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RH: Marsh rice rat home ranges and habitat

Ranging behavior of marsh rice rats in a southern Illinois wetland complex

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The marsh rice rat (*Oryzomys palustris*) inhabits wetlands that are often fragmented and isolated by upland cover types. Persistence of marsh rice rat populations and metapopulations likely depends on their ability to enter and traverse the upland matrix, yet basic information, such as home-range size and landcover use patterns, is lacking. Our goal was to quantify home-range size and habitat selection by marsh rice rats in southern Illinois. Between March and November 2011, we radio-collared 21 male rice rats (8 subadults and 13 adults) that were each located 7 to 24 times each via triangulation and homing. We estimated home-range size, compared landcover composition within kernel home ranges to what was available in the surrounding landscape, and quantified daily movement distances. Mean (± SE) home ranges were 3.53 ± 0.66 ha based on 95% kernel isopleths and 1.85 ± 0.49 ha based on minimum convex polygons. Home ranges were largest for individuals followed in early summer, but home-range sizes were similar for adults and subadults. Rice rats' use of emergent wetland vegetation was greater than availability, indicating they preferred emergent wetlands habitat at the home-range level. However, upland cover types made up >40% of each home range, on average. Daily movements averaged 46.6 ±3.4 m (maximum: 396 m), and rice rats were located up to 464 m from the nearest wetland. Based on by far the largest sample size (in individuals and locations per individual) available for space use of the marsh rice rat, our findings support the characterization of male rice rats as highly vagile, and suggest that rice rats move through upland cover more frequently than previously described.

Key Words: activity, home range, Illinois, landcover, marsh rice rat, movement, *Oryzomys palustris*, telemetry, wetland

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Home range is a spatial measure that represents the area in which individuals regularly move in search of resources and mates (Burt 1934, Mohr 1947). Often, home ranges are used to illustrate landscape-level habitat selection (Johnson 1980), and the extent of an animal's movement through the landscape (Bowman et al. 2002, Schooley and Branch 2006). A home range must contain all necessary resources for an individual's daily living, so comparing landcover composition of home ranges with the broader landscape (i.e., second-order selection; Johnson 1980) can provide information about which resources are most important or limiting. Also, the size and distribution of movements that make up an individual's home range can characterize the vagility of the species and predict the potential for long-distance dispersal (Bowman et al. 2002, Revilla et al. 2004). Identifying the landcover use and movement potential of a habitat specialist can help predict the persistence of a species in a highly-fragmented landscape (Fahrig and Merriam 1994).

Home ranges can shift in size and position over time due to fluctuations in resources and risk (Cameron and Spencer 1985, Byrne and Chamberlain 2011). Many small mammals expand their home range in the summer, coinciding with mating, resource foraging, and population recruitment (Gaines and McClenaghan 1980). In hispid cotton rats (*Sigmodon hispidus*), home range was largest during the breeding season (May-August) as male and female territories began to overlap (Cameron and Spencer 1985). Conversely, Cranford (1976) found that home ranges of dusky-footed wood rats (*Neotoma fuscipes*) expanded between November and December as animals foraged further for rare resources.

Home-range size and composition can change with age, especially if animals exhibit territorial behavior or natal dispersal (Burt 1934, Gaines and McClenaghan 1980). For many small mammals, younger individuals are pressured to seek out new territory through aggression by older, more dominant animals (Gaines and McClenaghan 1980, Eiris and Barreto 2009). Subadults tend to have smaller home ranges in territorial species, as established adults leave few suitable areas unoccupied (Cranford 1976). In round-tailed muskrats (*Neofiber alleni*), home range was larger in reproductive than non-reproductive males and increased with body mass (Schooley and Branch 2006). Additionally, Spencer et al. (1990) found hispid cotton rats exhibited similar daily home ranges across all age classes, but linear movements and elongated home ranges were more common in adults. Identifying the age class that exhibits the highest movement potential can help predict the life stage at which dispersal is most likely to occur (Hanski 1994, Gaines and McClenaghan 1980).

The marsh rice rat (*Oryzomys palustris*, hereafter rice rat) is a medium-sized rodent for which published information on home range is limited. As it is a specialist to emergent wetlands (Wolfe 1982), most research on the rice rat has taken place in the Gulf Coast and Florida Everglades. However, rice rats are found as far north as southern Illinois in the Midwest and New Jersey on the Atlantic coast (Wolfe 1982). Using capture locations within trapping grids in Brenton Island, Louisiana, Negus et al. (1961) estimated home-range size for rice rats at 0.33 ha for males and 0.21 ha for females. Birkenholz (1963) reported similar home-range sizes for rice rats (0.23 ha for males and 0.29 ha for females), again using simple grid trapping. McIntyre et al. (2009) presented much smaller home-range estimates (averaging about 0.06 ha) based on grid trapping in Brazoria County, Texas, but including animals with as few as 2 recaptures may have skewed the results. The only known study to use radio telemetry to characterize home ranges of rice rats was conducted at a reclaimed surface mine west of Harrisburg, Illinois (Hofmann and Gardner 1992). These workers estimated an average home range of 0.73 ha using the convex polygon method (Mohr 1947), but the study suffered from short duration (two nights of tracking), frequent collar detachment, and few relocations.

Rice rats are believed to be highly vagile for their size (W-olfe 1982, Wolfe 1985, Forys and Dueser 1993). In a controlled swimming-chamber experiment, Esher et al. (1978) found rice rats moving > 200 m in a single night, 10 times farther than hispid cotton rats exposed to the same conditions. Rice rats also have been reported moving into adjacent upland cover in response to flooding (Wolfe 1982, Kruchek 2004), wetland draw-downs (Smith and Vrieze 1979), and peaks in population density (Wolfe 1985). Different age classes may move differently through the landscape, and Kruchek (2004) captured subadults in uplands at a higher rate than their adult counterparts.

No study has quantified habitat selection by rice rats at the home-range level, although several larger-scale habitat assessments of the species have been published. Rice rats are associated with tidal marshes, estuaries, coastal wetlands, palustrine emergent wetlands, palustrine scrub-shrub wetlands, palustrine aquatic beds, and riverine aquatic beds (Cowardin and Golet 1995, Wolfe 1982, Hofmann et al. 1990). Additionally, rice rats have been captured in matrix types such as sawgrass (*Cladium spp.*) prairies (Smith and Vrieze 1979), cordgrass (*Spartina spp.*) uplands (Kruchek 2004), pine plantations (Miller et al. 2004), and lowland brome-dominated (*Bromus spp.*) meadows (McLaughlin and Robertson 1951). In southern Illinois, Eubanks et al. (2011) found that wetlands surrounded by upland grasses were more likely to be occupied by rice rats than those surrounded by upland forests and human development. Eubanks (2009) also found that wetlands surrounded by bare ground or agriculture rarely were occupied by rice rats and may be more isolated than wetlands surrounded by native plants. Visual obstruction < 0.5 m and herbaceous cover were the best predictive variables for occupancy, indicating that rice rats tend to persist in wetlands surrounded by dense ground cover. Rice rats have not previously been reported in row crop agriculture fields or in upland deciduous woodlots (Goertz and Long 1973; Wolfe 1985, Franz et al. 1998). Areas of open water (Forys and Dueser 1993) and wet, vegetated ditches (Hofmann et al. 1990) may serve as dispersal corridors.

Rice rat conservation and recovery efforts would benefit from accurate estimates of home-range size and composition to identify landscape-scale habitat selection and rank landcover preference. The objectives of our study were to quantify home-range size and movement distances, test whether movement and home-range size differed across age and season, and characterize habitat selection by rice rats in a wetland complex in the northern portion of the species' range. We expected that movement rates and home-range sizes would be greater for subadults than adults and during periods of fluctuating water level.

MATERIALS AND METHODS

Study area.—Our study took place from 30 March to 7 November 2011 within the Burning Star 5 Natural Wildlife Area, a 3400-ha reclaimed coal mine located 5 km east of DeSoto, Illinois, USA (37º 50’ 21” N, 89º 10’ 56” W; Fig. 1). During this period, Burning Star 5 was owned by CONSOL Energy (Consolidation Coal Company, Elkville, Illinois, USA) and managed by the combined efforts of the Illinois Department of Natural Resources, the National Wild Turkey Federation, and the Cooperative Wildlife Research Laboratory at Southern Illinois University Carbondale. Located along the Little Muddy River, Burning Star 5 was composed of approximately 1600 ha of cropland, 800 ha of timber, 400 ha of grassland, and 560 ha of lakes and wetlands (Illinois Department of Natural Resources 2011). Landcover was diverse throughout Burning Star 5, with mature oaks (*Quercus* spp.) and hickories (*Carya* spp.)

dominating bottomland forests; tall fescue (*Festuca* spp.), switchgrass (*Panicum virgatum*), and big bluestem (*Andropogon gerardii*) within grasslands; and corn (*Zea mays*), soybeans (*Glycine max*), sorghum (*Sorghum* spp.), and wheat (*Triticum* spp.) grown in croplands (Delahunt 2011).

Collaring and relocation **–** We placed radio transmitters on rice rats captured in 11 trapping grids in 4 wetlands during an ongoing study of matrix permeability (Cooney 2013), collaring adult and subadult male rice rats in equal proportion. We only tracked one sex to increase statistical power with a limited number of transmitters, and because we anticipated higher capture success for males (Bloch and Rose 2005). Captured animals were handled in accordance with an approved protocol (Southern Illinois University Carbondale, Institutional Animal Care and Use Protocol 10-009), which included anesthetizing rice rats by inhalation of isoflurane (Isothesia, Fisher Scientific, Pittsburgh, Pennsylvania, USA). We assigned age classes based on body mass criteria modified from Negus et al. (1961), who grouped rice rats < 30 g as juveniles, between 30-50 g as subadults, and > 55 g as adults (Wolfe 1985). We also placed considered rice rats between 50 g and 55 g to be adults if they exhibited adult breeding conditions (descended testes in males and perforated vaginas in females), otherwise they were considered subadults (Wolfe 1985). While each rat was under anesthesia, we attached a radio transmitter (Model SOM 2038; Wildlife Materials Inc., Murphysboro, Illinois, USA) around the neck using a 0.5-cm black cable tie. Transmitter mass (2.3-2.6 g) constituted 2.7-8.7% of body mass at capture. After tightening the cable tie to a snug fit and removing the excess portion, we allowed rats to recover from the anesthesia within a Sherman trap (H. B. Sherman Traps, Tallahassee, Florida, USA). Once we confirmed the frequency of the radio transmitter with a digital receiver (Communications Specialist Inc., Orange, California, USA), we released the animal at its point of capture and recorded the location with a handheld global positioning system (GPS) device (Model 60 CSX, Garmin Inc., Olathe, Kansas, USA).

We relocated each collared rice rat up to 6 times per week for up to 6 weeks, alternating between nighttime triangulation (2000-2359 hr Sunday, Tuesday, and Thursday) and daytime homing (0800-1159 hr Monday, Wednesday, and Friday). We alternated relocations of collared rice rats to include both nesting (diurnal) and activity (nocturnal) locations in home-range estimates. For triangulation, we used a 6-element Yagi antenna and digital receiver to record 3-4 intersecting bearings for each transmitter from points about 50 m from the wetland boundary, spaced >50 m apart, and taken within a 15-minute time frame. To minimize bearing error, we discarded readings ≤ 10 degrees from the previously recorded azimuth and took a new bearing from a different location. We later entered the Universal Transverse Mercator geographic coordinates (UTMs) and compass bearings of each reading into Program LOAS (Ecological Software Solutions LLC, Heymagas, Hungary) to estimate rice rat locations and calculate error polygons. We discarded all values with an error polygon > 5000 m^2 as inaccurate relocations. We located each collar by triangulation up to 18 times over the 6-week period.

For homing, we followed the signal on foot and recorded the location on hand-held GPS if we found a nest or burrow occupied by the collared rat. If the collar was found detached from the animal, we recorded date, location of the collar, and suspected fate of the animal (e.g., collar removal or animal mortality). Up to 18 homing locations were recorded for each collar over the 6-week period, producing up to 36 combined relocations from telemetry and homing to generate home ranges. If the transmitter signal could no longer be detected after 6 weeks of radio-tracking, we attempted to recapture the animal to replace or remove the transmitter. To do so, we deployed 25 Sherman traps in a 50- x 50-m grid surrounding the last known location and continued trapping until the rat was captured and the collar removed for up to 21 days or until we found the collar detached from the animal.

Data analysis **–**Removing the initial and final locations from each data set, we entered relocations into ArcGIS version 9.3 (ESRI 2009) and used the Animal Movements extension to calculate a 100% minimum convex polygon (MCP; Mohr 1947) and kernel home range (fixed-kernel 95% isopleth; Worton 1989) for each individual. For the fixed-kernel approach, we used least-squares cross validation to calculate the smoothing parameter (Habbema et al. 1974). In addition to home-range estimates, we used the Hawth's tools Extension in ArcGIS to calculate step-length (m) between relocations made on different days. We divided each step-length by the time between relocations to measure daily movement distance.

We used mixed-model two-way ANOVA (McCullough and Searle 2001) to test for the fixed effects of the categorical variables age class, collaring interval (March-April, May-June, July-August, September-October), and their interaction on the response variables of home-range size, average daily movement distance, and percentage of home range located outside of emergent wetland vegetation (i.e. the matrix). The trapping grid where each rice rat was captured was a random variable. The analysis was carried out using PROC GLM (SAS Institute Inc. 2011).

We used compositional analysis to characterize habitat selection by rice rats at the home-range level (Aebischer et al. 1993). Using ArcGIS, we calculated used habitat as the percentage of each rice rat's kernel home range composed of emergent vegetation, agriculture, forest, grassland, shoreline, open water, shrub cover, partially inundated ditches and gravel road. We defined available habitat in 2 ways. First, we calculated the percentage of each landcover type within 41.2-m buffers around the 4 study wetlands. This buffer represented the average distance rice rats traveled from suitable habitat. Second, we combined all rice rat relocations collected at each wetland and used them to generate a composite 95% isopleth, then calculated the percentage of each landcover type within the composite isopleth. We replaced zero values with 0.00001, calculated log-ratios, and used PROC BYCOMP (Ott and Hovey 2004) in SAS version 9.3 (SAS Institute Inc. 2011) to perform multivariate analysis of variance (MANOVA) to test whether the composition of rice rat home ranges differed from available (Aebischer et al. 1993). We then used t-tests to detect pairwise differences in cover type selection at $\alpha < 0.05$ (McCullough and Searle 2001) and ranked cover types from most to least preferred.

RESULTS

We collared 8 rice rats during March-April, 8 during May-June, 6 during July-August, and 3 during September-October (Table 1), as capture rate decreased over the course of the season (Cooney 2013). One collar was recovered from a recaptured rice rat, 12 collars were discovered detached from the rice rat, and 12 collars lost their signal and were never recovered (Table 1). Of the 12 detached collars, 3 were confirmed predator kills (Table 1).

In total, we collected 319 locations that were usable for analysis with a median error ellipse area of 518 m^2. We homed to rice rats 162 times in emergent wetland habitat, 3 times in ditches, and 21 times in upland matrix cover, compared to 85 triangulated locations in wetland habitat and 48 triangulated locations in the matrix. Of the 21 homed relocations in matrix cover types, we found rice rats 11 times in grassland cover, 7 times in agriculture cover, 2 times in forest cover, and 1 time in shrub cover. Rice rats were most often found in globular nests constructed from sedge and grass leaves, though we did home to individuals in root masses, underground burrows, and a pile of corn stalks.

We calculated home-range size and movement parameters using data from 21 rice rats (8 subadults and 13 adults) that were relocated ≥7 times (Table 1). We did not obtain any valid relocations for 2 subadults whose collars failed or detached. Home-range sizes estimated from 2 additional subadult rice rats with <7 relocations deviated visibly from the distribution of sizes for rats with larger sample sizes, so we do not report those estimates. We tracked the 21 rice rats an average of 32 days (range 13-54 days), collecting an average of 15 (range 7-24) relocations per rat. Average (± SE) home-range size was 1.85 ± 0.49 ha for MCP and 3.53 ± 0.66 ha for 95% kernel home range. Due to the small sample size (n = 2) of radiocollared rice rats in September–November, we dropped telemetry interval 4 from all ANOVA analyses that included telemetry interval. Kernel home-range size was similar ($P = 0.88$) for subadults (2.9 ± 0.9 ha; least squares mean ± SE) and adults (3.1 ± 0.7 ha), and the interactive effect of age class and telemetry interval on home-range size was not significant ($F_{2\,6} = 2.05$, $P = 0.21$). However, home-range size differed among telemetry intervals ($F_{2\,9} = 4.42$, $P < 0.05$), being largest for rice rats collared in May-June (5.12 ± 0.90 ha), followed by July-August (3.66 ± 1.06 ha), and smallest during March-April (1.49 ± 0.84 ha).

The distribution of daily movement distances was approximately exponential (Fig. 2) with a median of 26.3 m, an average of 46.6 ± 3.4 m, and a maximum of 396 m. The average distance rice rats were relocated from wetland habitat was 41.2 ± 6.2 m (maximum = 464 m). Average daily movement distance did not vary significantly by age class ($F_{1\,12} = 0.32$, $P = 0.58$), telemetry interval ($F_{2\,8} = 0.50$, $P = 0.62$), or their interaction ($F_{2\,5} = 1.17$, $P = 0.38$). We also found no evidence of interactive effects of age class and telemetry interval on the percentage of home ranges overlapping the upland matrix ($F_{2\,5} = 0.17$, $P = 0.85$). However, amount of rice rat home ranges composed of matrix differed among telemetry intervals, being greatest for rice rats collared during May-June, followed by July-August, and least in March-April. We found suggestive evidence that home ranges of adults contained a higher percentage of upland matrix than did those of subadults (Table 2). The interaction of age class and telemetry interval did not affect percentage matrix overlap (Table 2).

Rice rats showed habitat selection at the home-range level, using availability assessed with either 41.2-m buffers (Wilk's $\Lambda = 0.17$, $F_{8\ 15} = 9.19$, $P < 0.01$) and composite 95% isopleths (Wilk's $\Lambda = 0.14$, $F_{8\ 15} = 11.4$, $P < 0.01$). Both measures of availability yielded similar percentages of the various landcover types. Home ranges of rice rats contained more emergent wetland and agriculture but less grassland, forest, and shrub cover than either measure of availability (Table 3). Wetland (combining emergent wetland vegetation, shoreline, and open water) composed an average of only 55.9% of rice rat home ranges (Table 3). In pairwise comparisons, selection for emergent wetland vegetation was greater than for all other available cover types except partially inundated ditches. Selection against shrub cover was stronger than for all cover types except gravel roads, forest, and open water in the buffer analysis, whereas selection against open water was stronger than for all other cover except grassland and agriculture in the isopleth analysis. Selection ranking was consistently high for emergent wetland vegetation, shoreline, and agriculture; and low for open water, gravel roads, and shrub cover (Table 3).

DISCUSSION

We provide the most extensive and intensive study of home range for this species, and the average home-range size we estimated was substantially larger than any previous study (Negus et al. 1961, Hofman and Gardner 1992, McIntyre et al. 2009). These previous studies likely underestimated home-range size as a result of grid trapping and few relocations. Nevertheless, Hofmann and Gardner (1992) believed that rice rats in Illinois move farther to forage for resources than their southern counterparts. Most previous studies of rice rat home range took place in coastal wetlands and estuaries in the southern United States where suitable habitat is often contiguous (Negus et al. 1961, Wolfe 1982). Our study took place near the northern limit of rice rat distribution (Wolfe 1982), in an area where emergent wetlands are highly fragmented by upland grasses, forests, and agriculture (Illinois Department of Natural Resources 2011). Future work should monitor rice rats occupying contiguous wetlands within the Mississippi and Cache River watersheds. Also, studying female movements could provide insight into variation by sex in home-range size.

Movement distances seen in our study reflected the high vagility of rice rats seen elsewhere in their range. Negus et al. (1961) captured rice rats > 600 m from their original home range in Louisiana, and Forys and Dueser (1993) found that rice rats were capable of crossing > 300 m of open water between Virginia Barrier Islands. Esher et al. (1978) reported that rice rats moved an average of 232.8 m per night in a laboratory swimming chamber. One collared adult in our study traveled > 300 m in one night, only to return to its home range the following day. Relative to sympatric species, rice rats were seen making inter-patch movements more frequently than cotton rats in the Florida Everglades (Smith and Vrieze 1979), and moved up to 10 times further than cotton rats in an enclosed swimming chamber (Esher et al. 1978). Rice rats may have adapted to taking large daily movements in highly fragmented landscapes as a way to combat habitat isolation. The ability to frequently make long-distance movements could contribute to the persistence of rice rat metapopulations in fragmented habitats via gene flow, patch colonization, and the rescue effect (Hanski 1994, Fahrig and Merriam 1994).

The male rice rats we studied selected emergent wetland vegetation over all other available cover types. The vast majority of nesting occurred in emergent vegetation, as rice rats occupied woven grass nests (as described in Hofmann and Gardner 1992), underground burrows, and abandoned muskrat (*Ondantra zibethicus*) mounds. Partially-inundated ditches were also selected slightly more than other cover types, which supports the assertion of Hofmann et al. (1990) that irrigation ditches and roadside right-of-ways can be used as dispersal corridors. Rice rats may find vegetated ditches to be suitable secondary habitat due their similarity to emergent wetlands in vegetation structure and hydrology (Hofmann et al. 1990, Kruchek 2004). Additionally, open shorelines may be used by rice rats to move between patches of wetland vegetation alongside permanent, deep-water lakes.

Although the predominant use of emergent wetland habitat by rice rats in our study was expected, we also found that > 40% of home-range area extended beyond wetlands into the purportedly unsuitable upland matrix, including crop fields that made up > 20% of rice rat home ranges. Additionally, we homed to rice rats nesting in upland grasses, crop fields, and other upland land cover. The high amount of home range overlapping the matrix parallels the findings of our study of matrix permeability (Cooney 2013), which showed that upland areas (particularly soybean fields) were frequently entered and used by rice rats, presumably for foraging and dispersal, especially when vegetation cover was available in those fields and rice rats were abundant. Smith and Vreize (1979) found that rice rats occupied mesic sawgrass prairies in the Everglades, but only when hammock habitat was dry. Additionally, Kruchek (2004) captured subadult rice rats in upland grasses when adult densities in nearby wetlands were high. Eubanks (2009) found that wetlands adjacent to agriculture were less likely occupied by rice rats, but our findings suggest that mature crop fields facilitate matrix movement in the rice rat. It should be noted that we specifically selected wetland study sites that were isolated within the landscape to study permeability, so habitat fragmentation may have encouraged rice rats to occupy upland areas. Future research comparing habitat selection by rice rats in fragmented and unfragmented habitats would improve our understanding of the importance of upland to the species.

Wolfe (1982) and Kruchek (2004) noted that grassland may be more suitable to rice rats than other matrix cover types due to its structural similarity to emergent vegetation. Grassland buffers around wetlands could improve the suitability of wetland habitat for rice rats and increase the probability of rice rat occupancy (Kruchek 2004, Eubanks et al. 2011). We found male rice rats occupying nests and burrows under mounds of switchgrass (*Panicum virgatum*) and big bluestem (*Andropogon gerardii*) in upland cover. Although we did not capture rice rats in grasslands > 15 m from the wetland edge in the permeability study (Cooney 2013), we frequently radio-tracked rice rats occupying upland grasses and moving > 250 m into grassland patches. Unlike telemetry research, inferences about landcover use based on trapping rely heavily on animal trappability, which can differ between seasons and cover types (Balph 1968, Hammond and Anthony 2006). Radio-telemetry appears to be a more sensitive tool than trapping transects for assessing matrix use by rice rats.

During our study of male rice rats, home ranges were largest and overlapped matrix the most from late May to early July, corresponding with peaks in rice rat abundance and water depth in wetlands (Cooney 2013). Small mammals tend to expand their movements when population density peaks and individuals are forced out of the habitat to avoid intraspecific competition (Gaines and McClenaghan 1980). Hispid cotton rats in Texas had larger movement distances in summer than spring or fall (Spencer et al. 1990). Larger home ranges may also signal breeding activity, which is believed to occur from May–October in rice rats (Negus et al. 1961, Eubanks 2009). For instance, male Key Largo woodrats (*Neotoma floridana smalli*) had larger minimum convex polygon home ranges during June–August than in March–May and September–

November, likely as they sought females for mating (McCleery et al. 2006), which may explain expanded home ranges of males at this time.

Home ranges of adult males overlapped more matrix cover than did subadult males. Kruchek (2004) found adult rice rats entering grassy uplands during extended periods of flooding, but we did not find that rice rats at Burning Star 5 entered the matrix at a higher rate during site inundation (Cooney 2013). Our concurrent trapping study (Cooney 2013) also showed that adults were captured in wetland habitat at a higher proportion than their subadult counterparts, which contrasts with the high amount of matrix overlap in adult home ranges determined by radiotelemetry. As Hofmann and Gardner (1992) point out, adult rice rats have a tendency to shift home ranges and are likely to adopt multiple home-range centers over the course of a season. Establishing multiple nesting sites is also a common feature of this species, as Smith and Vrieze (1979) found 89% of rice rats were captured at multiple tree hammocks within the Florida Everglades. We observed that 2 adult males dispersed from the wetland where they were captured and established new home ranges > 100 m away. Dispersal in rice rats may not be age-biased, as adults, subadults, and juveniles were found dispersing in equal proportion from Cresent Island, Virginia (Forys and Dueser 1993). The willingness of adults to move through upland cover and disperse can stabilize rice rat metapopulations if individuals successfully breed in novel patches (Hanski 1994, Fahrig and Merriam 1994).

The relatively high dispersal potential of the rice rat should be considered when developing or conserving habitat that is accessible to this species for colonization. Using telemetry, we determined that rice rats can move at least 396 m in a day and may nest 464 m from wetland habitat. Partially inundated, vegetated ditches can also provide dispersal corridors by which rice rats could travel between permanent wetlands where breeding generally occurs (Wolfe

1985). Eubanks (2009) noted that improving connectivity between wetland complexes would facilitate the expansion of rice rats to suitable wetlands in Illinois that currently remain unoccupied. Although not a substitute for contiguous habitat, vegetated irrigation ditches can provide temporary cover for transient rice rats during dispersal (Hofmann et al. 1990).

The marsh rice rat persists in the southern portion of Illinois, where agricultural practices and urban development have historically contributed to wetland reduction (Suloway and Hubbell 1994). Continued wetland mitigation laws – where up to 5.5 ha of wetland must be replaced for every 1 ha developed – should ensure the availability of suitable habitat for the marsh rice rat in the near future (Illinois Administrative Code Title 17, Chapter 1, Subchapter C, Part 1090.10-100, 6 May 1996). Kruchek (2004) proposed that federal wetland protection should extend to adjacent upland habitat to account for the important role uplands play in providing sink habitat or refuges for rice rats and other wetland species. Additionally, mine reclamation in southern Illinois has contributed to the development of novel wetland habitat where none might have existed in the past (Nawrot and Klimstra 1989). Provided that wetlands are accessible to potential immigrants, reclamation sites have the potential to increase the range and stability of the rice rat in Illinois and similar areas (Nawrot and Klimstra 1989, Eubanks 2009).

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Table 1. Summary information and home-range and movement characteristics for the 25 radio-collared marsh rice rats (*Oryzomys palustris*) tracked during 30 March–7 November 2011 at Burning Star 5 Natural Wildlife Area (DeSoto, Illinois).

Collaring Interval	Collar Frequency	Age Class	Days Tracked	Relocations	MCP[a] (ha)	95% Isopleth (ha)	Average Daily Movement Distance (m)	Matrix in 95% Isopleth (%)	Collar Fate
March-April	149.125	Subadult	21	10	0.91	9.27	46.4	50.4	Detached
March-April	149.185	Adult	34	10	0.97	1.24	42.5	30.0	Detached
March-April	149.144	Subadult	40	20	1.11	2.04	60.4	20.9	Recapture
March-April	149.225	Subadult	39	16	0.28	0.45	19.5	5.5	Detached
March-April	149.104	Subadult	38	9	0.21	0.16	21.1	0.0	Signal Lost
March-April	149.304	Adult	25	8	0.81	2.49	22.7	58.3	Detached
March-April	149.425	Adult	16	8	0.47	2.13	28.7	43.9	Signal Lost
March-April	149.084	Adult	16	10	0.05	0.13	19.3	37.4	Signal Lost
May-June	149.245	Adult	16	7	0.83	0.82	76.7	68.8	Detached
May-June	149.405	Adult	40	24	1.32	3.62	27.6	48.4	Detached
May-June	149.044	Adult	24	14	6.41	6.52	158.0	83.7	Signal Lost
May-June	149.204	Adult	38	22	1.31	2.31	30.8	47.2	Signal Lost
May-June	149.445	Subadult	34	17	2.72	6.84	39.5	67.3	Detached[b]

Table 1 Continued.

Collaring Interval	Collar Frequency	Age Class	Days Tracked	Relocations	MCP[a] (ha)	95% Isopleth (ha)	Average Daily Movement Distance (m)	Matrix in 95% Isopleth (%)	Collar Fate
May-June	149.064	Subadult	36	15	9.26	7.29	84.2	72.1	Detached
May-June	149.024	Subadult	20	8	2.10	8.40	53.8	51.4	Detached[b]
May-June	149.024[c]	Subadult	4	0	DID NOT CALCULATE				Signal Lost
July-Aug.	149.385	Adult	42	22	1.86	2.92	38.5	58.8	Signal Lost
July-Aug.	149.003	Subadult	35	21	2.02	3.92	67.9	58.6	Signal Lost
July-Aug.	149.285	Subadult	14	4	DID NOT CALCULATE				Signal Lost
July-Aug.	149.345	Subadult	4	0	DID NOT CALCULATE				Detached[b]
July-Aug.	149.264	Adult	45	23	0.97	1.81	39.4	38.3	Signal Lost
July-Aug.	149.325	Adult	44	24	4.36	8.73	64.7	48.6	Signal Lost
Sept.-Oct.	149.766	Adult	13	7	0.65	2.50	21.1	81.0	Detached
Sept.-Oct.	149.825	Adult	54	17	0.26	0.50	21.9	56.2	Signal Lost
Sept.-Oct.	149.604	Subadult	13	3	DID NOT CALCULATE				Detached

[a] Minimum convex polygon

[b] Rat killed by predator

[c] Collar found detached, was reused

Table 2. Mixed model ANOVA for the response variable of percentage home range composed of upland matrix. Age class (Subadult and Adult) and collaring interval were categorical fixed-effect variables, while sub-location and wetland site were random effects.

Model Type	Effects	F-value	P-value	Parameters	Estimate (SE)
Main effects	AGE CLASS	4.44	0.06	Subadult	0.38 (0.07)
				Adult	0.55 (0.05)
	INTERVAL	4.94	<0.05	1[a]	0.36 (0.07)
				2[b]	0.63 (0.07)
				3[c]	0.44 (0.08)
Interactive	AGE CLASS	1.87	0.23	Subadult	0.41 (0.07)
				Adult	0.52 (0.06)
	INTERVAL	4.34	0.08	1	0.34 (0.07)
				2	0.62 (0.08)
				3	0.42 (0.08)
	AGE CLASS× INTERVAL	0.17	0.85	Subadult 1	0.27 (0.10)
				Subadult 2	0.60 (0.12)
				Subadult 3	0.35 (0.13)
				Adult 1	0.42 (0.09)
				Adult 2	0.64 (0.08)
				Adult3	0.49 (0.10)

[a] March-May

[b] May-July

[c] July-September

Table 3. Compositional analysis of used (within marsh rice rat [*Oryzomys palustris*] home ranges) and available landcover at Burning Star 5 Natural Wildife Area (DeSoto, Illinois), March 30 – November 7, 2011. Used data were compared with 2 measures of available habitat: landcover within 41.2-m buffer surrounding wetland patches and within composite 95% isopleth ranges. Compositional analysis PROC BYCOMP in program SAS ranked landcover types in order of decreasing preference (8-0).

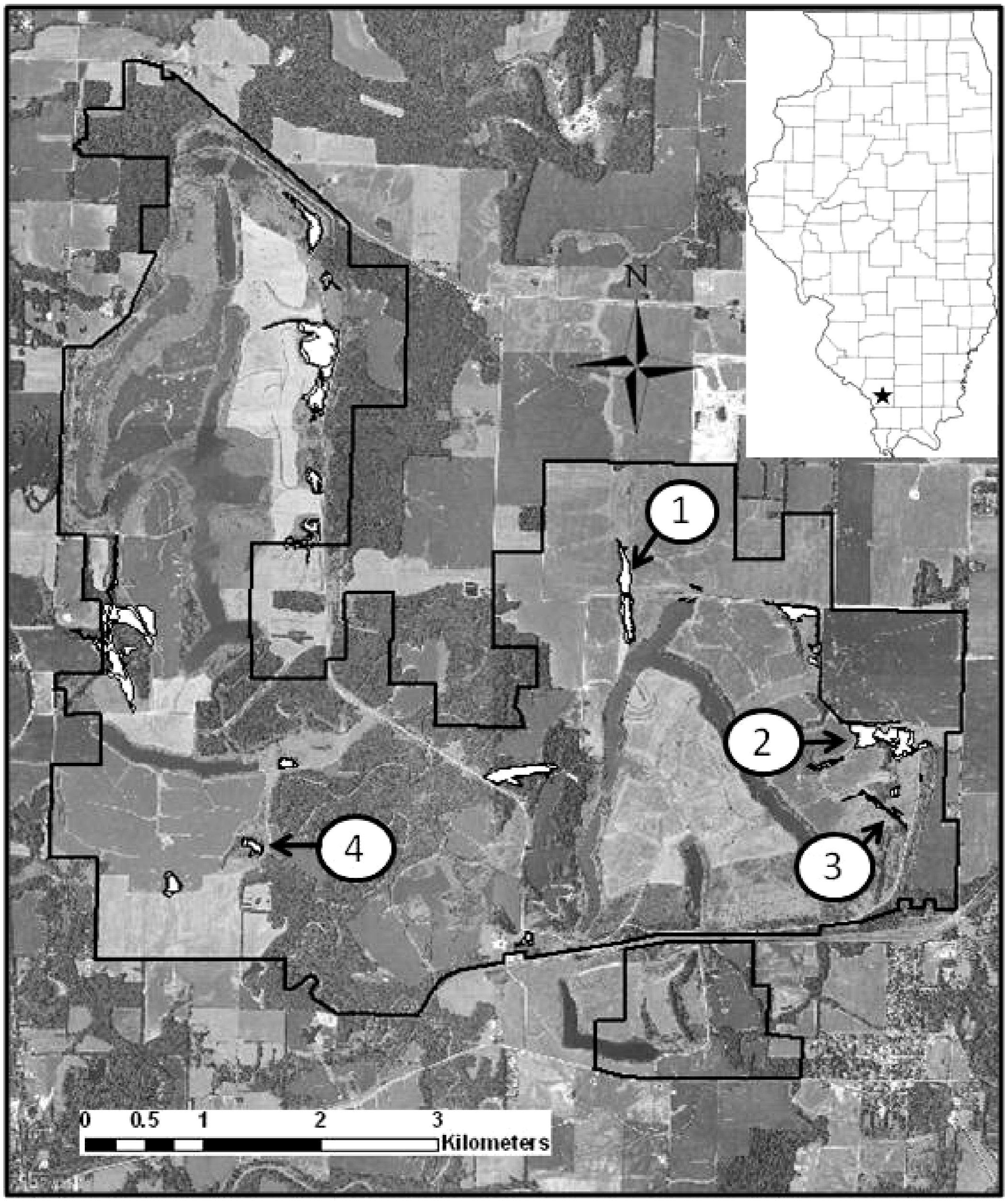
	Used	Available within wetland buffers		Available within composite ranges	
Landcover type	Average (±SE) %	Average (±SE) %	Selection rank	Average (±SE) %	Selection rank
Emergent wetland vegetation[a]	45.9 (4.3)	30.0 (3.6)	8	28.4 (4.2)	8
Shoreline	1.3 (0.9)	1.1 (1.1)	5	1.5 (1.5)	7
Agriculture	21.8 (4.2)	18.3 (11.5)	6	16.5 (7.7)	6
Partially inundated ditch	0.7 (0.4)	0.5 (0.5)	7	0.7 (0.4)	2
Grassland	11.0 (2.1)	17.8 (5.3)	4	16.6 (5.7)	5
Forest	8.3 (2.4)	16.2 (7.4)	3	14.3 (6.0)	4
Open water	8.7 (2.4)	10.3 (6.1)	2	13.8 (6.8)	0
Gravel road	2.5 (0.6)	4.3 (1.6)	1	3.2 (0.6)	3
Shrub cover	1.2 (0.4)	4.4 (3.0)	0	2.4 (1.1)	1

[a] Cover type was used significantly more than would have been expected based on availability

FIGURE LEGENDS

Fig. 1. Burning Star 5 Natural Wildlife Area in northwest Jackson County, near DeSoto, Illinois, USA (inset), showing property boundary and 4 wetlands where marsh rice rats (*Oryzomys palustris*) were livetrapped and radio-collared March–October 2011.

Fig. 2. Frequency distribution of daily movement distances made by radio-collared marsh rice rats (*Oryzomys palustris*) at Burning Star 5 Natural Wildlife Area, (DeSoto, Illinois) between March 30 and November 7, 2011.


N
1
2
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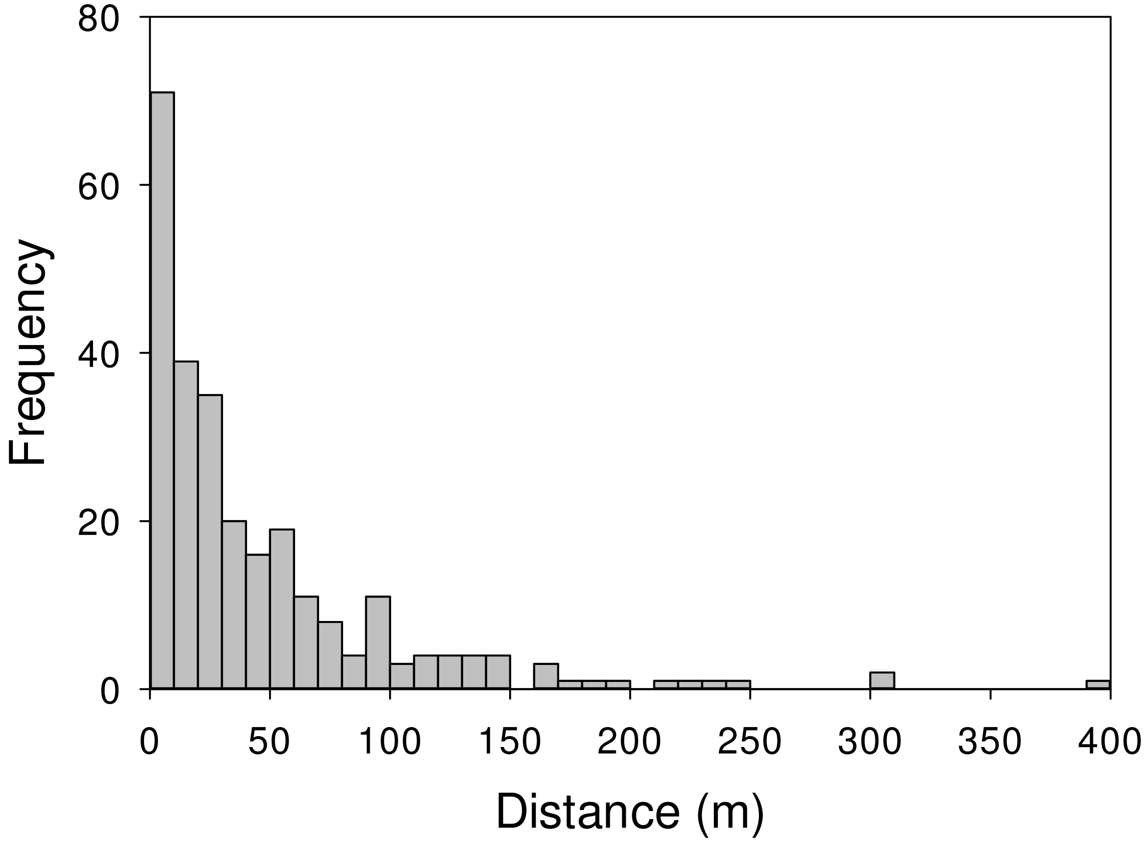
0 0.5 1 2 3
Kilometers



80
60
40
20
0
Frequency
0
50
100
150
200
250
300
350
400
Distance (m)