

Riverine Peninsulas: An Experimental Approach to Homing in White-footed Mice (*Peromyscus leucopus*)

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Source: The American Midland Naturalist, 151(2):408-413. 2004.

Published By: University of Notre Dame

DOI:

URL: <http://www.bioone.org/doi/full/10.1674/0003-0031%282004%29151%5B0408%3ARPAEAT%5D2.0.CO%3B2>

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Notes and Discussion

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ABSTRACT.—White-footed mice, *Peromyscus leucopus*, were removed from a riverine peninsula to assess the effects of a river functioning as a barrier to movement. During an 8-mo period in 2001, 101 mice were live trapped and released across a river from the 14.2-ha peninsula. No small mammals were found to emigrate from the peninsula; 6 of the mice removed, however, exhibited homing behavior and immigrated across a fifth-order river and returned to or near the original site of capture. More studies at this temporal and spatial scale need to be conducted to demonstrate how natural barriers, particularly riverine peninsulas, could be utilized as experimental mesocosms in the study of small-mammal population dynamics at the landscape scale.

INTRODUCTION

Boundary designation persists as a critical component to scientific investigation (Strayer *et al.*, 2003). Hypotheses based on fundamental ecological principles must, therefore, abide by boundary designation so proper variables can be analyzed adequately. Kozakiewicz (1993) suggested that habitat barriers can determine boundaries regarding the movements of single individuals (*e.g.*, individual home range level), can limit processes of recolonization of empty habitat patches (*e.g.*, metapopulation level) or can be effective enough to stop gene flow between metapopulations (*e.g.*, evolutionary deme level).

Numerous barriers, both natural and human-made, have been identified as effective means of limiting movements across landscapes. For example, road avoidance has been demonstrated for several species of small mammals (Oxley *et al.*, 1974; Garland and Bradley, 1984; Mader, 1984; Bakowski and Kozakiewicz, 1988; Merriam *et al.*, 1989). Oxley *et al.* (1974) suggested that small mammals in forest patches were reluctant to venture onto road surfaces where the distance between forest margins exceeded 20 m. Mader (1984) found that roads served as an effective hindrance to the mobility for two species of forest-dwelling mice (*Apodemus clavicles* and *Clethrionomys glareolus*). There is a paucity of information, however, regarding how natural barriers, such as streams and rivers, function as barriers to movement or restrict homing and dispersal behavior of small mammals. Even less is known regarding how riverine peninsulas created by meandering rivers function as experimental units or natural mesocosms to investigate the ecology of small mammal populations. A mesocosm is defined as a bounded or partially enclosed outdoor experimental ecosystem (Odum, 1984). He noted that mesocosms provide a degree of realism not possible in the laboratory.

We hypothesized that riverine peninsulas and rivers function as effective barriers restricting the movement and homing instinct of small mammal populations. Thus far, the relationship of riverine barriers to small mammal movement has centered predominantly on species diversity arising from Amazonian tributaries (Gascon *et al.*, 2000). The classic observations made by Wallace (1852) served to formulate the riverine barrier hypothesis which attempted to explain the rich diversity of small mammal species in the Amazon Basin. For example, Patton *et al.* (1994) noted that the reduction of gene flow among the arboreal spiny rat (*Mesomys* sp.) is restricted by an Amazon tributary. Peres *et al.* (1996) suggested that tributaries from the Amazon River effectively acted as a barrier to the dispersal of saddle-back tamarins (*Saguinus fuscicollis*). Lugon-Moulin *et al.* (1999) hypothesized that riverine barriers could be major contributions to the genetic structuring of the common shrew (*Sorex araneus*). More recently, however, Gascon *et al.* (2000) weakened the hypothesis that riverine barriers have played a geographically pervasive role in species diversification and in shaping patterns of species diversity.

The majority of studies concerning rivers as effective barriers to small mammal movement has centered on large river systems with focus on genetic and species diversity rather than on actual movement or lack thereof. In particular, there has been insufficient research addressing if stream systems function as barriers to small mammal movement. There is also a paucity of information questioning if peninsulas created by meandering streams or rivers isolate populations within their confines. There is evidence that deer mice (*Peromyscus maniculatus*) exhibits homing ability across rivers (Furrer, 1973; Teferi and Millar, 1993). Less is known, however, regarding the homing ability of the

white-footed mouse (*P. leucopus*) to cross streams or rivers. Savidge (1973) investigated the effectiveness of a small stream (3–4 m wide and 10–40 cm deep) to function as a barrier to movement by *P. leucopus*. He found that homing from across the stream was less successful than homing the same distance without a stream barrier. Carter and Merritt (1981) noted that the comparatively poor swimming ability of *P. leucopus* is thought to be a major factor accounting for its meager representation on islands.

We suggest that riverine peninsulas provide excellent experimental units (mesocosms) to address questions regarding the landscape ecology of small mammals (Barrett and Peles, 1999). Mesocosms function as intermediate-temporal/spatial scale systems, which correlate closely to a particular set of field conditions. We recommend that riverine peninsulas be considered as mesocosm-scale systems because of their size, the possibility for landscape-level replication and the abundance of native fauna inhabiting these systems.

We designed a study to focus on the dispersal behavior, homing ability and population dynamics of the white-footed mouse (*Peromyscus leucopus*). In this investigation we removed all white-footed mice ($N = 101$) from four of eight landscape patches located within a 14.2-ha bottomland forest peninsula. Individuals were relocated across a fifth-order river to address questions pertaining to homing ability and to determine if a riverine peninsula functioned as a barrier to movement. Stream order is based on the structure and function of stream ecosystems as described by Vannote *et al.* (1980) and Cummins (1988). The area of the North Oconee River watershed is 687 km². Mean stream width at the research site is 28.0 m (± 1.8 sd) wide and rate of discharge ranged from approximately 190 m³ in early spring to 5–10 m³ in late summer. Banks are steep adjacent to the river and contain sparse vegetation due to changes in stream depth. We hypothesized that *P. leucopus*, due to their poor swimming ability, would be incapable of traversing the North Oconee River, thus eliminating or decreasing immigration, homing and dispersal ability.

MATERIALS AND METHODS

Research design.—This investigation was conducted from March–November 2001 at the HorseShoe Bend experimental site, located near Athens, Georgia (33°57'N, 83°23'W). HorseShoe Bend is a 14.2-ha (35-acre) riverine peninsula formed by the North Oconee River and composed of bottomland and upland forest habitat (Fig. 1). The study site was dominated by water oak (*Quercus nigra*), sweet gum (*Liquidambar styraciflua*) and Chinese privet (*Ligustrum sinense*). River birch (*Betula nigra*) also was abundant in the lowland habitat, whereas white oak (*Quercus alba*) was found mainly in the upland habitat.

Eight experimental plots were established during 2001 in bottomland and upland forest habitat types ($N = 4$ each) within this riverine peninsula (Fig. 1). Each plot consisted of 2×6 grid trapping stations with each trapping station spaced approximately 10 m (± 2 m) apart. Each station consisted of two Sherman live traps, one located 1.5 m high on the trunk of a tree and the second located on the forest floor within 1 m of the same tree. Four trapping stations in each plot received four additional live traps placed 4.5 m into the forest canopy. Thus, there were 28 traps per trapping grid and 112 traps per habitat type (upland and lowland); a total of 224 traps were used during 2001.

Census and relocation procedures.—Sherman live traps were examined twice weekly from 22 March–16 November 2001. Traps were baited with black sunflower seed and supplied with cotton when temperatures were expected to fall below 10 C. A 2 wk rotation of trapping was implemented with ground and 1.5-meter traps examined 1 wk and the 4.5-meter high traps examined the second week. Each captured animal was identified to species, marked by toe clipping, examined for reproductive condition (females open or closed vaginal orifice; males abdominal or scrotal testes), weighed to the nearest gram, checked for overall health and appearance (*e.g.*, presence of botflies or wounds) and released at the site of capture.

To quantify potential homing instinct and movement behavior of *Peromyscus leucopus*, all white-footed mice were removed from four experimental removal plots (two upland and two lowland; *see* Fig. 1) between 1 June–16 November 2001, then immediately released in a similarly-wooded bottomland forest community across the North Oconee River (*i.e.*, outside the peninsula). Each translocated individual was released within 10 m along the opposite bank of the North Oconee River. Release locations, original site of capture, sex, reproductive condition, weight and general appearance were recorded for each animal. Extensive live-trapping also was conducted across the river during both 2000 (1440 trap nights)



FIG. 1.—Aerial photograph of the HorseShoe Bend, Georgia (33°57'N, 83°23'W) experimental site depicting the research design and arrangement of trapping grids. (U) represents upland grids; (L) represents lowland grids. Note that the North Oconee River creates a landscape peninsula

and 2001 (1140 trap nights) to determine if any small mammals had emigrated across the river from within the peninsula before, during, and following the period of experimentation.

RESULTS AND DISCUSSION

During the period 1 June–16 November 2001, 101 *Peromyscus leucopus* (67 males and 34 females) were removed from four experimental removal plots within the peninsular mesocosm and released along the opposite bank of the North Oconee River (*i.e.*, outside of the riverine peninsula). Six *P. leucopus* (5 males and 1 female) returned to the peninsula (*i.e.*, exhibited homing instinct) and were recaptured within or near the original site of removal. In fact, four of the six *P. leucopus* (adult 17-, 18-, 19- and 20-g males) that immigrated to the peninsula were recaptured in the same plot from which they were removed. An adult 20-g male following its second removal across the river actually returned to the peninsula to the patch a second time from which it was previously captured. Two individuals, a 14-g male and a 16-g female, returned to the peninsula but did not return to the exact plot from which they were removed. It is possible, however, that these individuals were live-trapped before they had the opportunity to immigrate to the original site of capture or that the patch from which they were recaptured was within the 0.1-ha home range size as reported by Lackey *et al.* (1985). The minimum and maximum distances moved for these six individuals were 250 m and 1750 m, respectively ($\bar{x} = 728$ m).

We observed that of 794 captures (138 different marked individuals) of white-footed mice during 2000, and 819 captures (254 marked individuals) during 2001, no *Peromyscus leucopus* were found to emigrate from the peninsula following >2500 trap-nights of live trapping across this fifth-order river (Pruett *et al.*, 2002). Neither were white-footed mice marked across the river found to immigrate into the peninsula.

There exists abundant evidence that deer mice (*Peromyscus maniculatus*) have a strong homing ability (Murie, 1963; Rawson, 1966; Furrer, 1973; Terferi and Millar, 1993). Homing ability is defined as the ability of an organism to return to the initial site of capture (presumed within its home range) after being displaced (Cooke and Terman, 1977). There exists much less evidence, however, regarding the

homing ability of white-footed mice (*P. leucopus*), especially where rivers may function as a physical landscape barrier to movement. We designed a study involving a landscape peninsula to better quantify homing ability of white-footed mice.

There is evidence that *Peromyscus leucopus* is able to swim (Teeters, 1945; Ruffer, 1961), but much less evidence that this species is a good swimmer. Sheppe (1965) reported that *P. leucopus* was able to swim in calm waters, but unable to remain afloat in the choppy waters of Lake Opinicon, Ontario. Carter and Merritt (1981) noted that only 4 of 10 *P. leucopus* actually reached shore when released 50 m from shore. Six of the mice appeared disoriented, changing course many times and often swimming in circles. They speculated that the poor swimming ability of *P. leucopus* was a significant factor accounting for its meager representation on islands in North America. No studies have demonstrated the ability of *P. leucopus* to traverse a fifth-order river. These findings suggest a poor orientation or decreased homing activity in white-footed mice when confronted with aquatic barriers.

We provide evidence that landscape features, such as rivers, do function as impediments to the movement of a small mammal species such as *Peromyscus leucopus*, and that riverine peninsulas do represent natural mesocosms that can be utilized for investigations focusing on the ecology of small mammals. For example, of 254 *P. leucopus* captured within the peninsula during 2001, no individuals were found to cross this fifth-order river (*i.e.*, emigration from the peninsula was found to be nonexistent). Although no *P. leucopus* were found to emigrate from the 14.2-ha peninsula following extensive live-trapping across the river during 2000 and 2001, it is significant to note that 6 of 101 white-footed mice did return (immigrate) across this fifth-order river when released in similar riparian habitat on the opposite shore. This suggests a strong homing ability, especially as this species is noted for its poor swimming ability. We failed to observe any other means (*e.g.*, fallen trees that might span the river) that these individuals might use to transverse this river barrier.

Of the six individuals that exhibit homing ability, five were males. Stickle (1949) also found that male *Peromyscus leucopus* exhibit a higher percentage of homing success than females, perhaps because males have a larger home range size than females (Metzgar, 1973; Wolff, 1985). Return to a home range could help to maintain an individual's status in the social structure, as well as to maintain an advantage regarding exploitation of known resources such as food, nest sites and refuges (Madison, 1977). Homing would also be an adaptive advantage should individuals be displaced during flood events (Blair, 1939), typical of riverine habitats.

We encourage ecologists and resource managers to consider the use of natural landscape features and elements when investigating landscape-scale small mammal ecology. More studies of this temporal and spatial scale need to be conducted to demonstrate how natural landscape features and barriers, particularly riverine peninsulas, could be utilized to investigate small mammal population dynamics at the landscape scale. Not only do natural barriers negate the construction of costly mesocosm structures (*e.g.*, Barrett, 1988; Collins and Barrett, 1997), natural mesocosms or landscape features should provide greater knowledge regarding how small mammals function within natural landscapes.

Acknowledgments.—We thank Terry L. Barrett for preparation of the manuscript. We also thank Jennifer Chastant, Matthew Shuman and Cayce Payton for field assistance.

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