6-2002

COOPERATIVE UPLAND WILDLIFE RESEARCH AND SURVEYS

Alan Woolf
Southern Illinois University Carbondale

Michael S. Barbour
Southern Illinois University Carbondale

W-106-R-12 Volume 2

COOPERATIVE UPLAND WILDLIFE RESEARCH AND SURVEYS

FINAL REPORT

VOLUME 2 OF 2

Federal Aid Project W-106-R-12

Submitted by:

Cooperative Wildlife Research Laboratory, SIUC

Presented to:

Division of Wildlife Resources
Illinois Department of Natural Resources

Principal Investigators

Alan Woolf

Graduate Research Assistants/Staff

Michael S. Barbour
(Graduate Research Assistant/Researcher II)

June 2002

TABLE OF CONTENTS

VOLUME 2 of 2

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

COOPERATIVE WILDLIFE RESEARCH LABORATORY
FINAL REPORT - VOLUME 2

STATE OF ILLINOIS
W-106-R (10-12)
Project Period: 1 July 1999 through 30 June 2001
Project: Cooperative Upland Wildlife Research and Surveys (Phase IV)

Prepared by Alan Woolf and Michael Barbour
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale

STUDY R-2. POPULATION DYNAMICS AND STATUS OF THE SWAMP RABBIT IN ILLINOIS

Executive Summary

In this Volume 2 of 2 volumes, we report the findings of Study R-2 (Population Dynamics and Status of the Swamp Rabbit in Illinois). Following is a summary of findings of the 3 main jobs in Study R-2.

Job R-2.1: Evaluate/Refine Population Monitoring System.—The objective of this job was to evaluate and refine the swamp rabbit population data collection and monitoring system previously developed. We evaluated effectiveness of a monitoring system that used 8 sites with 2-3 sites representing each of 3 categories of swamp rabbit distribution. Transects were replicated in 2000 and 2001 to evaluate observer effects and variance of indices of relative abundance. Sites recommended for monitoring are documented with text and maps to depict location, transect directions, and site limitations. We recommend that pellet group surveys be run each year on the recommended sites between 1 January and 28 February. If possible, data should be collected on all sites within a 2-week interval during this time. If the site has been extensively flooded within 2 months prior to data collection, transects should not be run that year, or at least not compared to other years. If snow cover is present, transects should not be run until the snow has cleared. Data should be collected by teams of 2 observers, 1 maintaining the transect bearing and distance and the other searching for pellet logs. Transects should be replicated twice, with a third replication if a large difference exists between the 2 runs.

Job R-2.2: Population Ecology.—This job was designed to determine population parameters and trends of swamp rabbits in Illinois. Although we had reliable data on current swamp rabbit status and distribution in Illinois, we lacked fundamental knowledge of the population ecology and demographics to assess viability and develop an effective population and habitat management plan. Therefore, we investigated swamp rabbit population parameters (survival, home range, and movement patterns) to contribute to development of a management model for the species in Illinois. Male and female home ranges were similar and did not differ by season. The rabbits tended to be sedentary, moving short distances and staying within a localized area of suitable habitat. Survival did not differ between season, and daily survival rates were similar but slightly higher than those previously reported. However, we determined survival rates during a relatively mild and snow free winter.

Job R-2.3: Management Model.—The objective of this job was to develop and evaluate alternative management strategies for swamp rabbits occupying wetland and riparian habitats in Illinois. To accomplish this, we identified potential habitat in 23 southern Illinois counties and then created a spatially explicit, stage-structured, stochastic model linked to the habitat we defined. We initially identified 142 sites of potential habitat, but when small sites (<5 ha) >2 km from large sites were eliminated, our best estimate of potential habitat was ~55,600 ha in 111 sites. Habitat was clustered in extreme southern Illinois along the Cache, Mississippi, and Ohio rivers, and a few interior rivers and their tributaries. Due to the patchy distribution of habitat, swamp rabbit populations remain vulnerable to habitat loss and stochastic events that can cause local extirpation.

Management options are identified, and we recommend that integrating both public and private lands into a partnership-based management plan is a preferred course of action. Further, we recommend that riparian zone habitat improvement be used as a tool to improve connectivity between isolated patches. This could be encouraged on private lands with existing conservation stewardship and incentive programs and easements. This management action should provide additional benefits of watershed and water quality improvement. Finally, the state-wide status of swamp rabbit populations should be re-examined every 10-15 years to maintain knowledge of their status because populations are subject to change. The survey should include a re-evaluation of potential habitat available.

STUDY R-2. POPULATION DYNAMICS AND STATUS OF THE SWAMP RABBIT IN ILLINOIS

Problem: Remaining bottomland forest habitats in Illinois are largely fragmented and the existing swamp rabbit (*Sylvilagus aquaticus*) population exists as a metapopulation. Not all suitable habitat patches are occupied and whether or not those that are support "source" or "sink" populations is unknown. Although we have reliable data on current status and distribution, we lack a proven method to monitor the population, and also lack fundamental knowledge of population demographics and ecology to assess viability and develop an effective population and habitat conservation plan.

Objectives:

1. Evaluate and refine the systematic swamp rabbit population and habitat data collection and monitoring system previously developed.
2. Determine population parameters and trends of swamp rabbits in Illinois.
3. Develop and evaluate alternative management strategies for swamp rabbits occupying wetland and riparian habitats in Illinois.

JOB R-2.1: EVALUATE/REFINE POPULATION MONITORING SYSTEM

Objective: Evaluate and refine the swamp rabbit population data collection and monitoring system previously developed.

Although the swamp rabbit is a valued game species in portions of its range (Mullin 1979, DeMaso 1994), it is a species of growing conservation concern, particularly along the northern periphery of its range. This concern is due to the decline in swamp rabbit distribution and abundance associated with the loss and fragmentation of forested wetlands with which swamp rabbits are associated (Terrel 1972,Whitaker and Abrell 1986, Dailey et al. 1993). Many bottomland hardwood areas have been cleared for development or converted to agriculture or other land uses (Ernst and Brown 1989, Smith et al. 1993*a*, Hodges 1994), with <25% of the historical forested acreage remaining within the Mississippi River floodplain (Creasman at el. 1992, Twedt and Loesch 1999). The remaining bottomland forests are highly fragmented with patch size highly skewed towards small fragments (Rudis 1995, Twedt and Loesch 1999). The loss and alteration of bottomland systems has been so extensive that bottomland hardwood forests have been identified as a habitat of regional concern (Hunter et al. 1993) and may have become an "endangered ecosystem" (Ernst and Brown 1989).

In Illinois, Kjolhaug et al. (1987) documented a decline in swamp rabbit distribution from their historical range, but the distribution appears to have remained stable over the past decade (Barbour et al. 2001). Although we have reliable data on the current distribution and status of Illinois swamp rabbits (Woolf 1998), continued monitoring of the population is necessary to maintain knowledge of their status.

Many methods have been used to assess lagomorph abundance and population trends, including mark-recapture (Brady and Pelton 1976, Krebs et al. 1987, Lochmiller et al. 1991), drive counts (Donoho 1972, Gross et al. 1974), game harvest records (Tapper and Parsons 1984, Trout et al. 1986), roadside surveys (Kline 1965, Suchy et al. 1991), line and strip transect flush counts (Gross et al. 1974, Pepin and Birkan 1981, Lochmiller et al. 1991, Langbein et al. 1999), spotlight line or strip transects (Flinders and Hansen 1973, Smith and Nydegger 1985), and fecal pellet counts (Hendrickson 1939, Terrel 1972, Lochmiller et al. 1991, McCollum and Holler 1994, Forys and Humphrey 1997, Langbein et al. 1999). Live trapping mark-recapture is likely to be the most accurate if the assumptions of the method are met (Forys and Humphrey 1997), but it is a costly and labor intensive method that is impractical for maintaining an inventory over a large area (Krebs et al. 1986, Shupe et al. 1987). The various transect counts that rely on observations of rabbits (by flushing or spotlight) are not likely to be effective for swamp rabbits because they are secretive animals that are relatively inactive diurnally (Holler and Marsden 1970) and cease activity in response to human approach (Hamilton 1955). Fecal pellet counts are likely to be the most efficient method for monitoring swamp rabbit population trends.

Throughout their range, swamp rabbits create latrines by depositing fecal pellets on logs, stumps, and other elevated objects (Lowe 1958, Whitaker and Abrell 1986, Zollner et al. 1996).

Several studies (Terrel 1972, Heuer and Perry 1976, Whitaker and Abrell 1986) have suggested fecal pellet counts could be used as an index to swamp rabbit population abundance. Fecal pellet counts have frequently been used to examine lagomorph abundance and distribution (Hendrickson 1939, Terrel 1972, Fa et al. 1992, McCollum and Holler 1994, Forys and Humphrey 1997, Diaz 1998) because there is a significant correlation between pellet counts and direct population size estimates of lagomorphs (Gibb 1970, Krebs et al. 1987, Velázquez 1994, Forys and Humphrey 1997). Fecal pellet counts are easily obtained for large areas (Orr and Dodds 1982), and provide an economic and efficient index that is likely well suited to long-term population monitoring (Krebs et al. 1987, Forys and Humphrey 1997). Therefore, we used pellet counts to monitor swamp rabbit populations in southern Illinois and evaluate the swamp rabbit population monitoring system recommended by Woolf (1998).

MONITORING SITES

Nine sites (Table 1) were selected to evaluate the monitoring scheme following the criteria established in Woolf (1998). Logistical limitations and the initial data collection in 1999 necessitated changes in the sites selected to monitor swamp rabbits. Initially, we selected 2-3 sites in each of 4 categories: large river, Cache River, inland, and peripheral (see Woolf 1998 for category criteria). Logistical and access problems with most of the sites along the Cache River resulted in combining the large river and Cache River categories into a single southern river category. Criteria for southern river sites then became sites adjacent to or within 0.5 km of the Cache, Mississippi, or Ohio rivers having a population abundance of moderate to high based on data collected in Job 1.1 from Woolf (1998) and containing good habitat (Jobs 1.1 and 1.2, Woolf 1998). The criteria for inland and peripheral sites remained the same as that identified in Woolf (1998), resulting in evaluation of the population monitoring system on 8 sites, with 2-3 sites within 3 categories (Table 2). See Appendix A for directions to the sites, transect layouts, and site limitations.

Table 1. Sites identified by Woolf (1998) for swamp rabbit population monitoring in southern Illinois. Sites were grouped into 4 classes (large river sites, Cache River sites, inland sites, and peripheral sites) using criteria based on proximity to rivers, population density, and habitat quality.

Site	County	1:24,000 7.5' Quadrangle Map Sheet	Section	Legal Description	Abundance[a]	Area (ha)	Ownership
large river							
Hodges Creek	Pulaski	Olmstead	29,28,33,4,3	T.15-16S-R.1E	high	249	private
Bumgard Island	Alexander	Cache/Thebes	6,7,8,16,17,18,21,22	T.17S-R.2W	high	628	private
Cache River							
Heron Pond	Johnson	Glendale	11,14	T.13S-R.4E	high	1,418	state
Cache River	Johnson	Cypress	8,9,10,11	T14S-R.2E	high	2,248	state
inland							
Bell Pond	Johnson	Vienna/Karnak	15,14,22,23,21,27	T.13S-R.2E	mod	2,248	federal
Horseshoe Lake Island	Alexander	Tamms/Cache	9,16,15	T.16S-R.2W	high	115	state
peripheral							
Kaskaskia	Randolph	Red Bud	4,5,8,9,16	T.3-4S-R.7W	low	1,259	state
Saline River	Saline	Rudemont	6	T.10S-R.7E	low	308	private
Bluff Lake	Union	Jonesboro/ Mill Creek	17, 18, 20	T.13S-R.2W	low	226	state

[a]Relative swamp rabbit abundance was classified as high, moderate, low, and absent according to the following number of pellet logs found per site: $\geq$20 pellet logs = high; 10-19 pellet logs = moderate; 1-9 pellet logs = low; 0 pellet logs = absent.

Table 2. Sites recommended for swamp rabbit population monitoring in southern Illinois. Sites were grouped into 3 classes (southern river sites, inland sites, and peripheral sites) using criteria based on proximity to rivers, population density, and habitat quality.

Site	County	1:24,000 7.5' Quadrangle Map Sheet	Section	Legal Description	Abundance[a]	Area (ha)	Ownership
southern river							
Hodges Creek	Pulaski	Olmstead	29,28,33,4,3	T.15-16S-R.1E	high	249	private
Bumgard Island	Alexander	Cache/Thebes	6,7,8,16,17,18,21,22	T.17S-R.2W	high	628	private
Heron Pond	Johnson	Glendale	11,14	T.13S-R.4E	mod	1,418	state
inland							
Bell Pond	Johnson	Vienna/Karnak	15,14,22,23,21,27	T.13S-R.2E	high	2,248	federal
HLCA	Alexander	Cache	21,22,27,28	T.16S-R.2W	high	830	state
peripheral							
Kaskaskia	Randolph	Red Bud	4,5,8,9,16	T.3-4S-R.7W	low	1,259	state
Saline River	Saline	Rudemont	6	T.10S-R.7E	low	308	private
Horseshoe Lake Island	Alexander	Tamms/Cache	9,16,15	T.16S-R.2W	low	115	state

[a]Relative swamp rabbit abundance was classified as high, moderate, low, and absent according to the following number of pellet logs found per site: ≥20 pellet logs = high; 10-19 pellet logs = moderate; 1-9 pellet logs = low; 0 pellet logs = absent.

Data collection in 1999 also resulted in changing the category in which some sites were classified. Initial data collection and reassessment of the results of the site survey (Porath 1997) indicated that an alternative peripheral site was needed to replace Bluff Lake (Union County Conservation Area). It also indicated that transect layout needed to be re-evaluated on the Horseshoe Lake Island (HLI) site and the site re-assessed to determine if it met the inland site criteria. HLI was searched for swamp rabbit sign January 2000, and the sign found was no longer abundant enough to meet the criteria of inland sites. However, it did meet the criteria for a peripheral site so HLI was chosen as the replacement site for Bluff Lake. Horseshoe Lake Conservation Area (HLCA) south of Horseshoe Lake was selected as the second inland site to replace HLI.

METHODS

Pellet counts were made using strip transects between 18 January-26 February 1999, 10 January-13 February 2000, and 28 January-20 February 2001. Transects were not replicated in 1999, but in 2000 each set of transects was replicated 3 times with different observers each time. Each set of transects was replicated twice with different observers each time in 2001. If there was a large variation in the resulting pellet indices, a third replication was completed.

Transects were placed systematically to provide optimum coverage of the site. There was >1,000 m of transect on each site, with more transect length on larger sites. The transects and their beginning points were marked on a 7.5' topographic map and digital orthophotographic quadrangle quarter (DOQQ) or aerial photographs and the bearing and length of the transect recorded (Table 3). An additional short transect was added at the Kaskaskia River site in 2001 to census a small area in which more rabbit sign was detected in the original survey (Porath 1997). Reference files for each site were maintained at the Cooperative Wildlife Research Laboratory, Southern Illinois University at Carbondale. The files included the coordinates of the transect origins and parking areas, bearings and distances of transects, directions to the sites and transect origins, a DOQQ or aerial photograph and topographic map with transects and their origins

Table 3. Origin, bearing (°), and distance (m) of transects used to monitor swamp rabbit populations on 8 sites in southern Illinois, January-February 1999-2001. Coordinates for the origins are in universal transverse mercator (UTM) North American datum (NAD) 83.

Site	Transect	Origin		Bearing	Distance
		Northing	Easting		
Bumgard Island	1	4104166.43	289723.14	140	300
	2	4103891.19	289862.21	320	650
	3	4104488.75	289563.14	140	170
Heron Pond	1	4136115.62	330802.21	46	700
	2	4136589.88	331395.66	226	830
Hodges Creek	1	4114041.26	312477.56	125	570
	2	4113727.85	312846.86	305	510
Horseshoe Lake Conservation Area	1	4109289.11	293016.87	190	600
	2	4108672.07	293060.53	10	600
Bell Pond[a]	1	4140007.10	345543.68	80	450
	2	4140094.19	346046.50	252	450
	3	4139928.48	345618.51	35	400
Kaskaskia[b]	1	4239333.67	244864.14	175	600
	2	4239335.96	245016.43	355	600
	3	4231054.38	247547.66	336	150
Saline River	1	4171684.99	370449.28	226	600
	2	4171259.05	370092.12	46	670
	3	4171801.22	370563.52	226	145
Horseshoe Lake Island[a]	1	4112016.73	292958.67	171	950
	2	4110909.88	293206.07	351	1,150

[a]Transects differed in 1999.
[b]First 2 transects shortened in 2001 from 800 m and third transect added.

marked, and land ownership information. Coordinates were recorded in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983. The files were archived on CD-ROM for distribution along with data from searches of potential habitat sites for swamp rabbit occupancy (Woolf 1998).

Pellet counts were conducted on 10-m wide strip transects run by following a bearing from the origin for the indicated distance (Table 3), counting objects of interest $\leq$5 m on both sides of the transect centerline. Directions to the initial transect origin and from the end of the transect to the origin of the next transect were provided (Appendix A). Teams of 2 ran transects; 1 person maintained the transect bearing, distance, and centerline and the other searched within the 10-m width. Transect distances were paced, and distances between transects were paced or measured with a range finder. Where possible, transects ended at landscape features (habitat edge, creek, road, etc.) to minimize differences in pacing measurements. Distances of objects from the transect for inclusion were measured with a 5-m string. Counts were made by tallying the number of logs and stumps, number of logs and stumps with pellets, and the number of pellet groups per log and stump along each transect (see Appendix B for a sample data form). Logs and stumps were counted only if they fit the following criteria:

<u>Log criteria</u>

- on the ground
- $\geq$10 cm diameter
- decayed, moss-covered, or moss on part of the log
- $<$70 cm high

<u>Stump criteria</u>

- flattened on top
- $\geq$10 cm diameter
- $<$70 cm height

If a log crossed or made contact with another log, the pile was counted as 1 log instead of counting each log separately. Logs that had not started to decay were not counted unless pellets were present on the log. A pellet group could be as small as 1 pellet, but groups had to have distinct separation (>50 cm) to be considered separate groups. Pellets found on the ground and pellet logs outside the 5-m half-width of the transect were not counted, but were noted in the comments. Data collection in 2000 suggested that latrine density was the least variable index. Because counting logs increased the time needed to run transects, added little new information, and required a subjective decision to differentiate what constituted a log, the number of logs and stumps was not counted in 2001. The number of pellet groups were counted in 2001 despite the high variance because it required little extra time. Other information recorded included the presence of giant cane (*Arundinaria gigantia*) thickets, the general habitat type the transect covered, if any rabbits were flushed while walking the transect, relative flood conditions, general weather conditions, and changes in the site from previous visits.

Eberhardt's (1978) classification of transect methods indicated strip transects would be the best method to use given the characteristics of swamp rabbit latrines. However, strip transects assume that all objects of interest within the strip are counted (Burnham and Anderson 1984, Burnham et al. 1985). This assumption can be tested using distance sampling theory (Buckland et al. 1993) if perpendicular distance of objects from the transect are recorded. Therefore, the perpendicular distance of latrines from the transect was recorded on 1 run on Horseshoe Lake Conservation Area in 2001 to compare results of the strip transect to distance sampling density calculated using the program DISTANCE (Laake et al. 1993).

Several population indices were evaluated to determine the most effective index of relative swamp rabbit abundance. Indices evaluated were the proportion of logs used, latrines/ha, and pellet groups/ha. Mean pellet indices were compared between 2000 and 2001 indices using a t-test (Zar 1996).

RESULTS

Swamp rabbit pellet indices were similar in all years except for increases in pellet logs/ha and pellet groups/ha on Heron Pond and HLCA and a decrease in these indices on HLI between 2000 and 2001 (Table 4; Appendix C). All indices gave similar trends among the sites in all years: Bumgard Island (BI), Heron Pond, and HLCA had much larger indices than any of the other sites. With the exception of Bell Pond, an inland site, and Kaskaskia in 2001 if the new transect was included, peripheral sites had much lower values for all indices (Table 4). The latrine density (80 latrines/ha) at HLCA calculated using the best fit distance sampling model - a uniform cosine detection function - was very similar to that estimated with the strip transect (79.2 latrines/ha).

There was more variability in the pellet index values for sites with abundant rabbit sign than for sites with scarce rabbit sign (Table 4). With the exception of Bumgard Island, the variability was lowest for latrine density and tended to be highest for pellet group density.

DISCUSSION

The optimal time to count swamp rabbit fecal pellets is January and February because there is minimal obstruction by vegetation and decomposition of pellets. However, winter weather and flooding can impose limitations on when sampling can be conducted. Extreme winter weather with snow or ice can make sampling difficult, if not impossible. Comparisons between years would be impractical if counts were made with snow cover because they would be sampling different intervals for rabbit presence. Flood conditions on the sites also are a concern. Flooding of a site can wash all pellets off logs and rearrange logs on the site. If a site has been recently flooded, fecal pellet counts would not be comparable to counts of previous or subsequent years without flooding because it would be a count of pellets deposited since the flood. Therefore, weather conditions may dictate when a site can be sampled.

The use of fecal pellet counts as an index to animal abundance assumes that there is a relationship between pellet density and animal density. Whether changes in swamp rabbit fecal

Table 4.

pellet density reflects a similar change in swamp rabbit abundance is uncertain because the relationship between sign abundance and rabbit abundance is not known. Previous studies have shown a significant correlation between pellet counts and direct population size estimates of other lagomorph species (Gibb 1970, Krebs et al. 1987, Velázquez 1994, Forys and Humphrey 1997). However, this relationship has not been investigated for swamp rabbits. Trapping was conducted within a 15 ha area on BI (see Job 2.2), but extremely low recapture rates prevented the use of density models (Pollock et al. 1990). Density estimates using the minimum number alive (Otis et al. 1978) were 1.25 rabbits/ha. Similar pellet indices on Heron Pond and HLCA likely indicate a similar density to that on BI, and almost certainly indicate a larger rabbit population and higher density on these sites than on the others. However, the relationship between sign and rabbit density at the lower densities found on the other sites is less certain. Further investigations into the relationship between swamp rabbit abundance and fecal pellet abundance are needed.

Several studies have recommended the need for distance data in transect sampling (Burnham and Anderson 1984, Buckland et al. 1993) because strip transect sampling assumes that all objects of interest are detected (Burnham et al. 1985). If some objects go undetected, the resulting estimates are biased (Burnham and Anderson 1984). Distance sampling (Buckland et al. 1993) relaxes this assumption based on a detection function that assumes the detection of objects decreases with increasing distance from the transect centerline. However, the density estimate from distance sampling was nearly identical to that from the strip transect for swamp rabbit fecal pellets when distances were collected. Logs and stumps tend to be conspicuous objects and are easily detected at 5 m except in thick vegetation so it is likely that the majority of logs are detected by a careful well-trained observer, as indicated by the relatively even distribution of distances for objects detected and the best fit model for the distance data being a uniform detection function (Fig. 1). Pellet density estimates then fall into standard finite population sampling theory (Cochran 1963).

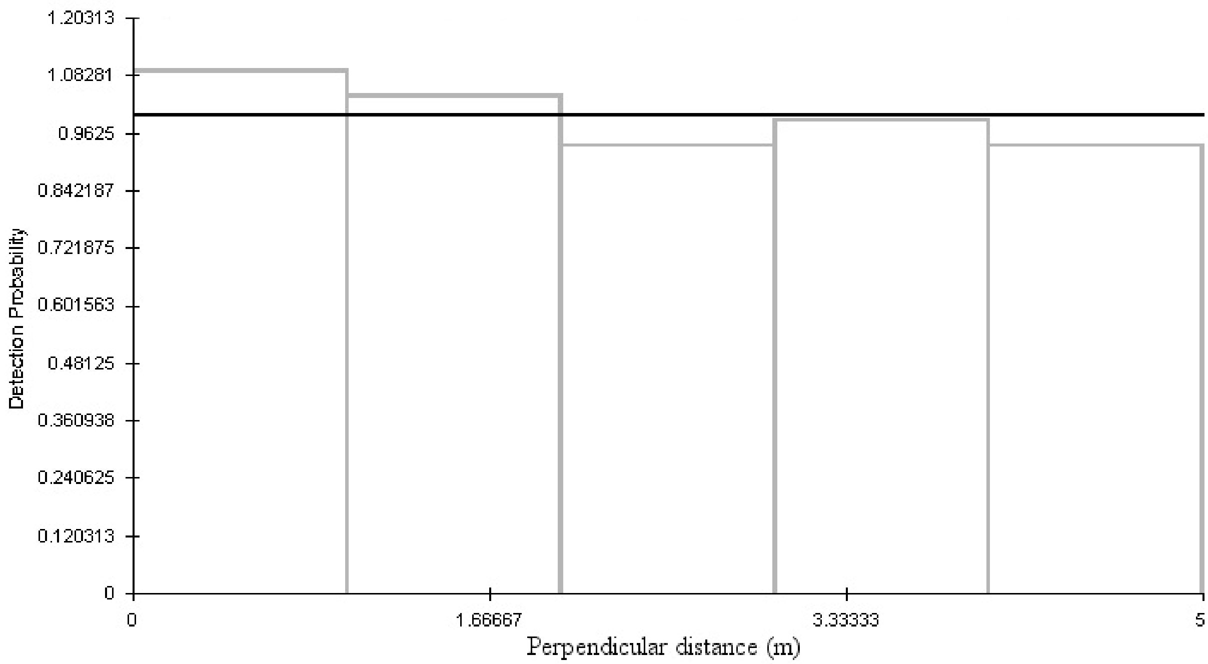

Figure 1. Histogram of swamp rabbit latrine distance from transect centerline using 5 distance categories and truncated at 5 m for data collected on Horseshoe Lake Conservation Area 20 February 2001. The line represents the best fit model - a uniform cosine detection function - to the data from the program DISTANCE (Laake et al. 1993).

Bias can be introduced into swamp rabbit pellet density estimates from factors unrelated to pellet density (Burnham et al. 1980, Burnham and Anderson 1984). These factors encompass limitations related to the observer and physical setting (Burnham and Anderson 1984, Burnham et al. 1985). Variables related to the physical setting include speed of travel down the transect, transect width, habitat types, time of day, sun angle, inclement weather, and size and shape of the object counted (Burnham and Anderson 1984). Variables related to limitations of the observer that result in observer bias and affect the detection probability include level of experience, differences in ocular acuity, degree of interest or training, differences in ability to distinguish objects, and fatigue. Bias or differences resulting from different observers on the swamp rabbit transects also could result from differences in ability to follow a compass bearing and to measure distances via pacing or other methods so that transect placement differed between observers. Comments made about ending points of transects on the data forms indicated that transect placement did differ between observers. Differences in transect placement are more likely to influence results on sites with low pellet densities than those with high densities. Comments about the transects indicated that transect placement differed on Heron Pond (high pellet density) and Kaskaskia (low pellet density) in 2001. The pellet indices were very similar on Heron Pond, but there were large differences between the results obtained from the first and second replication on the Kaskaskia site (see Appendix C). However, differences in transect placement cannot fully explain the large differences between runs in the number of pellet logs detected. We conducted a third replication with the same person from the second run maintaining the transect bearing. There were minor differences in coverage of the first transect and the origin of the second transect, but there was a large difference in the ending point of the second transect with the transect ending approximately 75 m east of the designed layout. As a result, the second transect covered different areas between the 2 runs with all pellet logs detected on the second transect occurring in a creek bottom that had not previously been sampled by the transects. However, the much larger number of pellet logs recorded on the first transect in the second run was not duplicated. Other factors which might have contributed to the variation in numbers are the likely presence of cottontails on a portion of the site and potential misidentification of other species fecal pellets on logs. While these biases might influence the numerical density estimate value, they are much less likely to influence the relative density compared to the other sites. Permanently marking the origin of at least the first transect should be done where possible so that the initial transect origin remains consistent.

Density estimates also could be influenced by environmental changes on the site. Beavers (*Castor canadensis*) moved into the area covered by the transects on Heron Pond and constructed a dam along Dutchman Creek between the 2 transects between 2000 and 2001. The resulting flooding behind the dam inundated almost the entire length of the second transect, and most of the pellets detected along this transect in 2001 were old pellets that were likely remnants from before the dam construction. In situations such as this, it may be necessary to change transect placement for future sampling. Changes that could be made include changing the initial transect origin, changing the transect bearing, shortening distances between transects, or a combination of these. An alternative transect placement for Heron Pond is provided in Appendix A.

RECOMMENDATIONS

The Illinois Department of Natural Resources (IDNR) has a statutory responsibility for management of wildlife in Illinois. Therefore, IDNR should take responsibility for swamp rabbit population monitoring. Populations should be monitored every year by means of pellet surveys conducted between 1 January and 28 February. If possible, data should be collected on all sites within a 2-week interval during this time. If the site has been extensively flooded within 2 months prior to data collection, transects should not be run that year, or at least not compared to other years. If snow cover is present, transects should not be run until the snow has cleared. Data should be collected by teams of 2 observers, 1 maintaining the transect bearing and distance and the other searching for pellet logs. Transects should be replicated twice, with a third replication if a large difference exists between the 2 runs. Counts should be made of the number of latrines and the number of pellet groups, although latrine density should be the main index for comparison between years.

APPENDIX A

SITES SELECTED FOR MONITORING SWAMP RABBIT POPULATIONS

Bumgard Island

Directions.—Access is from the levee along the Mississippi River in Alexander County (Fig. A-1). From the intersection of State Routes 127 and 3, go north on Route 3 approximately 1.3 km. Turn left on Promised Land Road at the sign for camping and the Horseshoe Lake Public Hunting Area. Travel approximately 7.5 km to the end of this road at its juncture with Miller City Road and turn left. Go approximately 3.8 km, and turn right on Central Bend Road, a gravel road at a sign for Willow Patch Hunting Club. Alternatively, from the intersection of Interstate 57 and State Route 3, travel north on State Route 3 approximately 7.5 km. Turn left on Miller City Road immediately after crossing the Cache River Diversion Channel; there is a sign to Miller City at this turn. Go approximately 8.5 km and turn left on Central Bend Road. Travel approximately 2.4 km and turn right on Bumgard Cemetery Road, the second intersection. Stay on this road for approximately 1.9 km, passing a cemetery on the right, until you reach the levee. Continue up on the levee to the left; the levee is narrow and may require a sharp turn at the top. Travel south along the levee approximately 0.2 km to a wire gate across the levee road where a road leaves the levee to the right. Follow the road off the levee until you reach a gate across the road. Park near the gate (coordinates 4104360.92 N, 289733.54 W).

Transect Directions.—There are 3 transects on this site (Fig. A-1). Walk along the road from the gate for 280 m to begin the first transect (origin 4104166.43 N, 289723.14 W). Follow a bearing of 140° for 300 m. From the end of the first transect, walk 70 m following a bearing of 230° to begin the second transect. From the second transect origin (4103891.19 N, 289862.21 W), follow a bearing of 320° back to the road. Continue across the road on the transect until you reach a second road. To begin the third transect, walk along the road following a bearing of 50° to the edge where the road curves to the right back to the main road. Continue on the 50° bearing for 60 m into the woods to start the third transect. From the third transect origin

(4104488.75 N, 289563.14 W), follow a bearing of 140° back to the road. It requires approximately 2 hours to complete the transects if you can drive to the gate.

Limitations.—This site is subject to flooding which can prevent access. High water or wet conditions can also present problems reaching the site. The road to the levee past the cemetery is not in good condition and may not be passable without a 4-wheel drive vehicle when very wet. The road running up the levee is very soft and may not be passable when the road leading to the levee is. If the road is soft, check the levee before proceeding up the road. Conditions may require parking at the bottom of the levee or at the cemetery and walking in. Sometimes there also is water flowing over the road leading off the levee to the site. If the water level is high, this may not be passable. This site is privately owned. The property is owned by Anderson Tully Company, and is leased by a hunt club so it might require waiting until the archery deer season is over before running transects. Ownership information is subject to change.

Figure A-1. Location of Bumgard Island site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Hodges Creek

Directions.—Access is off State Highway 37 in Pulaski County (Fig. A-2). To reach the site from Interstate 57, take exit 8 (Mounds Road) off I57. Travel east on Mounds Road approximately 2.7 km to its intersection with State Route 37. Proceed north on Route 37 approximately 6.4 km to the site at Hodges Creek. It is approximately 1.4 km north of American Road and before crossing the bridge over Hodges Creek. Pull off on the gravel area on the east side of Route 37 across from a gated cattle pasture (coordinates 4114003.95 N, 312420.8 W). If traveling south on Route 37 to reach the site, it is approximately 3.5 km south of Veach Oil Fill-Up at the intersection of Route 37 with Cedar Street in Olmstead.

Transect Directions.—There are 2 transects on this site (Fig. A-2). The first transect begins at the bottom of the embankment along the road. Starting directly across from the gate, walk 50 m north along Route 37, and then go to the bottom of the embankment for the beginning of the first transect (origin 4114041.26 N, 312477.56 W). Follow a bearing of 125° for 570 m to the edge of the woods and an agricultural field where the first transect ends. Go north along the edge of the woods 100 m for the start of the second transect. From the second transect origin (4113727.85 N, 312846.86 W), follow a bearing of 305° back to the road. It requires approximately 1½ hours to complete the transects.

Limitations.—This site is subject to deep flooding from backwash on the Ohio River which can prevent collection of data along the transects. The first transect is along the lower areas on the site and may be underwater if the water level is high. Wet conditions can make portions of the transect slippery particularly on the embankments on the site This site is privately owned by Florence Chambliss. Ownership information is subject to change.

Figure A-2. Location of the Hodges Creek site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Heron Pond

Directions.—Access is from the Heron Pond Access area of the Cache River State Natural Area north of Forman (Fig. A-3). Follow the signs for Heron Pond to reach the site. From State Route 146, go south on US Route 45 from Vienna to Belknap Road. Head west on Belknap Road approximately 2.6 km to Heron Pond Lane. Travel north on this gravel road approximately 1.3 km; do not go to the parking area at the end of the road. Pull off at the closed gate to the right of the road before the parking area (coordinates 4136129.18 N, 330772.39 W). A petroleum pipeline right of way crosses the road here, and there is a post with the number 532 at the top.

Transect Directions.—The first transect begins near the edge of the woods east of the gate (Fig. A-3). From the gate's edge, walk towards the woods following a 114° bearing. Continue on this bearing 20 m into the woods to a rectangular stone block at the beginning of the first transect (origin 4136115.62 N, 330802.21 W). Follow a bearing of 46° for 700 m to Dutchman Creek. Travel east along the creek bed 90 m to begin the second transect. From the second transect origin (4136589.88 N, 331395.66 W), follow a bearing of 226° until you reach the edge of the woods along the access road. It requires approximately 2 hours to complete the transects.

Alternative Transect Directions.—Begin the first transect from the gate's edge (coordinates 4136135.72 N, 330776.02 W). Follow a bearing of 46° for 670 m to Dutchman Creek (Fig. A-3). Travel east along the creek bed 60 m to begin the second transect. From the second transect origin, follow a bearing of 226° until you reach the edge of the woods along the access road. A second alternative would be to start from the gate but use a bearing of 30-35° for the transect to Dutchman Creek with a larger distance between transects.

Limitations.—The site may be subject to flooding if the water levels of the Cache River and Dutchman Creek are extremely high. However, this site is not as subject to flooding as other nearby sites. There is thick brush on this site and the person maintaining the transect will have to go through thick *Rubus* and greenbrier (*Smilax rotundifolia*) thickets. There is standing water on the site so extreme winter weather can cause ice formation making the site hazardous. Beavers have constructed a dam along Dutchman Creek so much more of the site is now flooded, and requires hip waders to keep dry. The site is a state natural area and nature preserve.

Figure A-3. Location of the Heron Pond site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares. The alternative transect layout is represented by the dashed lines.

Horseshoe Lake Conservation Area

Directions.—Access is south of the Horseshoe Lake spillway near West Side Drive (Fig. A-4). From the intersection of State Routes 127 and 3, go north on Route 3 approximately 1.3 km. Turn left on Promised Land Road at the sign for camping and the Horseshoe Lake Public Hunting Area. Travel approximately 5.1 km down this road passing the southern tip of Horseshoe Lake. Turn left on the gravel road across from the shop and public hunting parking lot just past West Side Drive. Alternatively, traveling south on State Route 3, from the intersection of State Routes 3 and 146 south of McClure, travel approximately 29.8 km to Olive Branch. Turn right on Miller City Road at the Branch Family Restaurant. Travel approximately 7.2 km and turn left on Promised Land Road just before the River Delta Hunting Club. Travel approximately 2.1 km along this road and turn right on the gravel road across from the shop and public hunting parking lot just before West Side Drive. This road has a gate that may be closed and locked. The key is the same as the one for Horseshoe Lake Island. Once past the gate, follow the road to the left and travel 0.4 km. There is a crop field to the right of the road starting at the gate; once past the end of this field there is an overgrown track curving back to the open field on the right. Park near here (coordinates 4109289.11 N, 292958.67 W).

Transect Directions.—There are 2 transects on this site (Fig. A-4). The first transect begins off the gravel road. From the intersection of the gravel road and the overgrown track (origin 4109289.11 N, 292958.67 W), follow a bearing of 190° for 600 m. From the end of the first transect, follow a bearing of 100° for 150 m to begin the second transect. From the second transect origin (4108672.07 N, 293060.53 W), follow a bearing of 10° back to the road.

Limitations.—This site may be subject to high water levels. There is permanent water on the site that is subject to fluctuating levels due to rainfall. Waders or knee boots are recommended for this site, particularly if there has been recent rainfall. A key to the gate may be required since the gate may be closed and locked. The key is the same as for Horseshoe Lake

Island. This is part of the public hunting area (goose, deer, squirrel, and dove) of Horseshoe Lake Conservation Area.

Figure A-4. Location of Horseshoe Lake Conservation Area site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Bell Pond

Directions.—Access is off State Route 146 east of Grantsburg in Johnson County (Fig. A-5). Follow 146 east from Grantsburg to Flatwoods Road, a gravel road 0.2 km east of Grantsburg. If you go past the cypress swamp on 146 you have gone past this road. Turn north on Flatwoods Road. There is a clearing to the right and the road curves to the left at the end of this clearing. Pull over on the side of the road anywhere near here (coordinates 4139914.57 N, 345620.02 W).

Transect Directions.—The first transect starts from the edge of the road 25 m north of the edge with the open area (coordinates 4140007.1 N, 345543.68 W) (Fig. A-5). Follow a bearing of 80° for 160 m to the creek. Continue parallel to the creek approximately 10 m from the waters edge for 200 m. The transect ends near a deer stand. From the end of the first transect, follow a bearing of 340° for 55 m to begin the second transect. From the second transect origin (4140094.19 N, 346046.50 W) follow a bearing of 252° back to the road. The third transect starts from the edge of the road 150 m north of the edge with the open area (coordinates 4139928.48 N, 345618.51 W). Follow a bearing of 35° for 400 m to the edge with a field. It requires approximately 1½ hours to complete the transects.

Limitations.—The site is subject to flooding when water levels are extremely high, including flooding of Flatwoods Road. There is permanent water on the site so extreme winter weather can cause ice formation creating unsafe conditions and preventing access. Hip waders are required for this site. This site is part of the Shawnee National Forest.

Figure A-5. Location of Bell Pond site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Horseshoe Lake Island

Directions.—Access to this site is south of Olive Branch in Alexander County (Fig. A-6). From the intersection of State Routes 3 and 127, travel north on Route 3 approximately 8.5 km to Olive Branch. Turn left on Miller City Road by the Branch Family Restaurant. There are signs at this intersection indicating the direction for Horseshoe Lake Conservation Area, Miller City, and Camping. Alternatively, traveling south on State Route 3, from the intersection of State Routes 3 and 146 south of McClure, travel approximately 29.8 km to Olive Branch. Turn right on Miller City Road by the Branch Family Restaurant. Go approximately 1.92 km and turn left on Island Road, a gravel road before some old hunting shacks. Worthington Hunt Club is on the right just past this turn. This is a gravel road that leads to the island. Go through the gate and cross the causeway to the island. Stay on the gravel road, passing through the shop area. Once past the shop, the gravel road stops but continue on the grass to the west side of the island. Once you reach the woods on the west side, continue south along the woods until you reach the edge of the field. Park here (coordinates 4112016 N, 292958.67 W). This is approximately 4.8 km from the gate.

Transect Directions.—There are 2 transects on this site (Fig. A-6). From the corner of the field (coordinates 4112016.73 N, 292958.67 W), follow a bearing of 171° to the end of the island. Walk southeast along the edge of the island 200 m to begin the second transect. From the second transect origin (4110909.88 N, 293206.07 W), follow a bearing of 351° back to the field. It requires approximately 2 hours to complete the transects.

Limitations.—The area may be subject to flooding that can flood the island and/or prevent access to the island, including flooding the causeway and roads around the island. Wet conditions may prevent driving on the grass to reach the western edge of the island without a 4-wheel drive vehicle. A key to the causeway road gate may be required because the gate is closed and locked when staff personnel are not on the island. This site is part of the Horseshoe Lake Nature Preserve.

Figure A-6. Location of Horseshoe Lake Island site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Saline River

Directions.—Access is off State Route 145 southeast of Harrisburg in Saline County (Fig. A-7). From the intersection of State Route 13 and US Route 45 in Harrisburg, travel south on Route 45 1.3 km to the intersection with State Routes 145 and 34. Travel south on Route 145 approximately 4 km passing through Pankeyville. Turn left on Whitesville Road (600 N) at the signs for Glen O. Jones Lake and the Saline County Landfill. Travel on this gravel road approximately 5.9 km to the Saline River. Pull off to the side of the road anywhere near the bridge (coordinates 4171670.96 N, 370486.75 W).

Transect Directions.—There are 3 transects on this site (Fig. A-7). Start the first transect from the road 20 m east of the bridge's end (coordinates 4171684.99 N, 244864.14 W). Follow a bearing of 226° for 600 m. From the end of the first transect, follow a bearing of 97° for 75 m to begin the second transect. From the second transect origin (4171801.22 N, 370092.12 W), follow a bearing of 46° back to the road. Cross the road and keep following a bearing of 46° for approximately 70 m. Depending on the water level, the transect may end at the edge of a flooded area. If it is dry, end the transect before reaching the powerline. Walk along the waters edge (or lowland edge if dry) 75 m to begin the third transect. From the third transect origin (4171801.22 N, 370563.52 W), follow a bearing of 226° back to the road. It requires approximately 2½ hours to complete the transects.

Limitations.—The site may be subject to high water. Most of the site is dry, but the transects run through standing water so waders are recommended. The majority of the second and third transects run through thick growths of giant cane and grape (*Vitis* sp.) so careful searching is required. Most of this site is privately owned by Emil Downey.

Figure A-7. Location of Saline River site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Kaskaskia

There are 2 areas within the Kaskaskia Fish and Wildlife Management Area for this site if the second area (south) added in 2001 will continue to be monitored.

North Directions.—Access is off State Route 154 in Baldwin (Fig A-8). From the intersection of State Route 154 and Baldwin Road in Baldwin, travel north approximately 10.1 km along Baldwin Road. Turn left on Baer Road. Alternatively, the site can be accessed from State Route 13 in St. Clair County. Travel north on Route 13 from Pinckneyville, passing through Marissa. Turn left on Schmoll-Hillston Road, approximately 3.4 km from the intersection of State Routes 4 and 13 in Marissa. Travel approximately 8.2 km to its intersection with Baldwin Road, and turn right on Baldwin Road. Take the first left, which is approximately 0.8 km north on Baldwin Road; this is Baer Road. Baer Road also is approximately 4 km south along Baldwin Road from its intersection with State Route 13 in New Athens. Travel approximately 4.5 km west along Baer Road to the gravel sportsmen parking area on the right before reaching Peabody Coal. Park here (coordinates 42310111.17 N, 247627.96 W).

North Transect Directions.—There are 2 transects on this site (Fig. A-8). Walk along the gravel road through the gate towards the river for 100 m to a telephone pole to begin the first transect (coordinates 4239333.67 N, 244864.14 W). Follow a bearing of 165° for 600 m. From the end of the first transect, follow a bearing of 90° for 80 m to begin the second transect. From the second transect origin (4239335.96 N, 245016.43 W), follow a bearing of 345° back to the gravel road. It takes approximately 1½ hours to complete the transects.

South Directions.—Access is off State Route 154 west of Baldwin in St. Clair County (Fig. A-9). Travel west on 154 through Baldwin. Travel approximately 3.2 km past the intersection of 154 and Baldwin Road. Turn right on Conservation Road; there is a sign indicating the direction to a boat ramp at this intersection. Travel approximately 0.6 km along Conservation Road, turning left into the boat ramp area. Park in the northeast corner of the parking lot (coordinates 4239945.28 N, 245035.50 W). You also can reach this site traveling the road through the Kaskaskia Fish and Wildlife Management Area if you have permission to be on the road.

South Transect Directions.—There is 1 transect in this area. From the northeastern corner of the parking lot, walk 60 m along the edge of the woods to begin the transect (origin 4231054.38 N, 247547.66 W). Follow a bearing of 335° until you reach a gravel road.

Limitations.—The site may be subject to high water. This site is part of the Kaskaskia Fish and Wildlife Management Area.

Figure A-8. Location of the Kaskaskia north site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

Figure A-9. Location of the Kaskaskia south site and transect layout for monitoring swamp rabbit populations in Southern Illinois. The thick, solid black line indicates the route for reaching the site, and the solid dot represents the area to park for access to the site. The transects are represented by the thick grey lines, with the transect origins indicated by white squares.

APPENDIX B

TRANSECT PELLET COUNT DATA

Site Location ____
Date ______________ Observers ______________________________
Time Started ______________ Time Finished ___________________________
Weather Conditions ____
____

Transect 1
Start Coordinate ______________ Bearing __________ Distance _________
Latrines ____
____
____
____
Pellet groups ____
____
____
____
Comments ____
____
____
____
____
____

Transect 2
Start Coordinate ______________ Bearing __________ Distance _________
Latrines ____
____
____
____
Pellet groups ____
____
____
____
Comments ____
____
____
____
____
____

APPENDIX C

Table C-1. Number of logs and stumps, latrines, and pellet groups for transects used to monitor swamp rabbit populations in southern Illinois 18 January-26 February 1999. Sites were grouped into 4 classes (large river sites, Cache River sites, inland sites, and peripheral sites) using criteria based on proximity to rivers, population density, and habitat quality.

Site	Transect		Objects		Latrines		Pellet Groups	
	#	length (m)	logs	stumps	logs	stumps	logs	stumps
Large river sites								
Hodges Creek	1	570	32	15	11	5	18	5
	2	510	19	10	5	5	8	5
Cache River sites								
Heron Pond	1	700	65	9	42	4	60	4
	2	830	55	5	23	4	34	4
Heron Pond	1	700	265	36	47	7	67	7
	2	830	236	29	78	6	105	6
Inland sites								
Bell Pond	1	500	57	6	0	0	0	0
	2	500	21	0	5	0	8	0
Horseshoe Lake	1	900	80	0	0	0	0	0
Island	2	900	45	0	0	0	0	0
Peripheral sites								
Kaskaskia	1	800	62	3	2	0	3	0
	2	800	50	1	2	0	5	0
Saline River	1	600	45	9	2	0	2	0
	2	600	46	10	0	1	0	1
	3	70	28	1	1	0	1	0
	4	145	31	4	2	2	4	2

Table C-1. Continued.

Site	Transect		Objects		Latrines		Pellet Groups	
	#	length (m)	logs	stumps	logs	stumps	logs	stumps
Bluff Lake	1	400	36	0	0	0	0	0
	2	500	17	0	0	0	0	0
	3	65	11	0	0	0	0	0
	4	90	13	0	0	0	0	0

Table C-2. Number of logs and stumps, latrines, and pellet groups for transects used to monitor swamp rabbit populations in southern Illinois 10 January-13 February 2000. Sites were grouped into 4 classes (large river sites, Cache River sites, inland sites, and peripheral sites) using criteria based on proximity to rivers, population density, and habitat quality.

		Transect		Objects		Latrines		Pellet Groups	
Site	run	#	length (m)	logs	stumps	logs	stumps	logs	stumps
Large river sites									
Bumgard Island	1	1	360	126	3	49	0	56	0
		2	170	54	2	19	0	24	0
		3	300	68	0	30	0	31	0
		4	300	62	0	28	0	36	0
	2	1	360	60	0	28	0	46	0
		2	170	17	0	7	0	11	0
		3	300	19	0	13	0	23	0
		4	300	31	0	10	0	17	0
	3	1	360	88	0	34	0	45	0
		2	170	37	0	14	0	18	0
		3	300	42	0	21	0	26	0
		4	300	47	0	20	0	27	0
Hodges Creek	1	1	570	85	24	18	8	21	8
		2	510	61	16	11	4	13	4
	2	1	570	100	42	12	10	16	12
		2	510	68	15	7	3	8	4
	3	1	570	67	29	13	13	17	22
		2	510	49	16	16	4	18	5
Cache River sites									
Heron Pond	1	1	700	121	6	38	2	53	2
		2	830	131	5	22	1	31	1
	2	1	700	89	6	24	2	30	3
		2	830	45	5	10	1	22	1
	3	1	700	84	7	35	2	48	2
		2	830	40	5	18	1	27	1

Table C-2. Continued.

Site	run	Transect		Objects		Latrines		Pellet Groups	
		#	length (m)	logs	stumps	logs	stumps	logs	stumps
Inland Sites									
Horseshoe Lake Conservation Area	1	1	500	106	16	24	5	32	5
		2	500	78	10	15	5	24	5
	2	1	500	89	9	28	5	34	5
		2	500	62	6	10	4	18	4
	3	1	500	168	17	26	6	35	7
		2	500	98	12	16	6	26	7
Bell Pond	1	1	350	31	0	0	0	0	0
		2	300	19	0	0	0	0	0
		3	500	89	0	6	0	9	0
	2	1	350	39	0	0	0	0	0
		2	300	21	0	0	0	0	0
		3	500	128	0	5	0	10	0
	3	1	350	28	0	0	0	0	0
		2	300	17	0	0	0	0	0
		3	500	69	0	4	0	6	0
Peripheral sites									
Kaskaskia	1	1	800	161	0	1	0	1	0
		2	800	54	1	0	0	0	0
	2	1	800	55	0	1	0	1	0
		2	800	88	0	0	0	0	0
	3	1	800	105	0	1	0	1	0
		2	800	70	0	0	0	0	0

Table C-2. Continued.

Site	run	Transect		Objects		Latrines		Pellet Groups	
		#	length (m)	logs	stumps	logs	stumps	logs	stumps
Saline River	1	1	600	112	5	0	0	0	0
		2	600	113	5	0	0	0	0
		3	70	53	2	0	0	0	0
		4	145	64	5	0	0	0	0
	2	1	600	87	18	0	0	0	0
		2	815	61	16	0	0	0	0
	3	1	600	143	20	0	0	0	0
		2	600	135	11	0	0	0	0
		3	70	75	9	0	0	0	0
		4	145	41	13	0	0	0	0
Horseshoe Lake Island	1	1	900	350	0	3	0	3	0
		2	1,000	176	0	0	0	0	0
	2	1	900	165	0	4	0	4	0
		2	1,000	118	2	1	0	1	0
	3	1	900	288	0	3	0	3	0
		2	1,000	148	0	1	0	1	0

Table C-3. Number of latrines and pellet groups for transects used to monitor swamp rabbit populations in southern Illinois 28 January-20 February 2001. Sites were grouped into 3 classes (southern river sites, inland sites, and peripheral sites) using criteria based on proximity to rivers, population density, and habitat quality.

		Transect		Latrines		Pellet Groups	
Site	run	#	length (m)	logs	stumps	logs	stumps
Bumgard Island	1	1	300	40	0	58	0
		2	650	58	0	90	0
		3	200	14	0	15	0
	2	1	300	20	0	36	0
		2	650	18	0	28	0
		3	200	31	0	42	0
	3	1	300	30	0	49	0
		2	650	75	0	106	0
		3	200	3	0	6	0
Hodges Creek	1	1	570	7	5	12	5
		2	510	11	3	13	3
	2	1	570	9	8	9	8
		2	510	5	2	7	2
Heron Pond	1	1	700	64	0	96	0
		2	830	26	0	32	0
	2	1	700	41	8	78	8
		2	830	61	4	61	4
Horseshoe Lake Conservation Area	1	1	600	41	11	54	11
		2	600	51	7	72	7
	2	1	600	54	10	64	10
		2	600	36	8	46	8
	3	1	600	48	10	57	10
		2	600	34	3	47	3
Bell Pond	1	1	450	6	0	7	0
		2	450	0	0	0	0
		3	400	0	0	0	0
	2	1	450	3	0	4	0
		2	450	0	0	0	0
		3	300	0	0	0	0
Kaskaskia	1	1	600	1	0	1	0
		2	600	0	0	0	0
		3	150	17	0	27	0
	2	1	600	20	0	20	0
		2	600	4	0	5	0
		3	150	28	0	41	0
	3	1	600	4	0	4	0
		2	600	2	0	2	0

Table C-3. Continued.

Site	run	Transect #	Transect length (m)	Latrines logs	Latrines stumps	Pellet Groups logs	Pellet Groups stumps
Saline River	1	1	600	0	1	0	1
		2	670	4	2	7	2
		3	145	4	0	4	0
	2	1	600	0	0	0	0
		2	670	2	0	2	0
		3	145	1	0	1	0
Horseshoe Lake Island	1	1	950	0	0	0	0
		2	1,150	0	0	0	0
	2	1	950	0	0	0	0
		2	1,150	0	0	0	0

JOB R-2.2: POPULATION ECOLOGY

Objective: Determine population parameters and trends of swamp rabbits in Illinois.

Swamp rabbits are a species of growing conservation concern, particularly along the northern periphery of their range, because of the decline in their distribution and abundance associated with the loss and fragmentation of forested wetlands as bottomland areas were cleared for agriculture and other land uses (Terrel 1972, Dailey et al. 1993). Porath (1997) suggested that swamp rabbits in Illinois exist as a metapopulation; however, the suggestion was supported only by anecdotal evidence. Although other *Sylvilagus* species have been investigated within a metapopulation framework (Litvaitis and Villafuerte 1996, Forys and Humphrey 1999), previous swamp rabbit studies have not investigated population structure, nor has dispersal between populations been documented. Previous studies in Illinois have investigated swamp rabbit distribution, survival, and home range, and provided a general habitat assessment (Kjolhaug 1986, Kjolhaug et al. 1987, Kjolhaug and Woolf 1988, Porath 1997). However, winter during Kjolhaug's (1986) study was severe and his findings may not reflect typical swamp rabbit behavior during winter. Only 2 other studies (Gould 1974, Zollner et al. 2000*a*) have used telemetry as the principal method to investigate how swamp rabbits use available space.

Although we had reliable data on current swamp rabbit status and distribution in Illinois (Woolf 1998), we lacked fundamental knowledge of the population ecology and demographics to assess viability and develop an effective population and habitat management plan. Therefore, we used telemetry to investigate swamp rabbit population parameters (survival, home range, and movement patterns) in Illinois to contribute to the scientific foundation of effective management of the species in Illinois.

STUDY AREAS

Trapping was conducted on 3 sites in Pulaski County (Hodges Creek, Cypress Slough, and Belrose Reserve) November 1998-February 1999; 2 sites in Massac County (Big Bay and Main Ditch) November 1998-February 1999; and 2 sites in Alexander County (BI and HLCA)

January-March 2000. The forest cover type on all sites was southern bottomland hardwood forest within the floodplain of Bay Creek and the Mississippi, Ohio, and Cache rivers.

Big Bay is a 62-ha privately owned site consisting of small woodlots surrounded by crop fields and pasture along Bear Creek Ditch. Dominant overstory species included oaks (*Quercus* spp.) and sycamore (*Platanus occidentalis*). Dominant understory species included honeysuckle (*Lonicera* sp.), grape (*Vitis* sp.), and grasses.

Main Ditch is a 347-ha tract owned by Westvaco Company managed for commercial timber production. The majority of the site consisted of a birch (*Betula* spp.) and sycamore plantation with occasional areas where the overstory included oaks and shagbark hickory (*Carya ovata*). The understory was sparse throughout most of the plantation area with thickets of honeysuckle, *Rubus*, grape, poison ivy (*Toxicodendron radicans*), and herbaceous vegetation extending from either side of a railroad track that ran through the site.

Hodges Creek is a 250-ha privately owned tract of bottomland timber along Hodges Creek near its confluence with the Ohio River surrounded by agricultural fields and pastures. Dominant overstory species included oaks, maples (*Acer* spp.), elm (*Ulmus* sp.), and hackberry (*Celtis* sp.). Dominant understory species included giant cane, *Rubus*, honeysuckle, and cocklebur (*Xanthium strumarium*).

Cypress Slough is a 111-ha narrow corridor of floodplain forest consisting of cypress (*Taxodium distichum*)-tupelo (*Nyssa aquatica*) swamp and stands of oaks, willow (*Salix* spp.), ash (*Fraxinus* sp.), and elm surrounded by agricultural land. Dominant understory species included giant cane, *Rubus*, and grasses.

Belrose Reserve is an approximately 60-ha waterfowl management unit along the Cache River within the Cypress Creek National Wildlife Refuge. Trapping was conducted within the narrow strip of forest along the Cache River dominated by willow, birch, cottonwood (*Populus deltoides*), and elm. The forested area is bordered by the waterfowl management area on one side and agricultural land on the other. Dominant understory species included giant cane, greenbrier, *Rubus*, cottonwood, and willow.

Bumgard Island is a 673-ha floodplain forest along the Mississippi River on the river side of the levee owned by Anderson Tully Company managed for commercial timber production. Dominant overstory species included willow, sycamore, cottonwood, maple, hackberry, and sweetgum (*Liquidambar styraciflua*). Dominant understory species included willow, cottonwood, honeysuckle, grape, kudzu (*Pueraria lobata*), and giant ragweed (*Ambrosia trifida*).

Horseshoe Lake Conservation Area is a state owned natural area. Trapping was conducted within the 250-ha public hunting area south of the Horseshoe Lake spillway. Dominant overstory species included cottonwood and sycamore adjacent to a cypress-tupelo swamp. Dominant understory species included cottonwood, willow, deciduous holly (*Ilex decidua*), and herbaceous vegetation.

METHODS

Capture

Traps were set 20 November-19 December 1998 at Big Bay, Cypress Slough, and Belrose Reserve; 24 January-2 February 1999 at Hodges Creek; and 2-19 February 1999 at Main Ditch. Trapping was conducted 20 January-13 February and 21 February-10 March 2000 at BI and 10-17 March 2000 at HLCA.

Burlap covered box traps were placed in runways in areas of high use in each patch with ≤36 traps set per patch. Initially, traps were not baited to minimize the probability of capturing nontarget species (Korte 1975). However, traps were baited with apples in 1998-99 after trapping on a site for 4-6 days without capturing a rabbit, and all traps were baited in 2000. Captured rabbits were removed from traps using a capture bag and uniquely marked with an eartag. Also, they were sexed, weighed, and fitted with a radio transmitter with mortality sensor to monitor movements and survival. Rabbits were monitored for mortality immediately after capture, and a 3-day recovery period was allowed before recording movements. Rabbits were monitored from 3 days after capture until death or transmitter failure.

Locations

Collared rabbits were located 4 times/week 3 February-4 May 1999 and 27 January-23 June 2000 using a receiver and a handheld yagi antenna. Rabbits were located twice during crepuscular hours and twice at midday (1000-1400 h) each week, with the order of time blocks for obtaining locations randomly selected each week. Crepuscular locations were obtained in the early morning and evening as close as possible to sunrise and sunset with the hours adjusted as the season progressed so locations were obtained within 2 hours of sunrise and sunset. Collared rabbits were located 3 times/week 26 June-1 September 2000; once each at early morning, midday, and evening. All locations were >24 hours apart to increase the likelihood of independence of observations.

Animals were located by homing to the strongest signal, with an effort made to locate the rabbit without flushing to minimize disturbance. Locations were marked on a 1:5,000 7.5' topographic map overlayed with a 50-m grid in 1999. Locations were marked on 1:2,000 DOQQs or 7.5' topographic map overlayed with a 50-m grid in 2000.

Survival

Collared rabbits were monitored for survival when locations were obtained 3 February-4 May 1999. Rabbits were monitored daily for survival 23 January-13 February and 21 February-10 March 2000, and when locations were obtained 11 March-1 September 2000. Thereafter, survival was monitored weekly until 15 October 2000.

Daily survival rates were calculated using the program MICROMORT (Heisey and Fuller 1985) for comparison to those reported by Kjolhaug (1986). Seasonal survival rates also were calculated. We used the bias corrected rates suggested by Heisey and Fuller (1985) because some sample sizes were small and we did not locate rabbits every day. Survival rates were calculated based on the number of rabbits collared and the number of deaths occurring over intervals. A staggered-entry with 1-week intervals was used in calculating survival rates. Rabbits were eligible for entry into the interval if they were equipped with a transmitter at the start of any interval (Pollock et al. 1989). Seasons were defined as periods with similar environmental conditions using the criteria from Kjolhaug (1986). Fall-winter included all periods between 1 January and 15 April, and spring-summer (15 April-5 October) began when green vegetation developed to 25 cm height. Kjolhaug (1986) subdivided fall-winter into periods of flooding and those with and without snow >2.5 cm; the periods without flooding or snow were labeled leaf-off. We had no periods of flooding or snow so the entire fall-winter time period corresponded to his leaf-off category. The z-test (Pollock et al. 1989) was used to compare survival between sex and season.

Home range

The UTM coordinates of the location of each swamp rabbit were used to estimate home range size. Swamp rabbit locations marked on DOQQs or topographic maps were digitized in ArcView (Environmental Research Systems Institute, Redlands, California, USA), and the UTM coordinates and associated rabbit information were exported for calculation of home range estimates in RANGES V (Kenwood and Hodder 1996). Following the criteria of Kjolhaug and Woolf (1988), seasonal home ranges were calculated for all rabbits for which I had $\geq$10 locations for the season. Annual home ranges were calculated for all rabbits for which seasonal home ranges were available in both seasons. The Home Range Extension (Rodgers and Carr 1998) for ArcView was used to calculate interfix distances.

We calculated 100% minimum convex polygon (Mohr 1947) estimates of home range to compare to home ranges reported by Kjolhaug and Woolf (1988). Other studies (Smith et al. 1993*b*, Zollner et al. 2000*a*) estimated swamp rabbit home range using harmonic mean (Dixon and Chapman 1980) and kernel estimators (Worton 1995). We did not have enough fall-winter locations to estimate home range using harmonic mean or kernel estimators. Therefore, we calculated 95% home range estimates using both harmonic mean and fixed kernel with least squares cross-validation smoothing for spring-summer and annual estimates. Home range overlaps were evaluated using RANGES V (Kenwood and Hodder 1996). Kruskal-Wallis one-way analysis of variance (Hollander and Wolfe 1973) was used to compare home ranges between sexes, seasons, and to the results obtained by Kjolhaug and Woolf (1988). Wilcoxon signed rank tests (Sprent 1993) were used to compare home range estimator methods.

Utilization plots were calculated with an increment area analysis in RANGES V (Kenwood and Hodder 1996) to determine the isopleth that would define a meaningful core area for spring-summer home ranges. Fall-winter home ranges lacked an adequate number of locations for establishing a definitive core area (Spencer and Barrett 1984).

RESULTS

Trapping

Traps were set for 474 total trap nights of effort 20 November-19 December 1998, but no swamp rabbits were captured. Between 24 January-19 February 1999 trap success was poor with 1 rabbit captured at Hodges Creek in 132 trap nights and 4 rabbits captured in 332 trap nights (1/83 trap nights) at Main Ditch. However, 2 areas of the Main Ditch site were trapped with no success 2-8 February and a success of 1/45 trap nights 8-19 February. Trapping effort at Hodges Creek was hampered by high water inundating the majority of the site after the initiation of trapping, including low areas where traps were set. Other species captured incidentally were raccoon (*Procyon lotor*), eastern cottontail (*Sylvilagus floridanus*), eastern fox squirrel (*Sciurus niger*), and opossum (*Didelphis virginianus*).

Between 20 January and 13 February 2000, 13 rabbits were captured in 655 trap nights (1/50 trap nights) on BI with 28 incidental captures of raccoons and opossum. Five rabbits were captured 6 times, with 68 incidental captures, in 565 trap nights (1/90 trap nights) on BI between 21 February and 10 March. On Horseshoe Lake Conservation Area, 1 rabbit was captured in 174 trap nights with 11 incidental captures. The majority of rabbits were captured on BI between 20

January and 7 February when 13 rabbits were captured in 471 trap nights (1/36 trap nights) with 11 incidental captures.

Extremely low recapture rates prevented the use of ratio-estimator models (Pollock et al. 1990) to estimate population density on the sites trapped. Therefore, density was estimated using the minimum number alive (Otis et al. 1978). Minimum density estimates were 1.25/ha for BI, 0.71/ha for Hodges Creek, 1.0/ha for Main Ditch, and 0.5/ha for HLCA.

Survival

Only 3 rabbits captured in 1999 yielded survival estimates (Table 5). Two deaths that could be evaluated were attributed to mammalian predation. One rabbit at Main Ditch had an unknown fate since the signal could no longer be detected after 49 days. The other rabbit was still alive 107 days after capture when monitoring was halted.

Fifteen rabbits were killed by predators in 2000 (Appendix D); 10 during fall-winter (2 female, 4 male) and 5 (2 female, 3 male) during spring-summer. Four deaths (2 female, 2 male) were assumed to be capture related since they occurred 1, 2, 4, and 8 days after capture and were censored from the data before calculating survival. The other 11 mortalities occurred 19, 23, 30, 48, 54, 69, 101, 194, 209, 218, and 224 days after capture. All mortalities were caused by predation, with the likely predators being great horned owl (*Bubo virginianus*) (3), coyote (*Canis latrans*) (2), mammalian (5), and unknown (5).

There was no difference in daily or seasonal survival rates between sexes, seasons, or years, except for between years if the lost contact on Main Ditch was assumed to be alive (Table 5). Kjolhaug (1986) reported a higher fall-winter daily survival rate (s = 1.0) on BI. All of his mortality for the corresponding time period occurred during flooding (s = 0.973, 95% 0.949-0.996) and winter (BI s = 0.989, 95% C.I. 0.9785-0.9997; pooled s = 0.9766, 95% C.I. 0.9615-0.9899), where confidence intervals overlapped with our results for BI. Kjolhaug (1986) reported a lower spring-summer daily survival rate (s = 0.993, 95% C.I. 0.9856 - 1.0), and study period survival rate (0.097, 95% C. I. 0.0213-0.4406), but the confidence intervals overlapped.

Table 5. Daily and seasonal survival rates (S) and 95% confidence intervals (C.I.) for swamp rabbits monitored 3 February-4 May 1999 at Main Ditch, Massac County and 23 January-15 October 2000 at Bumgard Island and Horseshoe Lake Conservation Area Goose Hunting Area, Alexander County, Illinois. Seasons were divided into fall-winter (Jan-15 Apr) and spring-summer (15 Apr-15 Oct). Missing values (-) indicate that rabbits were not monitored long enough to calculate survival for that season.

		Daily survival rates				Seasonal survival rates					
		Fall-winter		Spring-summer		Fall-winter		Spring-summer		Annual	
Site	*n*	S	C.I.	S	C.I.	S	C.I.	S	C.I.	S	C.I.
Main Ditch[a]	3	1.0A[b*]	1.0	-	-	1.0B[c*]	1.0	-	-	-	-
Main Ditch[d]	3	0.994[e*]	0.982-1.0	-	-	0.604[f*]	0.287-1.0	-	-	-	-
Bumgard Island											
females	8	0.994[*]	0.985-1.0	0.996[*]	0.991-1.0	0.559[*]	0.285-1.0	0.488[*]	0.175-1.0	0.291[*]	0.082-1.0
males	9	0.989[*]	0.979-0.9997	0.997[*]	0.993-1.0	0.451[*]	0.231-0.991	0.380[*]	0.124-1.0		
males[g]	10	0.990[*]	0.981-0.9998	0.997[*]	0.992-1.0	0.494[*]	0.269-0.997	0.486[*]	0.176-1.0	0.197[*]	0.054-0.720
pooled[g]	18	0.992A[*]	0.985-0.998	0.996[*]	0.993-0.9996	0.530B[*]	0.332-0.893	0.407	0.205-0.921	0.237	0.096-0.581

[*]$0.101 < z < 1.228$, $0.219 < P < 0.920$ for comparisons between seasons within sex, between sex within season, and between years: columns with the same letter indicate significant differences A - $z = 2.46$ $P < 00.014$, B - $z = 3.42$, $P < 0.0006$

[a]Assuming lost contact was alive

[b]Survival decreased to 0.995 (95% C.I. 0.985 - 1.0) if additional 2 weeks monitored was included.

[c]Survival decreased to 0.571 (95% C.I. 0.190 - 1.0) if additional 2 weeks monitored was included.

[d]Assuming lost contact was a mortality

[e]Survival decreased to 0.990 (95% C.I. 0.975 - 1.0) if additional 2 weeks monitored was included.

[f]Survival decreased to 0.374 (95% C.I. 0.094 - 1.0) if additional 2 weeks monitored was included.

[g]Includes male captured at Horseshoe Lake Conservation Area

Home Range

Home ranges were determined for 2 rabbits in 1999 and 12 rabbits in 2000 (Table 6). Nine rabbits were used to calculate spring-summer and annual home ranges (Table 6). There was no difference between male and female home ranges for any season in 2000 (Table 6), nor did spring-summer home ranges differ from fall-winter home ranges ($H = 0.67$, $P = 0.415$). There was no difference in spring-summer home range estimates among the 3 methods used ($0.180 < P < 0.217$). The extremely small sample sizes for sites other than BI precluded statistical tests between sites, but home ranges tended to be larger on Main Ditch (Table 6). Our minimum convex polygon (MCP) estimates of home range for 2000 did not differ from Kjolhaug and Woolf's (1988) estimates for leaf-off ($H = 0.01$, $P = 0.925$), spring-summer ($H = 0.21$, $P = 0.643$), or annual ($H = 0.36$, $P = 0.549$) home ranges.

The increment area analysis failed to identify an isopleth that characterized core area for the swamp rabbits. The inflection point for the majority of rabbits was >80%, indicating rabbits were not using core areas within the habitat.

Mean overlap for all individual home ranges was 6.4% in 1999 and 34.8% in 2000. There was less intrasexual overlap in home ranges during spring-summer than fall-winter (Table 7). However, the overlap for all individual home ranges remained about the same between seasons (Table 7). There was much more overlap in home ranges among males than females, with more extensive intersexual home range overlap than intrasexual.

Swamp rabbits tended to be sedentary, moving short distances and staying in a localized area. The majority (78.2%) of interfix distances on BI and HLCA were <50 m with nearly half (44.6%) <25 m (Fig. 2). The longest distance not associated with a mortality was 220 m, and only 2 (0.4%) movements were >200 m. However, interfix distances on Main Ditch tended to be larger and more evenly distributed (Fig. 2) with fewer short distances and 9 (19.6%) movements >200 m. Although interfix distances tended to be lower during spring-summer than fall-winter on BI (Table 8), only 1 male and 1 female had significantly lower mean spring-summer interfix

Table 6. Seasonal home range estimates (ha) and number of locations used (*n*) for swamp rabbits at Main Ditch, Massac County, Illinois February-May 1999 (males only) and Bumgard Island and Horseshoe Lake Conservation Area Goose Hunting Area, Alexander County, Illinois, January-September 2000. Home ranges were estimated using 100% minimum convex polygon (MCP), 95% harmonic mean (HM), and 95% fixed kernel (FK) methods.

	Fall-winter		Spring-summer				Annual			
Frequency	*n*	MCP	*n*	MCP	HM	FK	*n*	MCP	HM	FK
Main Ditch										
143	12	4.5								
414	14	4.7								
Bumgard Island and Horseshoe Lake Conservation Area										
female										
594	19	1.4	48	1.1	1.4	0.9	67	1.9	1.6	1.4
563	17	0.2	50	1.4	1.4	1.2	67	1.4	1.6	1.1
505	26	0.5								
264	33	0.3	10	0.3	0.06	0.5	43	0.5	0.6	0.5
113	26	0.8	42	0.4	0.5	0.6	68	0.8	1.3	0.9
Mean[a]		0.6A		0.8B	0.8C	0.8D		1.2E	1.3F	1.0G
male										
534	15	0.6	41	1.0	1.3	0.5	56	1.3	1.4	1.4
474	15	0.4	48	1.4	1.5	1.0	63	1.5	1.7	1.2
354	19	3.0	50	1.6	1.5	1.2	69	4.0	4.2	1.7
293	25	1.3	49	0.5	0.7	0.4	74	1.6	1.4	0.6
204	14	1.2								
023	16	1.5								
234[b]	14	0.1	51	2.5	2.4	3.0	65	2.5	2.8	1.1
Mean[a]		1.2A		1.4B	1.5C	1.2D		2.2E	2.3F	1.2G
Pooled		0.9		1.1	1.2	1.0		1.7	1.8	1.1

[a]Means with the same letters indicate no differences (0.138 > P > 0.807).
[b]Rabbit captured at Horseshoe Lake Conservation Area.

Table 7. Percentage overlap of swamp rabbit home ranges on Main Ditch, Massac County, Illinois January-April 1999 and Bumgard Island, Alexander County, Illinois, January-October 2000.

	Fall-winter	Spring-summer	Annual
Main Ditch	6.4	-	-
Bumgard Island			
male	22.3	13.8	17.2
female	7.5	0.0	0.0
all	28.0	26.4	34.8
female-male[a]	59.3	41.4	62.2
male-female[b]	23.1	23.0	35.6

[a]% of female home range overlapped by males.
[b]% of male home range overlapped by females.

Table 8. Mean interfix distance (m) and standard deviation (SD) for swamp rabbits captured February 1999 at Main Ditch, Massac County, Illinois and January-March 2000 at Bumgard Island and Horseshoe Lake Conservation Area, Alexander County, Illinois. Seasons were defined as fall-winter (Jan-Apr 15) and spring-summer (15 Apr-15 Oct). Missing values (-) indicate that no locations were collected for that season.

	Fall-winter			Spring-summer		
Animal #	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Main Ditch						
143	11	244.9	140.0	8	41.3	37.8
324	8	108.1	54.0	-	-	-
414	13	106.2	66.8	6	64.3	38.9
Bumgard Island						
Female						
594	18	44.4	51.1	48	29.9	19.3
563	16	24.2	12.8	50	45.0	25.0
505	25	31.7	43.2	-	-	-
444	6	39.5	21.8	-	-	-
264	32	20.4	18.3	10	31.8	25.5
113	25	56.4	42.5	43	25.0	16.1
Mean	122	35.1	44.7	151	33.6	22.4
Male						
534	14	49.7	29.4	41	36.2	29.6
474	14	33.5	20.8	47	28.9	17.9
383	7	62.4	26.6	-	-	-
354	18	75.9	61.0	50	39.9	29.3
293	24	40.9	42.1	49	26.7	18.5
204	13	51.1	48.9	-	-	-
173	5	30.6	26.4	-	-	-
023	15	61.2	52.3	-	-	-
Mean	110	51.7	44.7	187	32.9	24.8
Horseshoe Lake Conservation Area						
234	12	20.0	11.2	52	46.9	32.7

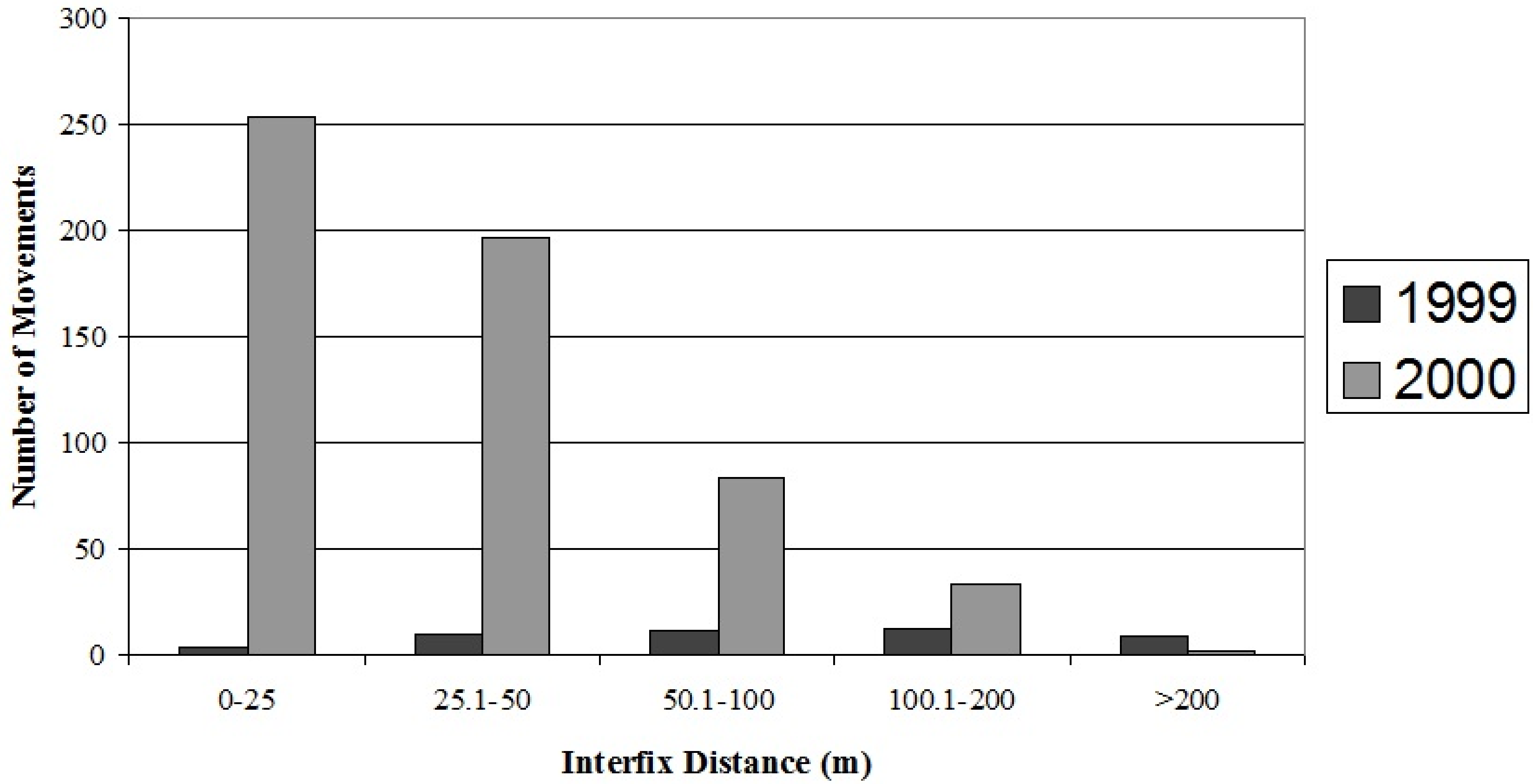

Figure 2. Number of swamp rabbit movements at Main Ditch, Massac County, Illinois February-May 1999 and Bumgard Island and Horseshoe Lake Conservation Area, Alexander County, Illinois January-October 2000 in 5 distance categories.

distances. The male at HLCA and 1 female at BI had higher mean spring-summer interfix distance, but the fall-winter locations for both these rabbits were likely a preferred form. Males had a higher (t = 3.05, df - 213.7, P = 0.0027) fall-winter mean interfix distance than females, but there was no difference in spring-summer (t = 0.29, df - 336, P = 0.773). When all animals were pooled, there was no difference (t = 0.38, df -188.2, P = 0.704) in mean interfix distance for females between seasons, but males had a lower mean spring-summer interfix distance (t = 4.07, df - 149.1, P =0.0001).

DISCUSSION

Survival

While there were no differences in survival between seasons, there were differences in the timing of the mortalities. Winter mortality occurred throughout the winter period, but mortality during spring was more clumped. The longest mortality free period during winter was 27 days, while the longest mortality free span during spring-summer was 94 days. There were no spring-summer days with multiple mortalities or spans between mortalities of <7 days until after 1 October, and the majority of mortalities (60%) occurred at the end of the season in October.

The survival rates from this study were similar to those obtained by Kjolhaug (1986), but were slightly higher. All of the winter mortality Kjolhaug (1986) reported occurred during the seasons he defined as flooding, or winter with snow. However, the winter of 1999-2000 was very mild, and there were no days with significant snow accumulation nor any days during which any of the island was inundated. All mortalities which occurred during our study at comparable times to these seasons were considered fall-winter (or leaf-off) mortalities, resulting in a lower survival during leaf-off than Kjolhaug (1986) reported and a higher estimate than his fall-winter with snow or flooding during a comparable time period. Although statistical comparisons between our fall-winter survival and Kjolhaug's (1986) fall-winter survival with snow or flooding were not possible, the confidence intervals of the estimates overlapped. Kjolhaug (1986) suggested that survival was higher during mild winter environmental conditions, but decreased significantly during flooding and periods of snow-cover. While this may hold for winters in which harsh environmental conditions occur, our results suggest that mortality during mild winters may be nearly as high as that occurring under the stressor conditions Kjolhaug (1986) reported.

Home range

The extremely small fall-winter home range estimates for some rabbits raises concerns over what these estimates defined. Swamp rabbits are crepuscular to nocturnal (Gould 1974, Holler and Marsden 1970) so locations may not have been obtained when rabbits were most active. The times at which crepuscular locations were taken were chosen to maximize the likelihood that rabbits were active, but some were likely to be form locations more than sites of activity, particularly during fall-winter. As the season progresses and sunset occurs later in the day, onset of activity is delayed until April when activity begins before sunset (Holler and Marsden 1970). Because no locations were collected at night and several of the rabbits exhibited a strong fidelity to 1 or 2 form locations that affected the home range estimates, our fall-winter home range estimates may have been identifying preferred forms rather than home range for approximately half the rabbits, particularly the females. The 3 females with MCP estimates $\leq$0.5 ha exhibited a strong fidelity to a form site, 2 (264 and 505) to single brush piles and 1 (563) to a patch of thicker vegetation surrounded by relatively open areas. The majority of locations were in or near these forms, but capture or telemetry locations away from the brush piles and the presence of fecal pellets in the more open areas indicated that they range from these forms farther than most of the telemetry locations indicated. It appears that fall-winter home range estimates more likely identify preferred forms than home ranges.

Although we made statistical comparisons, the small sample sizes and concerns over what was defined make conclusions tenuous. However, trends from the data can be examined. Excluding the very small ranges, male and female home ranges were similar, but male home ranges, especially the annual, tended to be larger. Fall-winter and spring-summer home ranges were similar in size for both sexes. However, when home range size changed between seasons, females tended to contract their spring-summer home range and males tended to expand their spring-summer home range relative to fall-winter. There was a slight shift in home range between seasons so annual home ranges tended to be larger than either seasonal home range. Kjolhaug and Woolf (1988) reported similar patterns, and this seasonal difference also is seen in cottontails (Trent and Rongstad 1974, Althoff and Storm 1989). Smaller female home ranges during spring-summer relative to fall-winter and males may be a result of the greater availability of food and cover during spring and summer, females restricting movements to areas near the nest, and males increasing their movements seeking potential mates (Trent and Rongstad 1974, Althoff 1983).

With the exception of the 2 rabbits captured in 1999, home range estimates in this study were similar to those reported by Kjolhaug (1986) in Illinois and winter home ranges in Missouri (Toll et al. 1960) (Table 9). Fall-winter home ranges were similar to the 95% fixed kernel fall-winter estimates reported by Zollner et al. (2000*a*), but their inundated, spring-summer, and annual estimates were larger. Smith et al.'s (1993*b*) estimates calculated using MCP and harmonic mean were much larger. Possible explanations for smaller home range estimates in our study are a lack of nocturnal locations used to generate estimates and different responses by rabbits to habitat quality and inundation patterns.

Zollner et al. (2000*a*) suggested that their use of nighttime locations may have contributed to their larger home ranges because sampling at night when nocturnal animals are more active can lead to larger home range estimates (Holzman et al. 1992). However, Zollner (1993) reported larger home range estimates derived from diurnal observations than those for nocturnal observations, and the nocturnal home range estimates greatly overlapped or were contained entirely within the diurnal estimates. In addition, rabbits should have been active when crepuscular locations were obtained during the spring-summer season.

Table 9. Home ranges (ha) reported from previous swamp rabbit studies.

Method and Study	Location	Season	Sex	Home Range	Method[a]
Telemetry					
Zollner et al. (2000*a*)[b]	Arkansas	Fall-winter	female	1.00	95% kernel
		Spring-summer	both	4.30	
		Inundated	female	4.90	
		Dry	female	1.20	
		Annual	female	3.10	
Smith et al. (1993*b*)[b]	Arkansas	Fall-winter	female	7.10	MCP
		Spring-summer	both	19.80	
		Inundated	female	11.40	
		Annual	female	20.20	
Smith et al. (1993*b*)[b]	Arkansas	Fall-winter	female	12.80	HM
		Spring-summer	both	48.40	
		Inundated	female	11.60	
		Annual	female	44.30	
Kjolhaug and Woolf (1988)	Illinois	Fall-winter	both	0.79	MCP
		winter	both	0.61	
		flood	both	0.60	
		Spring-summer	both	0.83	
		Annual	both	1.83	
Gould (1974)	Louisiana	Fall-spring	male	4.30	MCP
			female	2.50	
Trapping					
Mullin (1979)	Louisiana	Annual	male	1.50	MCP
			female	2.40	
Terrel (1972)[c]	Indiana	Fall-winter	both	4.50	MCP
Toll et al. (1960)	Missouri	Winter	male	0.73	MCP
			female	0.85	

[a]MCP - 100% minimum convex polygon; HM - 95% harmonic mean.
[b]Results are from the same data set.
[c]Also used visual observation.

Zollner et al. (2000*a*) also suggested that the patchy nature of good habitat and response to the dynamic nature of water flow and inundation may have caused more movement that was reflected in their larger home range sizes. The habitat at BI and HLCA was relatively homogenous with a minimal patchy distribution of cover and good habitat. Rabbits did not need to move large distances to remain in good habitat with plentiful resources. In contrast, good habitat at Main Ditch and in Arkansas (Zollner et al. 2000*a*) was patchily distributed. Although the small sample size at Main Ditch make comparisons tenuous, the larger home range estimates there and Zollner et al.'s (2000*a*) larger estimates suggest that these differences are a response to habitat structure.

The sex of neighboring rabbits influenced home range overlap. There was extensive overlap in intersexual home ranges with several females having most or all of their home range encompassed by a single male. The degree of intrasexual overlap depended on the season and sex of the animal. There was extensive overlap among males during fall-winter with the majority (71.4%) overlapping home ranges of 3 or 4 other males and only 1 male having an exclusive home range.

Females exhibited exclusive home range use during spring-summer with very limited overlap during fall-winter. The overlap among females during fall-winter was a single female that minimally overlapped 2 other female ranges, but the overlap with 1 range did not occur until the other female was killed. Although females exhibited exclusive use during spring-summer, the spatial distribution of the females that lived through winter were such that only 2 were likely to overlap anyway. Kjolhaug and Woolf (1988) also reported extensive intersexual home range overlap but limited intrasexual overlap. In contrast, Toll et al. (1960) reported considerable overlap in both intra- and intersexual home ranges.

Swamp rabbits were relatively sedentary and rarely moved far between locations. They tended to move farther distances during fall-winter than spring-summer on BI, where 75% of movements >100 m occurring during fall-winter. Distances moved in this study are lower than those reported by Terrel (1972) and Mullin (1979), but those studies included juveniles which were likely to increase the mean distance with movements to establish a home range. Another factor likely to explain the shorter distance moved is better quality habitat allowing the rabbits to meet their needs with shorter distances traveled. Other studies have reported movements of up to 700 m on areas with lower rabbit densities (Terrel 1972, Korte 1975). Good habitat on Main Ditch was more patchily distributed, and rabbits move farther distances there than on BI.

We were unable to provide evidence to support the conjecture that swamp rabbit populations have a metapopulation structure in Illinois. Since juvenile males tend to be the dispersing individual for leporid species (Forys and Humphrey 1996), dispersal movements may have occurred before the initiation of trapping and thus went undetected. Further investigations into swamp rabbits movements and dispersal is needed to determine if swamp rabbits have a metapopulation or a patchy population structure.

APPENDIX D

Appendix D. Capture record, data recorded at capture, and fate for swamp rabbits captured on sites in southern Illinois January-February 1999 and January-March 2000. Data recorded included the ear tag number (ID), radio transmitter frequency, sex, and weight.

Site	Date	ID	Frequency	Sex	Weight	Fate	Date of fate	Days to fate
Hodges Creek	01/30/99	1008	148.053	m	2,310	mortality	03/11/99	40
Main Ditch	02/13/99	1003	148.143	m	2,100	alive	05/01/99	-
Main Ditch	02/15/99	1005	148.414	m	1,770	mortality	04/30/99	74
Main Ditch	02/16/99	1009	148.324	m	1,830	unknown	04/06/99	49
Bumgard	01/22/00	1002	148.505	f	2,260	mortality	03/11/00	69
Bumgard	01/26/00	1004	148.084	m	1,820	mortality	02/03/00	8
Bumgard	01/26/00	1001	148.383	f	1,780	mortality	01/27/00	1
Bumgard	01/31/00	1007	148.173	f	1,940	mortality	02/02/00	2
Bumgard	02/01/00	1015	148.264	f	1,860	mortality	05/12/00	81
Bumgard	02/01/00	1017	148.534	m	1,940	mortality	02/05/00	4
Bumgard	02/02/00	1010	148.113	f	2,220	mortality	08/14/00	194
Bumgard	02/02/00	1012	148.383	m	2,130	mortality	02/25/00	23
Bumgard	02/02/00	1006	148.444	f	1,860	mortality	02/21/00	19
Bumgard	02/04/00	1014	148.356	m	2,180	alive	10/15/00	-
Bumgard	02/04/00	1013	148.204	m	1,910	mortality	03/23/00	48
Bumgard	02/05/00	1018	148.023	m	2,140	mortality	04/14/00	69
Bumgard	02/07/00	1016	148.293	m	1,820	alive	10/15/00	-
Bumgard	02/22/00	1025	148.173	m	2,330	mortality	03/23/00	30
Bumgard	02/27/00	1011	148.594	f	1,900	alive	10/15/00	-
Bumgard	02/28/00	1019	148.474	m	2,250	mortality	10/03/00	218
Bumgard	02/28/00	1020	148.534	m	2,080	mortality	10/10/00	224
Bumgard	02/28/00	1025r	148.173	m	2,120	mortality	03/23/00	30
Bumgard	03/04/00	1023	148.563	f	2,200	alive	10/15/00	-
HLCA	03/15/00	1022	148.234	m	1,760	mortality	10/10/00	209

JOB R-2.3: MANAGEMENT MODEL

Objective: Develop and evaluate alternative management strategies for swamp rabbits occupying wetland and riparian habitats in Illinois.

Swamp rabbit status and distribution in Illinois is now established, but concern remains about risk of decline because of the fragmented nature of remaining habitats in Illinois. If the remaining populations and their habitat are not managed, they might become more vulnerable to stochastic decline or extirpation (Palmer et al. 1991). Development of a spatially-explicit population model would help identify risks to the population.

All potential habitat had not been identified. While most of the larger and more important habitat patches were known, all patches needed to be identified to build a spatially-explicit model. Porath (1997) used a geographic information system (GIS) to help identify areas to search, but did not build an image of potential swamp rabbit habitat usable in a model. He focused on identifying and searching large patches, and probably missed some habitat in the northern counties and many smaller patches. These smaller areas may be an important component for dispersal and connectivity among the larger patches.

Allen (1985) developed a habitat suitability index (HSI) model for swamp rabbits based on water regime and tree, shrub, and herbaceous canopy cover. Since the model was developed for application over the swamp rabbit's entire range, the method used to calculate the HSI varied based on habitat type. Allen's (1985) model was used as the basis for modeling swamp rabbit habitat suitability in Indiana (Goldblatt 1992) and Kentucky (Busch 1995) using a GIS and National Wetland Inventory (NWI) data. These models attempted to identify areas where rabbits occurred, but neither was field checked or validated.

Knowledge of the population ecology, and possibly the metapopulation dynamics, of the swamp rabbit will be the scientific foundation of effective management of the species in Illinois. The construction of a management model incorporating this knowledge will facilitate management of populations on public lands and also provide recommendations to manage the species on private lands. Development of effective management models can lead to formation of habitat conservation plans to protect these important wetlands and their biota.

METHODS

Potential Habitat

Potential swamp rabbit habitat was identified in 23 southern Illinois counties using the Illinois Land Cover (ILC) database (Illinois Department of Natural Resources 1996). The ILC database contained a raster image of land cover/land use for the entire state that was projected to UTM and clipped for the 23 southern counties. All pixels classified as forested wetland, swamp, or shallow water wetland were identified, and the resulting image was converted to a shapefile for further analysis.

The wetlands portion of the ILC database contains NWI database information. The NWI classification identifies 3 types of wetland systems in Illinois: palustrine, lacustrine, and riverine. Only palustrine systems were considered swamp rabbit habitat because lacustrine and riverine systems lack the appropriate vegetation. All other classes were considered nonhabitat. Areas classified as palustrine within the NWI database were identified and converted to a shapefile. This image was merged with the ILC database image to associate a NWI code with areas identified as potential swamp rabbit habitat.

The initial image of potential habitat contained many patches that acted as 1 functional site, but were represented in the image by multiple polygons that either shared adjacent borders or were close enough to be a single functional site. To condense the number of areas represented, polygons that were adjacent to or within 150 m of other polygons were merged to form 1 polygon.

Small isolated sites are probably biologically insignificant and do not contribute to maintaining the swamp rabbit populations in the state. All patches <5 ha were identified and deleted. All patches <50 ha were identified and distance criteria were applied to delete those that were isolated. Initially, only small (<50 ha) patches <5 km from large patches (>100 ha) were retained. This probably resulted in a liberal estimate of potential habitat since 5 km is a long distance for swamp rabbit movement. A more conservative estimate of potential habitat was obtained by retaining only small patches ≤2 km from large patches.

To eliminate errors resulting from misclassifying data or changes in land use since the classification, the image was ground-truthed. Corrections also were made to the shapes of the remaining areas based on observations while ground-truthing the image and interpretation of current aerial photography. The selection criteria were then reapplied to produce the final image of potential habitat. The Patch Analyst extension for ArcView was used to calculate the mean nearest neighbor distance of the patches.

Population Model

A spatially explicit, stage-structured, stochastic population model was developed using the program RAMAS/GIS (Akçakaya 1997) to evaluate risks to the population. This program is designed to link landscape data from a GIS with a metapopulation model by assigning habitat suitability values based on spatial data. The spatial structure of the model can be based on habitat data that is imported and analyzed according to a habitat suitability (HS) function that links the habitat characteristics to some habitat suitability measure. The image of potential habitat served as the spatial basis of the model. Habitat suitability values were assigned to patches in ArcView using the selection criteria described below. The image was then converted to a 50-m grid for importation into RAMAS/GIS.

Habitat Suitability Values.—Swamp rabbits occupy variable habitat making it difficult to detect vegetative differences useful for differentiating good and poor habitat from remotely sensed data. The habitat suitability model developed by Allen (1985) was too general to be useful in assigning habitat suitability values (Busch 1995). Porath (1997) sampled vegetation on occupied and unoccupied patches and was unable to develop a model that discriminated between the sites. It would require very extensive field work to measure habitat variables that might be useful to predict habitat suitability with certainty. Therefore, habitat suitability values were assigned to areas identified as potential habitat using subjective criteria based on the area assessments conducted while surveying swamp rabbit status. Since few of these patches had homogenous vegetation structure, patches were subdivided before assigning habitat suitability values. National Wetlands Inventory codes were used to identify areas permanently flooded or intermittently exposed, and habitat suitability values were assigned based on Allen's (1985) water regime index. Areas permanently flooded were given a suitability of 0, and intermittently exposed areas were assigned values of 0.1. The remainder of the patch was assigned habitat suitability values ranging from 0.3 to 1.0 based on the size of the patch, vegetative characteristics, and population level present when surveyed. Areas considered to be the most suitable habitat in the state, such as BI and some Cache River areas, were given suitability values of 1.0 with other areas given values relative to these sites. All sites with evidence indicating a high rabbit density were assigned suitability values of 0.9 or 1.0. Sites which were classified as having moderate density (Porath 1997) were given suitability values of 0.6, and low density sites were assigned values of 0.4 if >100 ha and 0.3 if <100 ha.

Link to Metapopulation.—The link between the habitat map and the metapopulation model was characterized by 2 parameters, threshold HS and neighborhood distance. These parameters are used by a patch-recognition algorithm to delineate patches on the habitat map that provide the spatial structure for the population model. Threshold HS is the minimum habitat suitability value below which the habitat is not suitable for reproduction and/or survival; this was set at 0.3. Neighborhood distance is used to identify nearby cells that belong to the same patch when identifying patches of suitable habitat. Neighborhood distance was set at 4 corresponding to approximately 200 m.

Carrying Capacity and Initial Abundances.—The mean carrying capacity (K) of a patch was assumed to be directly related to patch area and habitat suitability. The program allows carrying capacity for each population (or patch) to be calculated as a function of area or total habitat value within a patch (i.e., the sum of habitat values of all cells that are included in a patch). We used total habitat value instead of total area because area did not reflect the differences in habitat quality, and we estimated carrying capacity based on density. The maximum density was assumed to be 1.5 rabbits/ha based on trapping results and densities reported by Kjolhaug (1986). We used this density converted to a per cell basis (0.5 rabbits/cell) as a scaling constant in calculating K of each patch by multiplying it with the total habitat suitability of each patch. Since the vast majority of patches were heterogeneous in structure and contained portions unsuitable for swamp rabbits, K was calculated based on 75% of the patch being occupied. To evaluate sensitivity of the model to K, we estimated K at 50% and 100% occupancy. We also evaluated sensitivity to K using different densities on proportions of the patch such as 50% being occupied at the maximum density and 25% occupied at half maximum. We used the estimate of K to assign initial abundances with a stable age distribution on occupied patches, and patches on which swamp rabbits were absent when searched were assigned an initial abundance of 0.

Stage Structure.—The dynamics within each patch were modeled using a stage-structured, stochastic model with 2 stages (juveniles and adults). A stage-structured model in RAMAS/GIS is specified using a Lefkovitch matrix (Lefkovitch 1965, Caswell 2001) based on fecundity and survival for each stage. Values in the first row of the matrix are fecundities, and values in the second row for a 2 stage model are survival rates. In parameterizing this stage-structured model, we assumed (1) the population is censused immediately after each breeding season (a post-reproductive census, Caswell 2001), (2) all adults breed (so that the proportion of the previous year's adults who breed in the current year is simply the adult survival rate), and (3) juveniles do not breed in the year they are born.

Fecundity values were based on studies on swamp rabbit reproduction in Missouri (Toll et al. 1960, Holler et al. 1963, Sorensen et al. 1968). Breeding was modeled to occur only in adults since studies have found no breeding among juveniles (Martinson et al. 1961, Sorensen et al. 1968). Annual reproduction was estimated at 10.5 young/individual, with sensitivity being evaluated by changes of 25% increments. The maximum annual rate of increase was set at 1.5. Sensitivity of the model to this parameter was evaluated using an upper bound comparable to cyclic populations of snowshoe hares (*Lepus americanus*) during an increase ($\lambda = 2.0$; Keith and Windberg 1978) and a lower bound of 1.2. Survival values were based on estimates for rabbits in southern Illinois from Kjolhaug (1986) and this study, with an annual survival estimate of 0.18 and a standard deviation of 0.07.

Dispersal.—In our model, dispersal refers to the movement of rabbits among habitat patches, and dispersal rate is the proportion of a population dispersing to another specific population, not the total rate of dispersal from a given population. Dispersal rate may depend on the distance between the 2 populations, population abundance, and whether the rabbit is a juvenile or adult. Dispersal patterns of swamp rabbits are unknown, so they were based on movement trends observed in this and other studies of swamp rabbits (Kjolhaug 1986, Kjolhaug and Woolf 1988, Smith et al. 1993*b*), as well as dispersal patterns from other species of *Sylvilagus* (Forys and Humphrey 1996) and snowshoe hares (Windberg and Keith 1976). Dispersal was assumed to be low because of the small movements observed (Job R-2.2). In our model, dispersal was density dependent and occurred exclusively among juveniles. Dispersal distance fit an exponential model ($M = a \cdot \exp(-d/b)$), where M is the dispersal rate, d is the distance (km) between populations, a is the maximum dispersal rate, and b is the average dispersal distance. The model was fitted with $a = 0.25$ and $b = 0.75$ (Fig 3A). A maximum dispersal distance (D_{max}) of 3 km was used. To evaluate sensitivity of the model to dispersal, we used an upper bound of $a = 0.5$, $b = 1.5$, and $D_{max} = 5$ km, with a lower bound of $a = 0.05$ and $b = 0.2$ (Fig. 3A). We also modeled density independent dispersal.

Density Dependence and Allee Effects.—For most models we assumed a contest density dependence model, which uses the Beverton-Holt equation (Beverton and Holt 1957). We also modeled density dependence using a scramble model (Ricker 1975). Allee effects (Allee et al. 1949), which may cause a reduction in vital rates when populations are very small, have not been

Figure 3. Estimated dispersal rate (A) between 2 swamp rabbit populations as a function of distance (d) between the populations, and (B) correlation distance functions [C = exp (-D/b)] used in the model. The dispersal function is $M = a \cdot \exp(-d/b)$. The correlation function gives the correlation between the vital rates of 2 populations of a given distance (D) apart.

studied in swamp rabbits. We evaluated the influence of Allee effects by specifying a local extinction threshold for each population. The model assumes the population to be extinct once it falls below the local threshold, and the patch remains unoccupied unless recolonized. We set the local thresholds at 0, 2.5, 5, and 10% of the carrying capacity of the patch. The model need not accurately predict population dynamics at low abundances if the population is considered extinct when below the threshold. In addition, we specified a metapopulation threshold of 1,000 and calculated viability results in terms of falling below this threshold.

Catastrophes.—Flooding has the potential to have catastrophic effects on swamp rabbit populations (Conaway et al. 1960, Martinson et al. 1961). We incorporated 2 types of flooding in the model, with flood frequency taken from estimates by Knapp (1994) and river stage data from United States Geological Survey weather data stations. Short term floods can reduce swamp rabbit population abundance by increasing their risk of predation. Kjolhaug (1986) reported an approximately 10% decrease in survival during flooding so we incorporated a mild catastrophic decline of 10% with a 10% probability of occurrence. We evaluated sensitivity of the model to mild flood frequency and intensity of effect using no flooding and a 20% probability as bounds for probability of occurrence and 0 and 30% reductions in populations. A large scale prolonged flood has the potential to be more detrimental to swamp rabbit populations, but population response to prolonged flooding is unknown. We initially set this as a 60% decrease in populations with a 2.5% probability of occurrence. We used a lower bound of 40% decrease and an upper bound of 90% decrease in the population, and examined the influence of probability of occurrence using 0, 1.25, and 5% probability.

Demographic and Environmental Stochasticity.—Demographic stochasticity was incorporated by sampling the number of survivors from a binomial distribution and number of young produced from a Poisson distribution (Akçakaya 1997). In addition, we incorporated demographic stochasticity in dispersal, with the number of dispersers drawn from a binomial distribution. The model also was run without incorporating demographic stochasticity.

Environmental stochasticity was incorporated by sampling the set of vital rates from random (lognormal) distributions.

Environmental Correlation.—Parameters related to dynamics at the metapopulation level include the interdependence of environmental fluctuations among populations. The model used a function based on the distances between geometric centers of patches to calculate coefficients of correlation among population fluctuations. The function used was an exponential model $C = \exp(-D/b)$, where C is the coefficient of correlation between the vital rates of 2 populations, D is the distance (km) between the centers of the 2 populations, and b is a parameter that describes how fast the correlation declines with increased distance between populations. Values for the model parameters were based on correlation among rainfall and temperature values from weather stations in southern Illinois. The model was fitted with $b = 40$ (Fig. 3B). To evaluate sensitivity of the model to environmental correlation, we used an upper bound of $b = 80$, with a lower bound of $b = 15$ (Fig. 3B). We also modeled no environmental correlation.

Habitat Abundance.—To evaluate the relative importance of habitat changes as successional changes make habitat less suitable for swamp rabbits, we incorporated a negative temporal trend in carrying capacity. Temporal trend was evaluated using annual declines of 2, 5, and 10%.

Analysis and Viability.—Each simulation consisted of 1,000 replications with a 25 year duration. We choose a 25-year simulation period to avoid unrealistic assumptions of long-term stability of extrinsic factors that may affect swamp rabbit populations. In addition, successional changes in the habitat are likely to cause changes in populations over any longer period. Previous researchers have used longer simulation periods of 50 (Akçakaya and Atwood 1997) and 100 years (Doak et al. 1994) to evaluate risks to populations. However, the life history traits of the species differed from those of swamp rabbits (e.g., long-lived, lower reproductive rates) and required longer periods to detect population changes. We ran 3 (or more) simulations for each parameter using lower, median, and upper estimates of the parameter with median estimates of the other parameters (Table 10). Risks to the population we expressed using 2 measures: (1) probability of population decline and (2) risk of "quasi-extinction" or risk of falling below the metapopulation threshold. Differences for risk of decline curves from the median model were compared using a 2-sample Kolmogorov-Smirnov test (Press et al. 1986).

Management Alternatives.—We considered several management options. Option 1 assumed no action would be taken to improve conditions for swamp rabbits. Option 2 was an increase in habitat suitability on selected patches simulated by the use of an increasing trend in K on these patches. Option 3 was habitat management to improve connectivity among the patches. This was modeled by inclusion of riparian buffers connecting selected patches to decrease the distance between the patches. We also modeled a translocation of rabbits from 2 of the secure southern populations (BI and HLCA) to 2 sites in the northeastern counties along the Little Wabash River. An alternative stage matrix with reduced survival and fecundity was used for the translocated population. We modeled harvest levels of the population using median values of all parameters and harvest levels in 5% increments from 0 to 50% of the population. Not all swamp rabbit populations in Illinois are hunted. To more closely approximate harvest patterns in Illinois, we also ran models with the majority of the harvest in the southernmost counties, with protected sites having no harvest and <5 northern populations experiencing harvest. We also incorporated harvest into worst case and best case models with regard to reproduction and into models with a negative temporal trend in K. The worst case model set $R_{max} = 1.2$ and fecundity at 50%; we also ran low reproduction models with increased flooding. The best case model set R_{max} at 2.0.

RESULTS

Potential Habitat

The initial image identified 33,784 polygons covering 120,275 ha. Condensing the number of sites by merging near polygons resulted in the identification of 5,263 polygons covering the same area. However, the majority (96%) were <50 ha. Eliminating small isolated

Table 10. Low, median, and high estimates of parameters used in the swamp rabbit metapopulation model.

Parameter	Parameter estimate		
	Low	Median	High
Habitat suitability		0.3-0.4 low 0.6 moderate 0.9-1.0 high	0.5 low 0.75 moderate 0.9-1.0 high
Carrying capacity (K) multiplier[a]	0.5	0.75	1.0
Mean dispersal distance (km)		3	5
Dispersal parameters [b]	*a* = 0.5 *b* = 0.2	*a* = 0.25 *b* = 0.75	*a* = 0.5 *b* = 1.5
Annual maximum rate of increase	1.2	1.5	2.0
Density dependence type	scramble	contest	
Allee effects (local threshold as % of K)	0	2.5	5, 10
Density dependent dispersal	none	present	
Correlation of fluctuations (*b*)[c]	0, 15	40	80
Mild flooding probability	0	0.1	0.2
Mild flooding intensity[d]	0.0	0.1	0.3
Prolonged flooding probability	0.0125	0.025	0.05
Prolonged flooding intensity[d]	0.4	0.6	0.9
Metapopulation extinction threshold	500	1,000	

[a]This number is multiplied by the product of total habitat suitability of the patch and density converter to calculate carrying capacity.

[b]Dispersal is estimated by the function M = $a \cdot (-d/b)$ where d is the distance between patches.

[c]Environmental correlation of population parameters is estimated by the function C = $(-d/b)$ where d is the distance between patches.

[d]Intensity value represents the percent decline in the population.

sites and ground-truthing the resulting image produced a final image containing 142 sites covering 57,259 ha in 23 counties. The potential habitat was patchily distributed, and appeared as <10 clusters concentrated along the rivers and their tributaries when viewed at low resolution (Fig. 4). The mean nearest neighbor distance was 2.5 km. When small sites >2 km from large sites were excluded, 111 sites covering 55,591 ha were retained.

Population Model

With most parameter combinations, there was relatively little risk of total swamp rabbit extinction and the probability of decline for the population was low (Fig. 5). However, the probability of a 40% population decline was 0.25, with larger probabilities as percent decline decreased. With median estimates of all variables, there was 0% chance of total extinction, and the risk of falling below the metapopulation threshold of 1,000 was 0.084 (Fig. 5). The median time to fall below the threshold was >25 years.

Sensitivity of the model results are taken from cumulative time to decline curves, cumulative probability to fall below the metapopulation threshold curves, and metapopulation occupancy. The model was relatively insensitive to changes in dispersal (Fig. 6A,B), fecundity (Fig. 6C,D), local threshold (Allee effects) (Fig. 7A,B), or environmental correlation (Fig. 7C,D). However, the model with high dispersal was the only one to result in the colonization of some unoccupied patches, mostly in the southernmost counties.

The model was sensitive to changes in flooding, both frequency and intensity of effect, and the maximum rate of increase (R_{max}) (Fig. 8). It was most sensitive to changes in intensity of effect from prolonged flooding and prolonged flooding frequency. Decreasing R_{max} had a proportionately larger effect than increasing the parameter.

Incorporating a negative temporal trend in K caused an increase in the probability of falling below the metapopulation threshold (Fig. 9). It also resulted in a decrease in the average number of patches occupied at the end of 25 years. Although the probability of 100% or near 100% declines remained the same regardless of temporal trend, increasing the negative temporal

Figure 4. Potential swamp rabbit habitat in 23 southern Illinois counties as identified from Illinois land use/land cover database. The image served as the spatial basis for a spatially explicit, stage-structured stochastic population model.

Figure 5. Risk of decline (A) and risk of falling below the metapopulation threshold (B) for swamp rabbit populations in southern Illinois; dashed lines indicate 95% confidence intervals. The probability of decline curve (A) can be interpreted as "there is a Y% risk that, in year 25, the metapopulation abundance will be X% less than the initial abundance". For time to quasi-extinction (B), the continuous curve is the cumulative probability distribution, and it shows the probability of falling below the metapopulation threshold (1,000 individuals) at or before a specific time step. Each point on this cumulative curve can be interpreted as "there is a Y% risk that the metapopulation abundance will fall below the threshold in or before the year X".

Figure 6. Risk of decline (A) and risk of falling below the metapopulation threshold (B) for swamp rabbit populations in southern Illinois predicted by models with low, median, and high dispersal. Risk of decline (C) and risk of falling below the metapopulation threshold (D) for swamp rabbit populations in southern Illinois predicted by median model and models with increased and decreased fecundity. D is the 2-sample Kolmogorov-Smirnov test statistic for comparison to the median model.

Figure 7. Risk of decline (A) and risk of falling below the metapopulation threshold (B) for swamp rabbit populations in southern Illinois predicted by models with population thresholds set at 0, 2.5, 5, and 10% of the local population. Risk of decline (C) and risk of falling below the metapopulation threshold (D) for swamp rabbit populations in southern Illinois predicted by models with high, median, low, and no environmental correlation. D is the 2-sample Kolmogorov-Smirnov test statistic for comparison to the median model.

Figure 8. Risk of decline (A) and risk of falling below the metapopulation threshold (B) for swamp rabbit populations in southern Illinois predicted by the median model and models with increased and decreased flood frequency and intensity of effects. Risk of decline (C) and risk of falling below the metapopulation threshold (D) for swamp rabbit populations in southern Illinois predicted by models with a low, median, and high maximum population annual rate of increase (R_{max}). D is the 2-sample Kolmogorov-Smirnov test statistic for comparison to the median model.

Figure 9. Risk of decline (A) and risk of falling below the metapopulation threshold (B) for swamp rabbit populations in southern Illinois predicted by models with a negative temporal trend in K incorporated into the model. D is the 2-sample Kolmogorov-Smirnov test statistic for comparison to the median model.

trend caused an increase in the probability of declines of <60%. The effect of a declining temporal trend increased with an increase of the duration of the run. The decline could be offset with an increasing temporal trend in K on selected patches. The models including translocations of rabbits resulted in the successful establishment of rabbits on the patches, but no dispersal to other patches.

The model was sensitive to the level of harvest (Table 11). Although the probability of a total decline remained relatively low (<0.1) for the models with median parameters up to 40-50% harvest levels, the probability of a 50% decline approximately doubled with each 5% increase in harvest up to 15% where the probability of a 50% decline was 0.83. The probability of a 50% population decline was effectively 1.0 at harvest levels ≥25%. When models were run with harvest patterns that more likely simulated harvest in Illinois, the model was less sensitive to harvest; the probability of a 50% decline was 0.84 at 30% harvest and never reached 1.0 even at 50% harvest. The effects of harvest were intensified in the worst case models and those incorporating a negative temporal trend in K, and were lessened in the higher reproduction models (Table 11).

DISCUSSION

Swamp rabbits and their habitat is patchily distributed in Illinois concentrating along the rivers and their tributaries. The habitat is clustered in the extreme southern portion of the state along the Cache, Mississippi, and Ohio rivers and along a few of the interior rivers (Big Muddy, Kaskaskia, and Saline) and their tributaries. Due to the patchy distribution of habitat, swamp rabbit populations remain vulnerable to habitat loss and stochastic events that can cause local extirpation. The Cache and Mississippi rivers provide some of the best and most contiguous habitat in the state, and populations along these rivers are among the most important for long-term persistence of swamp rabbit populations. The larger sites, such as the Cache River, BI, Horseshoe Lake, and Heron Pond were the more important sites and retained populations in all models. Populations are likely to remain in Illinois as long as habitat exists on these sites.

Table 11. Probability of decline, probability of falling below the metapopulation threshold (1,000 individuals), and % change in metapopulation occupancy for swamp rabbit populations in southern Illinois predicted by population models with varying levels of harvest as a % of the population and with best and worst case scenarios for reproduction and negative effects of flooding.

	Harvest Level										
Model	0	5	10	15	20	25	30	35	40	45	50
Probability of 100% decline											
median	0.0	0.0	0.001	0.001	0.001	0.006	0.077	0.203	0.531	0.878	1.0
low reproduction	0.001	0.001	0.002	0.047	0.176	0.378	0.930	0.997	1.0	1.0	1.0
increased flooding	0.001	0.001	0.004	0.031	0.055	0.109	0.341	0.529	0.819	0.979	1.0
low reproduction and increased flooding	0.005	0.018	0.165	0.270	0.553	0.685	0.987	1.0	1.0	1.0	1.0
high reproduction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.052	0.236
with -5 temporal trend in K	0.0	0.0	0.001	0.001	0.009	0.260	0.119	0.0	0.67	0.985	1.0
with -10 temporal trend in K	0.0	0.0	0.001	0.001	0.008	0.026	0.106	0.293	0.735	0.996	1.0
Modified harvest[a]	0.0	0.0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Probability of 50% decline											
median	0.163	0.248	0.485	0.826	0.985	0999	0.999	0.999	0.999	1.0	1.0
low reproduction	0.474	0.776	0.980	0.990	0.999	0.999	1.0	1.0	1.0	1.0	1.0
increased flooding	0.351	0.508	.0768	0.950	0.998	0.999	1.0	1.0	1.0	1.0	1.0
low reproduction and increased flooding	0.793	0.945	0.999	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
high reproduction	0.062	0.086	0.154	0.238	0.514	0.796	0.986	0.990	0.997	0.999	1.0
with -5 temporal trend in K	0.351	0.621	0.862	0.985	0.999	0.999	0.999	1.0	1.0	1.0	1.0
with -10 temporal trend in K	0.626	0.856	0.968	0.999	0.999	0.999	1.0	1.0	1.0	1.0	1.0
Modified harvest[a]	0.0	0.212	0.274	0.387	0.538	0.706	0.840	0.907	0.903	0.918	0.923
Probability of falling below metapopulation threshold											
median	0.084	0.146	0.265	0.390	0.452	0.556	0.957	0.999	1.0	1.0	1.0
low reproduction	0.264	0.380	0.462	0.778	0.987	1.0	1.0	1.0	1.0	1.0	1.0
high reproduction	0.027	0.045	0.069	0.102	0.230	0.358	0.437	0.452	0.644	0.995	1.0

Table 11. Continued.

Model	Harvest Level										
	0	5	10	15	20	25	30	35	40	45	50
increased flooding	0.283	0.402	0.562	0.681	0.717	0.867	0.995	1.0	1.0	1.0	1.0
both	0.552	0.682	0.813	0.956	0.998	1.0	1.0	1.0	1.0	1.0	1.0
with -5 temporal trend in K	0.139	0.256	0.365	0.395	0.472	0.707	0.991	1.0	1.0	1.0	1.0
with -10 temporal trend in K	0.237	0.341	0.381	0.461	0.490	0.854	0.998	1.0	1.0	1.0	1.0
Modified harvest[a]	0.084	0.117	0.154	0.213	0.266	0.305	0.398	0.383	0.404	0.398	0.923
% Change in metapopulation occupancy											
median	0.0	0.0	-3.6	-10.7	-17.9	-25.0	-53.6	-64.3	-82.1	-89.3	-96.4
low reproduction	-7.1	-10.7	-21.4	-35.7	-57.1	-96.4	-96.4	-96.4	-100.0	-100.0	-100.0
increased flooding	-7.1	-10.7	-17.9	-28.6	-35.6	-46.4	-71.4	-78.6	-92.9	-96.4	-98.9
low reproduction and increased flooding	-28.6	-35.	-46.4	-60.7	-78.6	-85.7	-96.4	-100.0	-100.0	-100.0	-100.0
high reproduction	+3.6	+3.6	0.0	0.0	-3.6	-3.6	-14.3	-17.9	-25.0	-64.3	-60.7
with -5 temporal trend in K	-53.6	-53.6	-53.6	-57.1	-60.7	-60.7	-71.4	-75.0	-89.3	-92.9	-98.2
with -10 temporal trend in K	-71.4	-71.4	-71.4	-71.4	-71.4	-71.4	-75.0	-82.1	-89.3	-96.4	-100.0
Modified harvest[a]	0.0	0.0	-3.6	-7.1	-10.7	-17.9	-32.1	-42.9	-53.6	-57.1	-60.7

[a]Harvest modified to reflect more realistic pattern of harvest in Illinois with most of the harvest occurring in the southernmost counties with some patches protected from harvest.

However, swamp rabbits will remain vulnerable if issues pertaining to habitat on other sites are not addressed.

If swamp rabbit populations have a metapopulation structure in Illinois it is not a single unit. Rather the structure is multiple metapopulations separated approximately by watersheds (Appendix E). The southernmost populations along the Cache and Mississippi rivers appear to be the most important for swamp rabbit persistence.

Swamp rabbits appear to be in little danger of total extinction from the state. However, the probability of a 40% decline was 0.25. Most of the parameters were not precisely known, but the model was relatively insensitive to the range of parameters modeled. The probability of a total decline was >0 only when flooding, particularly prolonged flooding, was increased or when the population maximum annual rate of increase (R_{max}) was lowered. These conditions also are the only ones to produce a probability >10% of falling below the metapopulation threshold. The model was sensitive to changes in flooding frequency and intensity of effect, and several authors (Conaway et al. 1960, Martinson et al. 1961) have suggested flooding negatively impacts swamp rabbits. Zollner et al. (2000*a*) provided the first documentation that swamp rabbits move to adjacent uplands during seasonal flooding, and Kjolhaug (1986) suggested that survival during flooding decreased. However, the magnitude of the impact of recurring or irruptive flooding is unclear. We recognize that obtaining this information will be difficult, but further study of the impact of flooding on swamp rabbits is needed.

Changes in dispersal had relatively little effect on probabilities of decline. The only models in which unoccupied patches were colonized were those incorporating a very high rate of dispersal, but only a few patches were colonized. These sites were mostly in the southernmost counties where sites tended to be closer together. The distance between the majority of patches was too great to readily accommodate movements between patches. Habitat improvement along riverine corridors to improve connectivity among the patches might facilitate movement. Riparian zone management of riverine corridors to connect habitat patches will require landowner cooperation that can be encouraged with existing conservation stewardship and incentive programs, easements, and other programs.

Previous studies (Korte 1975, Kjolhaug 1986, Whitaker and Abrell 1986, Zollner et al. 2000*b*) have shown that canopy gaps promoting understory vegetation are beneficial to swamp rabbits. As bottomland forest matures and this understory disappears, habitat becomes less suitable for swamp rabbits. The incorporation of a negative temporal trend in carrying capacity resulted in negative effects on swamp rabbit populations. Although the probability of total decline did not change, probability of lower percentage declines and probability of falling below the metapopulation threshold increased, and the metapopulation occupancy decreased with increasingly negative trends. This suggests a need to manage habitat patches to ensure swamp rabbit persistence. Dependence on natural events (e.g., windstorms, insect damage, floods, and others) to create canopy openings and patches of early-succession vegetation will leave swamp rabbit persistence to chance. Given their limited distribution and vulnerable status in Illinois, we believe that proactive adaptive management is a more reasonable strategy.

Swamp rabbit presence was not detected in the northeastern counties when searched (Woolf 1998). The distance between these sites and other occupied sites is too great for rabbits to reach them by natural colonization. If swamp rabbits are to occupy this portion of their historic range, it will require translocations of rabbits to selected sites. Models incorporating translocations led to the successful reestablishment of populations in these counties even with the use of decreased survival of translocated rabbits and low numbers of rabbits translocated. Swamp rabbits tend to be relatively sedentary and readily lend themselves to trap and transport reintroductions.

Palmer et al. (1991) suggested that swamp rabbits might be vulnerable to overharvest because of their lower reproductive potential relative to cottontails (*Sylvilagus floridanus*). The sensitivity of our model to harvest levels supports this suggestion. The increased risk to the population with increasing harvest levels was mainly associated with decreased metapopulation occupancy with fewer patches retaining populations. However, current harvest levels in Illinois are not likely to impact the population. Harvest levels are relatively low, with the majority of harvest occurring in the southernmost counties (Larry David, Illinois Department of Natural Resources, personal communication). Some of the important populations, such as Heron Pond, are protected from harvest, and it is unlikely that any of the other large populations have harvest levels high enough to impact their population.

The sensitivity of results and uncertainty around most parameters suggests that results should not be interpreted in absolute terms. There is too much uncertainty about some parameters to predict with absolute confidence what the population size will be, or risk to the population. The model can be used to evaluate management options and which parameters need to be estimated more carefully. The model also can be used to evaluate various scenarios because despite the uncertainty of some parameters, it is possible that the relative rankings of management options may not be as sensitive to those parameters. Using an increasing temporal trend in carrying capacity to simulate habitat modifications to create canopy gaps and improve swamp rabbit habitat resulted in a decrease in probability of decline and an increase in metapopulation occupancy.

The uncertainty also helps identify areas for further study. The model could be improved if a habitat suitability model were developed that differentiated occupied and unoccupied sites. The model also could be improved with further study on swamp rabbit reproduction and the effects of flooding on swamp rabbit populations.

MANAGEMENT OPTIONS AND RECOMMENDATIONS

Monitor Only

The easiest and lowest cost option is to take no management actions for swamp rabbits in Illinois other than periodic monitoring to maintain knowledge of their status. The monitoring system outlined in Job 2.1 is easily implemented with minimum time requirements for personnel, and would provide information on population trends within the state. However, it does not provide information on populations not monitored and sensitivity of the monitoring scheme to population changes is unknown. This option is weakly justified by the model output which predicted a low risk of extinction. While it is likely that swamp rabbits will persist without management, habitat quality on many patches will diminish over time as succession progresses. Dependence on natural events (e.g., windstorms, insect damage, and floods) to create canopy openings and patches of early succession vegetation will leave swamp rabbit persistence to chance and populations remaining vulnerable to extirpation.

Population Management

Options for population management include varying levels of protection from harvest by imposing restrictions on seasons and/or bag limits. However, there is no evidence that harvest poses any risk to swamp rabbits, nor is there any evidence that reduced harvest will improve population status. Rabbit populations have high reproductive potential and there is ample evidence that the species' relationship to its habitat is the key factor affecting its distribution and abundance.

Manage Existing Habitat

Management of existing habitat patches likely provides the best opportunity to maintain or increase swamp rabbit populations. Larger patches tend to be more important for swamp rabbit persistence, so management efforts should be directed toward these patches. The management goal should be to maintain patches of early succession understory vegetation by creating gaps in the forest canopy.

Any management practice that involves timber harvest and is perceived to contribute to "forest fragmentation" is likely to be unpopular. Therefore, any management plan for public lands that disturbs the forest canopy will require an educational outreach component to win public support. Also, any management action implemented should be undertaken within an adaptive management framework because swamp rabbit response to various silvicultural practices is unknown. Previous studies (Korte 1975, Kjolhaug 1986, Whitaker and Abrell 1986, Zollner et al.

2000*b*) have shown that canopy gaps promoting understory vegetation are beneficial to swamp rabbits, but swamp rabbits avoid canopy gaps for certain activities (Zollner et al. 2000*b*). Smith (1982) reported that silvicultural practices had a pronounced effect on swamp rabbit cover and forage abundance, with all management practices he examined providing increased cover and forage abundance over unmanaged areas. However, he did not examine rabbit response to the silvicultural practice.

Public Land Focus.—Approximately 68% of occupied sites are in public ownership, including many of the larger habitat patches (Cache River, Heron Pond, Horseshoe Lake Area, Kaskaskia River, Mermet Lake, Oakwood Bottoms, and Union County Conservation Area). These sites include a mixture of abundant and sparse populations, providing opportunities to manage habitat in various ways and with varying intensity. Publicly owned sites include some of the most critical habitats (large blocks listed above) in Illinois for swamp rabbit persistence and should receive priority for management.

However, public support is lacking to generate and sustain agency "will" to manage public lands for species that require early successional habitats. Simply stated, species such as the swamp rabbit inhabit early successional communities, and these have not captured the public's fancy and therefore are a low conservation priority. Strong public opposition to activities that create and maintain early successional habitats is likely to continue to limit efforts to provide this habitat (Dessecker and McAuley 2001, Litvaitis 2001). Conservation efforts in the U.S. have historically been strongly identified with woodlands and preservation of mature forests, and shrublands and early successional vegetation have largely been ignored (Askins 2001). Conservation priorities are often affected by people's perceptions of the habitat. Early successional habitats tend to have thick closed vegetation leading to the common perception that these habitats are uninteresting or unappealing because they lack the open views and structure that people find aesthetically pleasing (Askins 2001, Gobster 2001). Decisions to provide early successional habitats through disturbance may be determined more by societal values and management budgets than by scientific arguments

(Lorimer 2001). Providing knowledge about the purpose of management practices to provide early successional habitat helps increase public support and tolerance of such practices (Gobster 2001), but opposition is likely to remain. Therefore, decisions to manage habitat for swamp rabbits is likely to require an "agency will" for swamp rabbit management, and there likely are differences among the agencies (e.g., DNR, USFW, USFS) and their priorities for future management.

Private Land Focus.—Some sites important to swamp rabbit persistence are in private ownership (BI, Main Ditch, Hodges Creek, Saline River, most sites along the Big Muddy River), and a focus on private land management likely would provide more flexibility in management options than on public land. Several of the large patches (BI, Main Ditch) are owned by timber companies and are currently managed, and are likely to continue to be managed, in ways that provide swamp rabbit habitat. However, most privately owned sites are unmanaged, and a public-private partnership should provide many opportunities to manage existing habitat for swamp rabbits. However, focusing on private land ignores some of the most critical swamp rabbit habitat in Illinois, and could increase the vulnerability of swamp rabbit populations. It also would leave habitat vulnerable to economic changes that could decrease the attractiveness of conservation stewardship and incentive programs.

Public and Private Land Integration.—Integrating both public and private lands into a partnership-based management plan would provide more flexibility in options available for management. This is the recommended course of action.

Improve Connectivity of Patches

In most cases, distance between habitat patches is too great to readily allow successful movement of rabbits between suitable patches. Connectivity of some patches could be improved by creating habitat along perennially flowing water courses connecting patches. Riparian zone management of riverine corridors would require landowner cooperation that could be encouraged with existing conservation stewardship and incentive programs, easements, and other similar programs. This should provide the additional benefit of enhancing water quality. This option is recommended in concert with management of existing habitats.

Transplant Rabbits to Unoccupied Patches

Unoccupied patches with suitable swamp rabbit habitat exist, particularly in the Wabash River and the Big Muddy River watersheds. It is extremely unlikely that rabbits will naturally recolonize these patches because they are too far from existing populations. Transplanting rabbits to selected unoccupied habitat patches could easily be done with minimal efforts. Rabbits readily lend themselves to trap and transplant operations, and their sedentary nature suggests they would not move far from the introduction site. This option would require willing landowner and public support.

Long-term Action

Regardless of the management strategy employed, the state-wide status of swamp rabbit populations should be re-examined every 10-15 years to maintain knowledge of their status because populations are subject to change. The survey should include a re-evaluation of potential habitat available. Land-use changes are likely to cause loss of some bottomland areas, and some areas, particularly along the Mississippi River, may develop into suitable habitat depending on disturbance regimes and succession.

APPENDIX E

Figure E-1. Potential swamp rabbit habitat within the Bay Creek watershed as identified from the Illinois land use/land cover database.

Figure E-2. Potential swamp rabbit habitat within the Big Muddy watershed as identified from the Illinois land use/land cover database.

Figure E-3. Potential swamp rabbit habitat within the Cache watershed as identified from the Illinois land use/land cover database.

Figure E-4. Potential swamp rabbit habitat within the Kaskaskia watershed as identified from the Illinois land use/land cover database.

Figure E-5. Potential swamp rabbit habitat within the Little Wabash watershed as identified from the Illinois land use/land cover database.

Figure E-6. Potential swamp rabbit habitat within the Saline watershed as identified from the Illinois land use/land cover database.

JOB R-2.4: ANALYSIS AND REPORT

Objectives: Provide recommendations to facilitate management of swamp rabbits in Illinois and contribute to protection of the palustrine forested wetlands they inhabit.

Requirements for this job have been met with the preceding recommendations and with the data presented in Annual Performance Reports and the Final Project Report for this study. In addition, the following list identifies a manuscript submitted, and professional papers presented on research conducted under the auspices of this Federal Aid project:

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 Academy of Science 94:in press.

_____, _____, and _____. 2000. Swamp rabbit status and distribution in southern Illinois - an update. 91st Illinois State Academy of Science Annual Meeting, Carbondale, Illinois, USA.

_____. 2000. Swamp rabbit research and population monitoring in Illinois. Presentation to the Missouri Swamp Rabbit Working Group.

LITERATURE CITED

Akçakaya, H. R. 1997. RAMAS/GIS: Linking landscape data with population viability analysis (version 2.0). Applied Biomathematics, Setauket, New York, USA.

_____, and J. L. Atwood. 1997. A habitat-based metapopulation model of the California gnatcatcher. Conservation Biology 11:422-434.

Allee, W. C., A. E. Emerson, O. Park, and K. P. Schmidt. 1949. Principles of animal ecology. Saunders, Philadelphia, Pennsylvania, USA.

Allen, A. W. 1985. Habitat suitability index models: swamp rabbit. U.S. Fish and Wildlife Service Biological Report 82(10.107).

Althoff, D. P. 1983. Daytime home range, habitat selection, and microenvironments used by cottontail rabbits in central Pennsylvania. Dissertation, Pennsylvania State University, University Park, Pennsylvania, USA.

_____, and G. L. Storm. 1989. Daytime spatial characteristics of cottontail rabbits in central Pennsylvania. Journal of Mammalogy 70:820-824.

Askins, R. A. 2001. Sustaining biological diversity in early successional communities: the challenge of managing unpopular habitats. Wildlife Society Bulletin 29:407-412.

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 Academy of Science 94:in press.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. (Great Britain) Ministry of Agriculture, Fisheries and Food. Fishery Investigations Series 2 119:5-533.

Brady, J. R., and M. R. Pelton. 1976. A comparison of some census techniques for the cottontail rabbit. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:546-551.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman-Hall, London, United Kingdom.

Burnham, K. P., and D. R. Anderson. 1984. The need for distance data in transect counts. Journal of Wildlife Management 48:1248-1254.

_____, _____, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72:1-202.

_____, _____, and _____. 1985. Efficiency and bias in strip and line transect sampling. Journal of Wildlife Management 49:1012-1018.

Busch, B. 1995. The application of a swamp rabbit (*Sylvilagus aquaticus*) habitat suitability index to a portion of the Clarks River drainage and associated wetlands in western Kentucky utilizing a geographic information system. Thesis, Murray State University, Murray, Kentucky, USA.

Caswell, H. 2001. Matrix population models: construction, analysis, and interpretation. Second edition. Sinauer Associates, Sunderland, Massachusetts, USA.

Cochran, W. G. 1963. Sampling techniques. Second edition. John Wiley & Sons, New York, New York, USA.

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

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, Louisiana, USA.

Dailey, T. V., T. M. Vangilder, and L. W. Burger, Jr. 1993. Swamp rabbit distribution in Missouri. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:251-256.

DeMaso, S. J. 1994. Upland game investigations. Oklahoma Department of Wildlife Conservation, Performance Report, Federal Aid Project W-82-R-33, Oklahoma, USA.

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29:456-465.

Diaz, A. 1998. Comparison of methods for measuring rabbit incidence on grasslands. Mammalia 62:205-212.

Dixon, K. R., and J. A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61:1040-1044.

Doak, D., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the Western Mojave desert. Ecological Applications 4:446-460.

Donoho, H. S. 1972. Dispersion and dispersal of white-tailed and black-tailed jackrabbits, Pawnee National Grasslands. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Eberhardt, L. L. 1978. Transect methods for population studies. Journal of Wildlife Management 42:1-31.

Ernst, J. P., and V. Brown. 1989. Conserving endangered species on southern forested wetlands. Pages 135-145 *in* D. D. Hook and R. Lea, editors. Proceedings of the symposium: the forested wetlands of the southern United States. United States Forest Service General Technical Report SE-50.

Fa, J. E., F. J. Romero, and J. Lopez-Paniagua. 1992. Habitat use by parapatric rabbits in a Mexican high-altitude grassland system. Journal of Applied Ecology 29:357-370.

Flinders, J. T., and R. M. Hansen. 1973. Abundance and dispersion of leporids within a short-grass ecosystem. Journal of Mammalogy 54:287-291.

Forys, E. A., and S. R. Humphrey. 1996. Home range and movements of the lower keys marsh rabbit in a highly fragmented habitat. Journal of Mammalogy 77:1042-1048.

_____, and _____. 1997. Comparison of 2 methods to estimate density of an endangered lagomorph. Journal of Wildlife Management 61:86-92.

_____, and _____. 1999. The importance of patch attributes and context to the management and recovery of an endangered lagomorph. Landscape Ecology 14:177-185.

Gibb, A. J. 1970. An experiment in rabbit control. New Zealand Journal of Agriculture 120:28-31.

Gobster, P. H. 2001. Human dimensions of early successional landscapes in the eastern United States. Wildlife Society Bulletin 29:474-482.

Goldblatt, I. A. 1992. Using a geographic information system and the national wetland inventory to model swamp rabbit (*Sylvilagus aquaticus*) habitat. Thesis, Indiana State University, Terre Haute, Indiana, USA.

Gould, A. B. 1974. The home range and habitat preferences of swamp rabbits along a shell road in the intermediate marsh of southwestern Louisiana. Thesis, Louisiana State University, Baton Rouge, Louisiana, USA.

Gross, J. E., L. C. Stoddart, and F. H. Wagner. 1974. Demographic analysis of a northern Utah jackrabbit population. Wildlife Monographs 40:1-68.

Hamilton, W. J. 1955. Coprophagy in the swamp rabbit. Journal of Mammalogy 36:303-304.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668-674.

Hendrickson, G. O. 1939. Inventory methods for Mearns cottontail. Proceedings of the Annual North American Wildlife Conference 4:209-215.

Heuer, E. T. Jr., and H. R. Perry. 1976. Squirrel and rabbit abundances in the Atchafalaya Basin, Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissions 21:117-123.

Hodges, J. D. 1994. Ecology of bottomland hardwoods. Pages 5-11 *in* W. P. Smith and D. N. Pashley, editors. A workshop to resolve conflicts in the conservation of migratory landbirds in bottomland hardwood forests. U.S. Forest Service General Technical Report SO-114.

Hollander, J., and D. A. Wolfe. 1973. Non-parametric statistical methods. John Wiley and Sons, New York, New York, USA.

Holler, N. R., T. S. Baskett, and J. P. Rogers. 1963. Reproduction in confined swamp rabbits. Journal of Wildlife Management 27:179-183.

_____, and H. M. Marsden. 1970. Onset of evening activity of swamp rabbits and cottontails in relation to sunset. Journal of Wildlife Management 34:349-353.

Holzman, S. M., M. J. Conroy, and J. Pickering. 1992. Home range, movements, and habitat use of coyotes in southcentral Georgia. Journal of Wildlife Management 56:139-146.

Hunter, W. C., D. N. Pashley, and R. E. F. Escano. 1993. Neotropical migratory landbird species and their habitats of special concern within the Southeast region. Pages 159-171 *in* D. M. Finch and P. W. Stangel, editors. Status and management of neotropical migratory birds. U. S. Forest Service General Technical Report RM-229.

Illinois Department of Natural Resources. 1996. Illinois land cover, an atlas. Illinois Department of Natural Resources, Springfield, Illinois, USA. IDNR/EEA 96/05.

Keith, L. B., and L. A. Windberg. 1978. A demographic analysis of the snowshoe hare cycle. Wildlife Monographs 58:1-70.

Kenwood, R. E., and K. H. Hodder. 1996. RANGES V: An analysis system for biological location data. Institute of Terrestrial Ecology, Wareham Dorset, United Kingdom.

Kjolhaug, M. S. 1986. Status, distribution, and factors determining habitat quality of the swamp rabbit in Illinois. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

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

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

Kline, P. D. 1965. Factors influencing roadside counts of cottontails. Journal of Wildlife Management 29:665-671.

Knapp, H. V. 1994. Hydrologic trends in the Upper Mississippi River basin. Water International 19:199-206.

Korte, P. S. 1975. Distribution and habitat requirements of the swamp rabbit in Missouri. Thesis, University of Missouri - Columbia, Columbia, Missouri, USA.

Krebs, C. J., B. S. Gilbert, S. Boutin, and R. Boonstra. 1987. Estimation of snowshoe hare population density from turd transects. Canadian Journal of Zoology 65:565-567.

_____, _____, _____, A. R. E. Sinclair, and J. N. M. Smith. 1986. Population biology of snowshoe hares. I. Demography of food-supplemented populations in the southern Yukon, 1976-1984. Journal of Animal Ecology 55:963-982.

Laake, J. L., S. T. Buckland, D. R. Anderson, and K. P. Burnham. 1993. DISTANCE user's guide. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado, USA.

Langbein, J., M. R. Hutchings, S. Harris, C. Stoate, S. C. Tapper, and S. Wray. 1999. Techniques for assessing the abundance of brown hares *Lepus europaeus*. Mammal Review 29:93-116.

Lefkovitch, L. P. 1965. The study of population growth in organisms grouped by stages. Biometrics 21:1-18.

Litvaitis, J. A.. 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin 29:466-473.

_____, and R. Villafuerte. 1996. Factors affecting the persistence of New England cottontail metapopulations: the role of habitat management. Wildlife Society Bulletin 24:686-693.

Lochmiller, R. I., J. F. Boggs, S. T. McMurry, D. M. Leslie, Jr., and D. M. Engle. 1991. Response of cottontail rabbit populations to herbicide and fire applications on cross timbers range. Journal of Range Management 44:150-155.

Lorimer, C. G. 2001. Historical and ecological roles of disturbance in eastern North American forests: 9,000 years of change. Wildlife Society Bulletin 29:425-439.

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

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.

McCollum, R. C., and N. R. Holler. 1994. Comparative use of floodplains by swamp rabbits. Journal of the Alabama Academy of Science 65:263-275.

Mohr, C. O. 1947. Table of equivalent populations of North American mammals. American Midland Naturalist 37:223-249.

Mullin, K. D. 1979. Aspects of the ecology of the swamp rabbit (*Sylvilagus aquaticus*) in disturbed bottomland hardwoods and associated pinewoods in west-central Louisiana. Thesis, Northwestern State University of Louisiana, Natchitoches, Louisiana, USA.

Orr, C. D., and D. G. Dodds. 1982. Snowshoe hare habitat preferences in Novia Scotia spruce-fir forests. Wildlife Society Bulletin 10:147-150.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62:1-135.

Palmer, E. E., G. A. Hurst, B. D. Leopold, and D. C. Cotton. 1991. Body weights and sex and age ratios for the swamp rabbit in Mississippi. Journal of Mammalogy 72:620-622.

Pepin, D., and M Birkan. 1981. Comparative total- and strip-census estimates of hares and partridges. Acta Oecologica Oecologica Applicata 2:151-160.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

_____, J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:1-97.

Porath, J. W. 1997. Swamp rabbit (*Sylvilagus aquaticus*) status, distribution, and habitat characteristics in southern Illinois. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

Press, W. H., B. P. Flannery, S. A. Teukolsky, and W. T. Veterling. 1986. Numerical recipes. Cambridge University Press, Cambridge, United Kingdom.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191 of the Fisheries Research Board of Canada, Ottawa, Canada.

Rodgers, A. R., and A. P. Carr. 1998. HRE: The home range extension for ArcView™ user's manual. Centre for Northern Forest Ecosystem Research, Ontario, Canada.

Rudis, V. A. 1995. Regional forest fragmentation effects on bottomland hardwoods. Pages 35-46 *in* J. C. Brissette, editor. Proceedings of the 7th biennial southern silvicultural research conference. U.S. Forest Service General Technical Report SO-93.

Shupe, T. E., F. S. Guthery, and S. L. Beasom. 1987. Use of helicopters to survey northern bobwhite populations on a rangeland. Wildlife Society Bulletin 15:458-462.

Smith, G. W., and N. C. Nydegger. 1985. A spotlight, line-transect method for surveying jack rabbits. Journal of Wildlife Management 49:699-702.

Smith, W. P., P. B. Hamel, and R. P. Ford. 1993*a*. Mississippi alluvial valley forest conversion: implications for eastern North America. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 47:460-469.

_____, P. A. Zollner, and L. A. Brennan. 1993*b*. Ecology of the swamp rabbit in south-central Arkansas. Completion report, Study No. FS-SO-4104-92. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Stoneville, Mississippi, USA.

Smith, W. S. 1982. Effects of selected silvicultural practices on swamp rabbit (*Sylvilagus aquaticus*) habitat. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Sorensen, M. F., J. P. Rogers, and T. S. Baskett. 1968. Reproduction and development in confined swamp rabbits. Journal of Wildlife Management 32:520-531.

Spencer, W. D., and R. H. Barrett. 1984. An evaluation of the harmonic mean measure for defining carnivore activity areas. Acta Zoologica Fennica 171:255-259.

Sprent, P. 1993. Applied nonparametric statistical methods. Second edition. Chapman & Hall, New York, New York, USA.

Suchy, W. J., R. J. Munkel, and J. M. Kienzler. 1991. Results of the August roadside survey for upland wildlife in Iowa: 1963-1988. Journal of the Iowa Academy of Science 98:82-90.

Tapper, S., and N. Parsons. 1984. The changing status of the brown hare (*Lepus capensis* L.) in Britain. Mammal Review 14:57-70.

Terrel, T. L. 1972. The swamp rabbit (*Sylvilagus aquaticus*) in Indiana. American Midland Naturalist 63:398-412.

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.

Trent, T. T., and O. J. Rongstad. 1974. Home range and survival of cottontails in southwestern Wisconsin. Journal of Wildlife Management 38:459-472.

Trout, R. C., S. C. Tapper, and J. Harradine. 1986. Recent trends in the rabbit population in Britain. Mammal Review 16:117-123.

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.

Velázquez, A. 1994. Distribution and population size of *Romerolagus diazi* on El Pelado volcano, Mexico. Journal of Mammalogy 75:743-749.

Whitaker, J. O. Jr., and B. Abrell. 1986. The swamp rabbit, *Sylvilagus aquaticus*, in Indiana, 1984-1985. Indiana Academy of Science 95:563-570.

Windberg, L. A., and L. B. Keith. 1976. Experimental analysis of dispersal in snowshoe hare populations. Canadian Journal of Zoology 54:2061-2081.

Woolf, A. 1998. Illinois swamp rabbit study. Illinois Department of Natural Resources, Final Report, Federal Aid Project W-127-R-3, Springfield, Illinois, USA.

Worton, B. J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. Journal of Wildlife Management 59:794-800.

Zar, J. A. 1996. Biostatistical analysis. Third edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Zollner, P. A. 1993. Ecology of the swamp rabbit in south-central Arkansas. Thesis, Mississippi State University, Starkville, Mississippi, USA.

_____, W. P. Smith, and L. A. Brennan. 1996. Characteristics and adaptive significance of latrines of swamp rabbits (*Sylvilagus aquaticus*). Journal of Mammalogy 77:1049-1058.

_____, _____, and _____. 2000*a*. Home range use by swamp rabbits (*Sylvilagus aquaticus*) in a frequently inundated bottomland forest. American Midland Naturalist 143:64-69.

_____, _____, and _____. 2000*b*. Microhabitat characteristics of sites used by swamp rabbits. Wildlife Society Bulletin 28:1003-1011.