being said, we did house pocket gophers for up to 6 days in terrariums, given the greater time needed to live-trap sufficient numbers of pocket gophers for transportation. This increased holding time could be responsible for the mortality we observed in pocket gophers. However, given the larger size of pocket gophers, the stress resulting from increased holding time might have less impact on them than it does on smaller rodents such as voles. Holding time should be investigated further to determine its effect on survival.

Many past studies (e.g., Chitty, 1938; Hayssen, 1998) have used live traps to transport rodents, but small traps might not allow rodents to establish an appropriate nest structure, thereby increasing stress levels (Morgan and Tromborg, 2007). We readily observed large nests made from crinkle paper and timothy hay in all plastic boxes in our study. We also readily observed runways through the crinkle paper to food sources in vole boxes. Because we were not certain which food and water sources would be preferred by the captured rodents, we provided several options. Artichoke bracts provided voles with a food and water source they were familiar with; apples, carrots, timothy hay, and rodent chow provided additional food options. We provided pocket gophers with foods that were highly palatable to most rodents because we were not sure what food sources they would prefer. Although we did not attempt to measure the amount of each food consumed, the artichoke bracts and apple slices appeared to be consumed most frequently by voles, whereas pocket gophers seemed to strongly prefer carrots and timothy hay. Providing multiple food options is likely beneficial when preferred foods are unknown, but when known, foods that reflect a rodent's local diet (e.g., artichoke bracts for voles in this study) should be provided because these are the foods most likely to be accepted by the captured rodents.

Proper environmental conditions also factor into rodent survival. In our study, we housed voles and pocket gophers inside a temperature-controlled van for the duration of the transportation events. This allowed us to maintain relatively constant ambient temperatures that would be difficult or impossible to maintain if rodents were housed in an outside trailer or back of a truck. Much of the travel for this trip occurred at night, which lessened the risk of overheating. Additionally, we found the clear plastic boxes to be ideal for monitoring the health and activity of rodents, because we could check the status of the voles and pocket gophers without removing them from their boxes; if the rodents seemed stressed, we could alter temperatures and air flow to see whether this positively affected their appearance. It also allowed us to determine whether they were able to effectively utilize the nesting materials and allowed us to check the status of their food supply.

Our collective efforts to minimize holding time, to use sufficiently sized transportation containers that house abundant nesting materials and food resources, and to provide a safe range of environmental conditions during the transportation process appeared to positively affect survival rates of voles and pocket gophers and probably many other rodent species during long-distance transits. That being said, we did not specifically test the impact of

any of these potential stressors on survival of voles or pocket gophers during the capture and transportation event, so the impact of each individual stressor is unknown. A study that addressed each specific stressor would further our ability to successfully transport rodents long distances. However, at a minimum, the techniques and materials we have outlined should yield high survival rates when transporting voles and pocket gophers and should provide a useful framework for similar projects with other species.

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