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Angela M. Watland
Southern Illinois University Carbondale

Eric M. Schauber
Southern Illinois University Carbondale, schauber@siu.edu

Alan Woolf
Southern Illinois University Carbondale

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Translocation of swamp rabbits in southern Illinois

Angela M. Watland[1,2], Eric M. Schauber[1*], and Alan Woolf[1,3]

[1]Cooperative Wildlife Research Laboratory and Department of Zoology

Southern Illinois University, Carbondale, Illinois 62901

[2]Current address: The Nature Conservancy, 146 E. Main St. Abingdon, VA 24210; (276) 676-2209

awatland@tnc.org

[3]Deceased

[*]Corresponding Author: schauber@siu.edu; 618-453-6940

Abstract

Habitat of swamp rabbits in Illinois has been reduced and fragmented due to human land use. Translocation may enable swamp rabbits to colonize isolated habitat patches. We live-trapped and translocated 9 male and 8 female swamp rabbits to unoccupied habitat in southern Illinois in January and February 2004. Eight of 17 translocated rabbits died within 7 days after release. However, mortality rates appeared to drop rapidly over time after release. Predators killed at least 10 of 14 rabbits that died. For conserving swamp rabbits, translocation success is limited by poor live-trapping success and post-release predation. Intense live-trapping and predator control in release sites may be necessary to make translocation a viable management strategy.

Introduction

The swamp rabbit (*Sylvilagus aquaticus* Bachman) is a representative species of bottomland hardwood forests, occurring primarily in swamps, river bottoms, and lowland areas (Chapman and Feldhamer 1981). The swamp rabbit is a valued game species in portions of its range (Allen 1985), which extends from the Gulf coast of Mexico, in Alabama, Louisiana, and Mississippi, northward to include portions of Oklahoma, Tennessee, Kansas, Missouri, Illinois, and Indiana, and eastward from eastern Texas to western South Carolina (Hall and Kelson 1959, Chapman and Feldhamer 1981, Allen 1985). However, population declines and restricted distributions of swamp rabbits have been noted in Missouri (Korte and Fredrickson 1977), Kentucky (Sole 1994), Indiana (Mumford and Whitaker 1982), Arkansas (Sealander and Heidt 1990), and Illinois (Kjolhaug 1986).

Historical records indicate that swamp rabbits have occurred in riparian habitats throughout much of southern Illinois (Nelson 1909, Cockrum 1949, Layne 1958). However, swamp rabbits appear to have become less common in recent times, with a more restricted distribution than historical accounts indicated (Kjolhaug et al. 1987). Remaining swamp rabbit populations and their bottomland hardwood forest habitats are distributed patchily, clustered in the extreme southern portion of the state along the Cache, Mississippi, and Ohio rivers and along a few interior rivers and their tributaries (Kjolhaug et al. 1987, Woolf 1998, Barbour et al. 2001). Habitat loss and fragmentation of bottomland hardwood forests due to land use practices, like logging and conversion to agriculture, are most likely the principal causes of the restricted, patchy distribution of swamp rabbits in Illinois and other areas in the northern portion of their range.

Eighty percent of the historically forested acreage of the Mississippi alluvial floodplain has been cut for timber, converted to agriculture, or cleared for development. The 4.8 million ha of Mississippi alluvial bottomland hardwood wetlands that existed in 1937 had been reduced to 2.1 million ha by 1977 (Creasman et al. 1992). The remaining bottomland forests in Illinois are highly fragmented, having generally small patch sizes (Twedt and Loesch 1999), and typically lack dry upland areas for rabbits to move to during frequent flood events (Kjolhaug 1986). Loss and fragmentation of habitat result in reduced population sizes, which increase the probability of extinction by demographic and environmental stochasticity (Burkey 1995). The extensive habitat loss and fragmentation of bottomland hardwood forests, specifically in Illinois has most likely concentrated swamp rabbits in isolated habitat patches and subsequently increased vulnerability of populations to stochastic events, predators, and other dangers (Conaway et al. 1960, Toll et al. 1960, Korte and Fredrickson 1977). This decline in habitat and risk to populations causes concern among natural resource professionals about the status of swamp rabbits in Illinois (Barbour et al. 2001).

Because rabbits generally do not disperse long distances (Shields 1960, Chapman and Trethewey 1972, Richardson et al. 2002), translocation represents a potential approach to maintaining connectivity among remaining bottomland hardwood patches and allowing recolonization of suitable habitat from which swamp rabbits have become extinct. Several reintroductions of lagomorph species have occurred as part of recovery or restoration efforts (Calvete et al. 1997, U.S. Fish and Wildlife Service 1993, Hays 2001, Swanson 2002, Williams et al. 2002, Faulhaber 2003, Calvete and Estrada 2004, Letty et al. 2005). These reintroductions have enjoyed varying degrees of success. In some cases, as in reintroductions of Lower Keys marsh rabbits (*Sylvilagus palustris hefneri* Lazell) and riparian brush rabbits (*Sylvilagus bachmani riparius* Orr), survival in reintroduced populations has been similar to that of established populations (Faulhaber 2003, L. P. Hamilton pers. comm.). In contrast, Calvete et al. (1997) reintroduced European rabbits (*Oryctolagus cuniculus* Linnaeus) in Spain and observed 61% mortality during the first 10 days post-translocation. Letty et al. (2005) also observed high mortality (39% within first 10 days) of translocated European rabbits in France. However, both Calvete et al. (1997) and Letty et al. (2005) observed improved survival after an initial critical period after release had passed. Calvete and Estrada (2004) found that heavy cover and removal or exclusion of predators increased survival of translocated rabbits.

For swamp rabbits, predation is likely to be an important limitation on the success of translocated populations. Even in established populations, predation can be an important cause of mortality. Kjolhaug (1986) found that predation accounted for 83% of documented deaths in one swamp rabbit population. Predator species known to kill swamp rabbits include great horned owl (*Bubo virginianus* Gmelin), mink (*Mustela vison* Schreber), bobcat (*Lynx rufus* Schreber), and coyote (*Canis latrans* Say). Other documented predators of *Sylvilagus* species include feral cats (*Felis sylvestris* Linnaeus), domestic dogs (*Canis familiaris* Linnaeus), and several species of hawks and owls (Williams et al. 2002). Massengill and Smith (1989) monitored the fates of 10 swamp rabbits introduced to a wildlife management area in Tennessee, and 7 were killed by predators within 6 weeks after release.

The goals of this project were to assess the feasibility of translocation as a restoration strategy for swamp rabbits in southern Illinois, and offer recommendations for similar restoration projects. To do so, we identified suitable but unoccupied sites in southern Illinois where swamp rabbits could persist, habitats could be managed in the future, and landowner cooperation could be secured. After translocating swamp rabbits to the chosen site, we evaluated short-term success through post-release monitoring.

Study Site Description

Source areas

We captured swamp rabbits for translocation at Horseshoe Lake Conservation Area (HLCA), a state-owned natural area in Alexander County, on the southern tip of the state at the confluence of the Mississippi and Ohio Rivers. This site was previously trapped for swamp rabbits and is also the location of annual pellet count transects for swamp rabbit monitoring (Woolf and Barbour 2002). Land cover in Alexander County is characterized by 36.3% cropland, 8.1% grassland, 31.5% forest/woodland, 14.5% wetland, and 2% urban, with 7.5% open water (Luman et al. 1996). Dominant overstory vegetation included cypress (*Taxodium distichum* Rich)-tupelo (*Nyssa aquatica* Linnaeus) swamp with adjacent areas consisting of cottonwood and sycamore (*Platanus occidentalis* Linnaeus). Dominant understory species included willow, deciduous holly (*Ilex decidua* Walter), and herbaceous vegetation.

Release areas

Woolf and Barbour (2002) identified 111 patches, covering 55,591 ha, of suitable but unoccupied swamp rabbit habitat in their historical range in southern Illinois (Barbour et al. 2001). Among these 111 patches, we focused on 2 major watersheds, the Little Wabash and Wabash River watersheds, which were not currently occupied by swamp rabbits but contained large blocks of suitable habitat. Based on habitat patch area and quality, as well as landowner cooperation, we selected our primary release site along the Little Wabash River and north of county road 1250N in Wayne County (UTM coordinates 397280N, 4255096W) (Fig. 1). This 120-ha site had recently undergone timber stand improvement (selective logging) through cooperation with the Illinois Department of Natural Resources (IDNR) and, at the time of release, consisted of early-successional forest with thick piles of slash and occasional thickets of giant cane (*Arundinaria gigantea* Walter) along the river. Permanently flooded areas were patchily distributed throughout the site. No sign of swamp rabbits was found when bottomland hardwood patches in this area were searched in 1985 and 1995 (A. Woolf, unpublished data). Wayne County is located in the southeastern part of Illinois and consists of 457,696 acres. Land cover of Wayne County is characterized by 62.4% cropland, 22.4% grassland, 7.8% forest/woodland, 5.7% wetland, and 1.0% urban (Luman et al. 1996).

Methods

Trapping, handling, and translocation

Swamp rabbits were live-trapped from 9 January - 27 February 2004 at HLCA. Tomahawk collapsible live wire traps (26 cm x 9 cm x 9 cm) were concentrated in high-use areas, with □30 traps set in a given area. Traps were placed in brushy areas along runways, or near fresh tracks or fecal pellets. Traps were covered with burlap to provide greater security for rabbits and covered with brush where natural understory vegetation was lacking. Traps were baited with apple and checked daily in the early morning. Bait was replaced weekly, or as rotting apples were evident. When capture success was low, traps were relocated every 10-14 days. All nontarget species were immediately released unharmed and unmanipulated. Swamp rabbits are most active during cold temperatures (e.g., < 4.5ºC), whereas capture of nontarget species increases at higher temperatures. Therefore, the end of trapping in late February was dictated by rising temperatures.

Handling of captured animals followed Southern Illinois University Carbondale Animal Use Protocol 03-025. Captured swamp rabbits were weighed inside the trap to reduce handling time. Weight of individual swamp rabbits was measured using a spring scale to the nearest 0.10 kg. Rabbits were removed from traps, placed in capture bags, blindfolded, and held tightly against the handler's body to avoid injuries to rabbits due to struggling. We determined the sex of each rabbit according to the criteria of Dimmick and Pelton (1996). Each rabbit was marked with a tag in each ear, and a tissue sample was taken with an ear punch from one ear. Captured rabbits were then fitted with radio transmitters with mortality sensors for monitoring survival and movements. After being processed, rabbits were placed in large wooden box traps for transportation. Box traps were lined with a thick bed of grass and openings were covered with burlap to ensure that the rabbits remained as calm as possible during transport.

For many species, temporarily holding translocated animals in captivity to allow the animals to gain familiarity with and reduce dispersal away from the release site (i.e., soft release) has increased initial survival relative to animals that were released immediately (i.e., hard release; Scott and Carpenter 1987). However, the benefits of soft release appear to be ambiguous for translocated lagomorphs. Survival of translocated Lower Florida Keys marsh rabbits was relatively high, despite hard release (Faulhaber 2003). Calvete et al. (1997) found that a soft release increased survival of translocated European rabbits by 40%, but this improvement resulted from identification and removal of diseased rabbits prior to release rather than improved survival of healthy animals after release. Also, Letty et al. (2000) found that soft release provided only a small and very temporary (1-day) improvement in survival of translocated European rabbits. Finally, we did not know whether the stress of holding swamp rabbits in captivity would lead to increased mortality. Therefore, we elected to use hard release, and released swamp rabbits at the release site within 24 hrs of capture. We specifically chose a release site in an area of dense cover without abundant predator sign, to reduce vulnerability to predators.

Survival monitoring

We monitored swamp rabbit mortality via daylight radiotelemetry. Survival of each collared rabbit was checked at least every other day for the 2-3 week critical period after release (Calvete et al. 1997), with daily checks when maximum temperatures were 4.5º C until 27 February, to avoid accelerated carcass decomposition. After 27 February, monitoring was reduced to once per week, and continued weekly until 31 April 2004. Biweekly monitoring began in May, and continued until 15 June 2004. When a mortality signal was detected and the collar was located, the mortality site and carcasses were photographed and field evidence (presence of tracks, fur, burial mounds, etc.) was noted. Carcasses were then transported in a cooler and necropsied to determine causes of mortality.

Results

Trapping

Eighteen swamp rabbits (9 M, 8 F, 1 escaped) were captured at HLCA in 2,067 trap nights, with one rabbit that was captured twice (1 capture per 115 trap-nights). The recaptured rabbit was a male that was tagged and released at the trap location when first captured, to avoid translocating a highly skewed sex ratio at that time. However, he was translocated upon recapture at a later date. Therefore, 9 male and 8 female swamp rabbits were collared and translocated to the release site. The mean weight of captured swamp rabbits was 1.92 kg. Thirty-five nontarget animals were also captured, consisting of 27 raccoons (*Procyon lotor* Linnaeus), 7 opossums (*Didelphis virginiana* Kerr), and 1 gray squirrel (*Sciurus carolinensis* Gmelin).

Post-release monitoring

Rabbits were translocated and released between 14 January and 15 February 2004. Of the 17 swamp rabbits translocated, 14 died by 12 March 2004 and the remaining 3 were alive as of 15 June 2004, when monitoring was discontinued (Table 1). Eight out of 17 (47%) died within 7 days after release. A plot of the log-transformed number surviving versus time since release was decelerating, showing a decline in daily mortality rates as time passed since release (Fig. 2). Ten swamp rabbits were killed by predators. Based on the presence of tracks, scat, fur, burial mounds, and the condition of carcasses, six rabbits appeared to have been killed by mammalian predators, including *C. latrans*, *C. familiaris*, and *L. rufus*. Three rabbits appeared to have been killed by avian predators, based on a lack of other sign and condition of carcasses. One swamp rabbit was confirmed by a landowner to have been killed by a domestic dog. Another rabbit was found dead with the collar lodged inside the mouth. Three rabbits were killed by unknown causes. Carcasses that were retrieved were often in several pieces, or missing body parts. In general, rabbit carcasses had food in their stomachs and showed no signs of myopathy. However, only one rabbit carcass had substantial fat around the kidneys. Of the two intact rabbit carcasses we retrieved, carcasses mass was ca. 12% less than their mass at capture (1.5 kg carcass vs. 1.7 kg at capture; 1.75 kg carcass vs. 2.0 kg at capture).

Discussion

Swamp rabbit habitat in southern Illinois is highly fragmented, and there are large areas of potentially suitable habitat that are currently unoccupied by swamp rabbits. Therefore, translocation may provide a means to increase connectivity among existing populations and promote colonization of uninhabited patches. However, our results raise some concerns about the potential for using translocation as a restoration strategy for swamp rabbits in southern Illinois. The two main issues we encountered were difficulty of capturing large numbers of swamp rabbits to translocate and high levels of predation on newly translocated rabbits.

Capture success

Although several studies have presented methods for capturing swamp rabbits, few have reported high capture success, and even fewer present handling methods. Although some studies report catching swamp rabbits in nets, by hand, or with dogs (Conaway et al. 1960, Massengill and Smith 1989), most researchers have used variations of wooden or wire box traps (Lowe 1958, Toll et al. 1960, Martinson et al. 1961, Terrel 1972, Kjolhaug and Woolf 1988, Massengill and Smith 1989, Woolf and Barbour 2002). In previous studies, capture success has been limited, even in sites with high abundance (Woolf and Barbour 2002). In general, trapping for swamp rabbits in southern Illinois has only had high success rate during the coldest months, January-February (Kjolhaug 1986, Kjolhaug and Woolf 1988, Woolf and Barbour 2002). Kjolhaug (1986) captured a swamp rabbit in November 1984, but Woolf and Barbour (2002) were unsuccessful trapping in November-December and after 10 March. The highest capture success in southern Illinois reported previously was on Bumgard Island from 20 January-7 February 2000, when 13 rabbits were captured in 471 trap-nights (1/36 trap-nights) (Woolf and Barbour 2002). We had similar results, with the greatest capture success occurring from 14 January-28 February 2004, when 11 were captured at HLCA in 344 trap-nights (1/31 trap-nights). Thus, there is a narrow mid-winter window for high success rates in live-trapping for swamp rabbits in southern Illinois. We were limited by the availability of traps (n = 60) and personnel (n = 3). A higher level of trapping effort during this success window would likely have increased the number of rabbits we could translocate. Failure of mammal reintroductions decreased from 42% to 12% when initial populations were supplemented by additional releases (Fischer and Lindenmayer 2000).

High initial mortality

Translocated rabbits experienced initial high mortality rates in our study, with 8 out of 17 (47%) dying within 7 days after release. Some other studies of translocated lagomorphs have also documented high initial mortality rates (Calvete et al. 1997, Calvete and Estrada 2004, Letty et al. 2005) but others have not (Faulhaber 2003, L. P. Hamilton pers. comm.). Two main hypotheses to explain these results are capture-related harm to the animals and high vulnerability to predators in novel environments. Our trapping methods were designed to minimize stress and injury to the animals, and field evidence suggests that capture-related factors were probably not major mortality causes. We found that most swamp rabbits were relatively calm and easy to handle, and blindfolding captured rabbits significantly reduced struggling. Capture myopathy was not evident in any of the necropsies. With the exception of the single collar-related death, no deaths occurred as a direct result of being trapped, handled, or transported. Upon finding the rabbit carcass with the collar lodged in its mouth, we revised our protocol to ensure that subsequently deployed radio collars were not too loose. Poor condition prior to release may also contribute to low survival (Swanson 2002). Subcutaneous fat was lacking in several rabbit carcasses necropsied just a short time following release, and the rabbits appeared to lose mass after release. This could suggest that rabbits were in poor condition initially or had trouble finding food after release. However, the stomachs of all necropsied rabbits contained food, so they were finding food in the new environment.

Predation was the most important cause of swamp rabbit mortality in our study, with 10 of 14 (71.4%) deaths of translocated rabbits due to predation. Other studies have documented high mortality in reintroduced lagomorphs caused by predators (Massengill and Smith 1989, Swanson 2002). Predation is a major cause of mortality in studies of natural populations, as well. In Kjolhaug's (1986) study, predation accounted for 15 of 18 (83%) documented deaths. Of 19 swamp rabbits monitored in 2000, 15 suffered predation (Woolf and Barbour 2002).

Improvements in release design and increased management efforts may increase the effectiveness of translocations (Fischer and Lindenmayer 2000, Griffith et al. 1989, Wolf et al. 1996). For example, Calvete and Estrada (2004) found that dense cover, culling predators, and electric fencing to exclude predators increased the survival of translocated European rabbits. We intentionally released swamp rabbits in dense cover, but did not actively manage predators. Predator abundance in intended release sites should be studied, and control options considered. Predator control methods could be used in areas that experience high losses due to locally intense predation (Swanson 2002). Removing the major source of mortality in animal reintroductions can increase success (Fischer and Lindenmayer 2000). However, these methods are often resource-intensive and controversial. Efforts may be better focused on ensuring the presence of adequate understory cover, because this is probably most critical for translocated lagomorphs where predation rates are high (Swanson 2002). In addition, the choice of a hard vs. soft release may affect the success of translocation. We employed a hard release approach, which involves simply releasing the animal into its new environment as opposed to a soft release, which involves keeping the animal captive in the new environment for a period of adjustment (Scott and Carpenter 1987). However, Letty et al. (2000, 2005) found high initial mortality among translocated European rabbits, despite soft release techniques. Calvete and Estrada (2004) found that predator control had a much larger effect on survival of translocated European rabbits than the choice of hard versus soft release.

In the long term, persistence of swamp rabbits in Illinois will likely benefit more from efforts to increase the area and connectivity of habitat patches than from active translocation. Although viable swamp rabbit populations exist on public lands, restoration of populations or habitat will require cooperation of private landowners. At the time of this study, there were >128,000 ha of bottomland hardwood forests remaining on private lands in Illinois (Watland, unpubl. data). Currently, the largest contiguous blocks of habitat are concentrated along the watersheds of the Big Muddy and Kaskaskia rivers. However, managing or creating disturbance to allow early successional growth may be necessary if swamp rabbits are to recolonize to these areas. High-quality habitat for swamp rabbits consists of early-successional bottomland hardwood forest and canebrakes within 2 km of permanent water with adjacent upland refugia where the rabbits retreat during floods (Conaway et al. 1960, Terrel 1972, Korte 1975, Allen 1985, Kjolhaug 1986, Zollner et al. 2000). Schmidt et al. (2000) report that the area of sapling-seedling-size stands in Illinois has decreased since 1985, while the percentage of Illinois timberland consisting of saw-timber size trees increased from 64% in 1985 to 72% in 1998, indicating a lack of significant disturbance through natural occurrences or timber harvest (Schmidt et al. 2000). Therefore, public-private partnerships promoting afforestation of marginal agricultural land and active timber management are likely to have the greatest benefit for swamp rabbits in Illinois.

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Literature Cited

Allen, A.W. 1985. Habitat suitability index models: swamp rabbit. U.S. Fish and Wildlife Service Biological Report 82:1-20.

Barbour, M.S., A. Woolf, and J.W. Porath. 2001. Recent trends and future outlook for the swamp rabbit (*Sylvilagus aquaticus*) in Illinois. Transactions of the Illinois State Academy of Science. 94:151-160.

Burkey, T.V. 1995. Extinction rates in archipelagos: implications for populations in fragmented habitats. Conservation Biology 9:527-541.

Calvete, C., R. Villafuerte, J. Lucientes, and J.J. Osacar. 1997. Effectiveness of traditional wild rabbit restocking in Spain. Journal of Zoology, London 241:271-277.

Calvete, C., and R. Estrada. 2004. Short-term survival and dispersal of translocated European wild rabbits: improving the release protocol. Biological Conservation 120:507-516.

Chapman, J.A. and G. Feldhamer. 1981. *Sylvilagus aquaticus*. Mammalian Species 151:1-4.

Chapman, J.A., and D.E.C. Trethewey. 1972. Movements within a population of introduced eastern cottontail rabbits. Journal of Wildlife Management 36: 155-158.

Cockrum, E.L. 1949. Range extension of the swamp rabbit in Illinois. Journal of Wildlife Management 30:427-429.

Conaway C.H., T.S. Baskett, and J.E. Toll. 1960. Embryo resorption in the swamp rabbit. Journal of Wildlife Management 24:197-202.

Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. Report FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, D.C. 131 pp.

Creasman, L.N., J. Craig, and M. Swan. 1992. The Forested Wetlands of the Mississippi River: An Ecosystem in Crisis. The Louisiana Nature Conservancy, Baton Rouge, LA. 24 pp.

Dimmick, R.W., and M.R. Pelton. 1996. Criteria of sex and age. Pp. 169-214 *In* T. A. Bookhout (Ed.). Research and Management Techniques for Wildlife and Habitats. Fifth ed., Revised. The Wildlife Society, Bethesda, MD. 740 pp.

Faulhaber, C. 2003. Updated Distribution and Reintroduction of the Lower Keys Marsh Rabbit. M.S. Thesis, Texas A& M University, College Station, TX. 239 pp.

Fischer, J., and D.B. Lindenmayer. 2000. An assessment of published results of animal relocations. Biological Conservation 96:1-11.

Griffith, B., J.M. Scott, J.W. Carpenter, and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Hall, E.R., and K.R. Kelson. 1959. The Mammals of North America. Ronald Press, New York, NY. 1083 pp.

Hays, D.W. 2001. Washington State Recovery Plan for the Pygmy Rabbit. Addendum: Washington Pygmy Rabbit Emergency Action Plan for Species Survival. Washington Department of Fish and Wildlife, Olympia, WA. 24 pp.

Kjolhaug, M.S. 1986. Status, Distribution, and Factors Determining Habitat Quality of the Swamp Rabbit in Illinois. M.S. Thesis. Southern Illinois University, Carbondale, IL. 110 pp.

Kjolhaug, M.S., and A. Woolf. 1988. Home range of the swamp rabbit in southern Illinois. Journal of Mammalogy 69:194-197.

Kjolhaug, M.S., A. Woolf, and W.D. Klimstra. 1987. Current status and distribution of swamp rabbits in Illinois. Transactions of the Illinois Academy of Science 80:299-308.

Korte, P.A. 1975. Distribution and Habitat Requirements of the Swamp Rabbit in Missouri. M.S. Thesis, University of Missouri, Columbia, Missouri, USA. 127 pp.

Korte, P.A., and L.H. Fredrickson. 1977. Swamp rabbit distribution in Missouri. Transactions of the Missouri Academy of Science 10:72-77.

Layne, J.N. 1958. Notes on the mammals of southern Illinois. American Midland Naturalist 60:219-254.

Letty, J., S. Marchandeau, J. Clobert, and J. Aubineau. 2000. Improving translocation success: an experimental study of anti-stress treatment and release method for wild rabbits. Animal Conservation 3:211-219.

Letty, J., J. Aubineau, and S. Marchandeau. 2005. Effect of storage conditions on dispersal and short-term survival of translocated wild rabbits *Oryctolagus cuniculus*. Wildlife Biology 11:249-255.

Lowe, C.E. 1958. Ecology of the swamp rabbit in Georgia. Journal of Mammalogy 39: 116-127.

Luman, P., M. Joselyn, and L. Saloway. 1996. Critical Trends Assessment Project: Land Cover Databases. Illinois Natural History Survey, Champaign, IL. 149 pp.

Martinson, R.K., J.W. Holten, and G.K. Brakhage. 1961. Age criteria and population dynamics of the swamp rabbit in Missouri. Journal of Wildlife Management 25:271-281.

Massengill, D., and W.P. Smith. 1989. Introduction of swamp rabbits to Cordell Hull Wildlife Management Area: a status report. Journal of Tennessee Academy of Science 64:54.

Mumford, R.E., and J.O. Whitaker. 1982. Mammals of Indiana. Indiana University Press, Bloomington, IN. 537 pp.

Nelson, E.W. 1909. The Rabbits of North America. North American Fauna No. 29. U.S. Fish and Wildlife Service, Washington, D.C. 314 pp.

Richardson, B.J., R.A. Hayes, S.H. Wheeler, and M.R. Yardin. 2002. Social structures, genetic structures and dispersal strategies in Australian rabbit (*Oryctolagus cuniculus*) populations. Behavioral Ecology and Sociobiology 51:113-121.

Schmidt, T.L., M.H. Hansen, and J.A. Solomakos. 2000. Illinois' Forests in 1998. Resource Bulletin NC-198. U.S. Department of Agriculture, St. Paul, MN. 140 pp.

Scott, J.M., and J.W. Carpenter. 1987. Release of captive-reared or translocated endangered birds: what do we need to know? Auk 104**:** 544–545.

Sealander, J.A., and G.A. Heidt. 1990. Arkansas Mammals: Their Natural History, Classification, and Distribution. University of Arkansas Press, Fayetteville, AR. 308 pp.

Shields, P.W. 1960. Movement patterns of brush rabbits in northwestern California. Journal of Wildlife Management 24: 381-386.

Sole, J.D. 1994. Assessing swamp rabbit distribution in Kentucky. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 48: 145-151.

Swanson, K.A. 2002. Movements, Survival, and Habitat Relationships of Snowshoe Hares Following Release in Northeast Ohio. M.S. Thesis. Ohio State University, Columbus, OH. 103 pp.

Terrel, T.L. 1972. The swamp rabbit (*Sylvilagus aquaticus*) in Indiana. American Midland Naturalist 87:283-295.

Toll, J.E., T.S. Baskett, and C.H. Conaway. 1960. Home range, reproduction, and foods of the swamp rabbit in Missouri. American Midland Naturalist 63:398-412.

Twedt, D.J., and C.R. Loesch. 1999. Forest area and distribution in the Mississippi alluvial valley: implications for breeding bird conservation. Journal of Biogeography 26:1215-1224.

U.S. Fish and Wildlife Service (USFWS). 1993. Recovery Plan for the Lower Keys Marsh Rabbit (*Sylvilagus palustris hefneri*). U.S. Fish and Wildlife Service, Atlanta, GA. 15 pp.

Williams, D.F., P.A. Kelly, and L.P. Hamilton. 2002. Controlled Propagation and Reintroduction Plan for the Riparian Brush Rabbit (*Sylvilagus bachmani riparius*). California State University, Stanislaus, Turlock, CA. 94 pp.

Wolf, C.M., B. Griffith, C. Reed, and S.A. Temple. 1996. Avian and mammalian translocations: update and reanalysis of 1987 survey data. Conservation Biology 10:1142-1154.

Woolf, A. 1998. Illinois Swamp Rabbit Study. Final Report, Illinois Federal Aid Project W-127-R-3. 61 pp.

Woolf, A., and M.S. Barbour. 2002. Population Dynamics and Status of the Swamp Rabbit in Illinois. Final Report, Illinois Federal Aid Project W-106-R-12. 110 pp.

Zollner, P.A., W.P. Smith, and L.A. Brennan. 2000. Home range use by swamp rabbits (*Sylvilagus aquaticus*) in a frequently inundated bottomland forest. American Midland Naturalist 143:64-69.

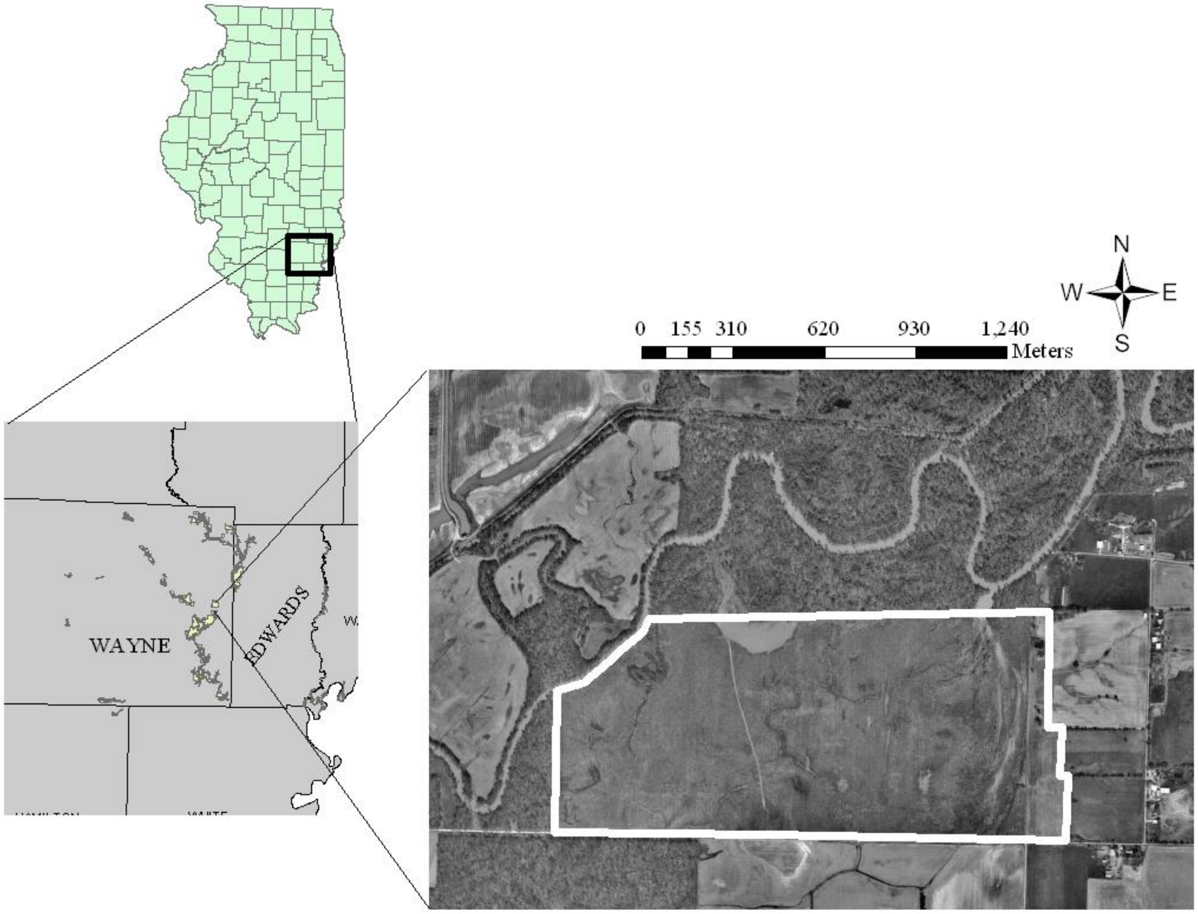
Table 1. Characteristics and fates of swamp rabbits translocated from Horseshoe Lake Conservation Area to a release site in Wayne County, Illinois, 2004.

ID	Sex	Mass at capture (kg)	Capture date	Mortality date	Mortality cause
01	M	2.0	14 January	14 February	Predation -- likely mammalian
02	M	1.9	14 January	30 January	Predation -- likely mammalian
03	F	2.2	16 January	7 February	Collar lodged in mouth
04	F	1.6	16 January	---[a]	---
05	M	1.9	16 January	23 January	Unknown
06	M	1.9	19 January	1 February	Predation -- likely mammalian
07	M	2.1	19 January	---	---
08	F	2.0	19 January	23 January	Domestic dog
09	M	1.7	19 January	26 January	Unknown
10	F	2.0	26 January	1 February	Predation -- likely avian
11	M	2.1	28 January	1 February	Predation -- likely avian
12	M	1.9	8 February	11 February	Predation -- likely avian
13	F	2.2	9 February	11 February	Predation -- likely mammalian
14	F	1.9	12 February	---	---
15	F	1.6	12 February	18 February	Predation -- likely mammalian
16	M	1.9	13 February	24 February	Unknown
17	F	1.8	14 February	12 March	Predation -- likely mammalian

[a]Alive as of 15 June, 2004.

Figure 1. Release site (outlined in white) of 2004 swamp rabbit translocation in Wayne County, Illinois. In inset highlighting Wayne county, polygons depict bottomland hardwood forest.

Figure 2. (A) Number alive (N_t; logarithmic scale) and (B) instantaneous daily mortality rate (m_t) of swamp rabbits translocated to Wayne County, Illinois, 2004, at varying days after release (t). Instantaneous mortality rates were calculated as: $\ln(N_t/N_{t+\Delta t})/\Delta t$. In each panel, the dashed line represents the expected number alive or daily mortality rate given the following relationship, fitted by maximum likelihood: $m_t = 0.090e^{-0.054t}$.


N
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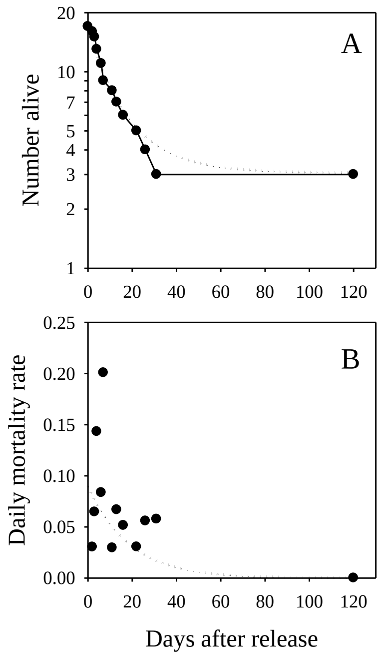
20
A
10
7
5
4
3
2
1
Number alive
0 20 40 60 80 100 120
0.25
B
0.20
0.15
0.10
0.05
0.00
Daily mortality rate
0 20 40 60 80 100 120
Days after release