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# RODENT POPULATION STUDY IN THE NORTH SHORE RESTORATION AREA, PART I (SURVEY OF RODENTS NEAR LAKE APOPKA)

by

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# Executive Summary

Eight small mammal trapping grids were established by stratified random placement within the 5,592-hectare (ha) Lake Apopka North Shore Restoration Area. Each grid was designed to sample approximately 0.5 ha with 49 Sherman traps spaced at 10-meter intervals. Traps were opened for two successive days at approximately five-day intervals for a total of eight days during November and December 1999. Limited trapping with Sherman live traps was conducted on transects and in farm buildings. A total of 3,456 trap nights were registered and 1,319 individuals of three species were captured. About 70% of the rodent captures were cotton rats (*Sigmodon hispidus*). Two hundred and thirty-four house mice (*Mus musculus*) were marked with numbered monel ear-tags and released at the point of capture. All house mouse captures were marked on the grids. House mice were also ear-tagged on one trapping transect. The third species of rodent captured in the live traps was the rice rat (*Oryzomys palustris*).

Captures per trap night was used as a standard metric to compare grids and relative abundance of species among grids. Capture success was very high due to the extraordinary numbers of cotton rats present in the abandoned muck farms. Capture success of house mice was much lower than for cotton rats. Nonetheless, mark-recapture estimates suggested that modest to very high densities of house mice were present. Recapture success was fairly poor for tagged house mice and may suggest a large pool of individuals from which the live-trapped samples were derived. Alternatively, a negative trap response on the part of tagged individuals may explain the low recapture success.

High spatial variation in rodent abundance was observed. Food supply, vegetative cover, predators, and interactions among the rodents may have contributed to this variation. During the period of study, reproduction was essentially halted. Lactating female house mice were not observed. Male house mice were not observed to be in reproductive condition. Some evidence of reproduction was observed in December 1999 when a single pregnant house mouse was captured.

One possible explanation for the high number of rodents may be the occurrence of two successive mild winters in 1997 and 1998. Food and cover may have been sufficient to allow the local rodent populations to outpace the normal limiting factors, for example, local predators and self-regulating mechanisms. Additional work is ongoing and will be presented in a future report.

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## Figures



## Tables

# Introduction

The purpose of this study was to document the assemblage of small mammals presently inhabiting former muck farm land found along the north and east shores of Lake Apopka, Florida. Particular attention was given to determine the relative abundance of the house mouse (*Mus musculus*) in three habitat settings: fallow fields, levees or canal banks, and abandoned buildings. The native rodents, for example, cotton mouse (*Peromyscus gossypinus*), cotton rat (*Sigmodon hispidus*), and rice rat (*Oryzomys palustris*) were of lesser interest relative to the house mouse.

During 1999, unusually dense populations of house mice were known to have been present in various structures adjacent to the muck farms, for example, homes and businesses, as well as several miles away. It was not known how the house mice came to be distributed in the landscape. Further, it was not known where the house mouse population began to increase beyond the low numbers normally associated with agricultural areas, rural homes, subdivisions, and commercial developments. House mouse numbers apparently began to increase as early as November 1998.

In this study, intensive live trapping studies were conducted at a number of study sites within the muck farms to document presence and relative abundance of house mice and other native rodents.

# Study Hypotheses

The null hypothesis of this study was that no difference in house mouse abundance would be found among the three habitat strata (fallow fields, levees, and abandoned buildings) selected for study.

The alternative hypothesis was that a significant difference would be found in the abundance of house mice among the three habitat strata.

It was expected that house mouse numbers would be greatest in the abandoned buildings, with far fewer individuals present along the levees, and fewer yet in the fallow fields.

# Study Area

The study area was located in the eastern portion of the 5,592-hectare (ha) North Shore Restoration Area (Figure 1). The study area, about 3,800 ha, was subdivided into eight units of roughly equal size.

The eight sites were located on land that had sustained intensive agriculture for several decades. All of the properties had been abandoned for more than a year and supported a dense growth of

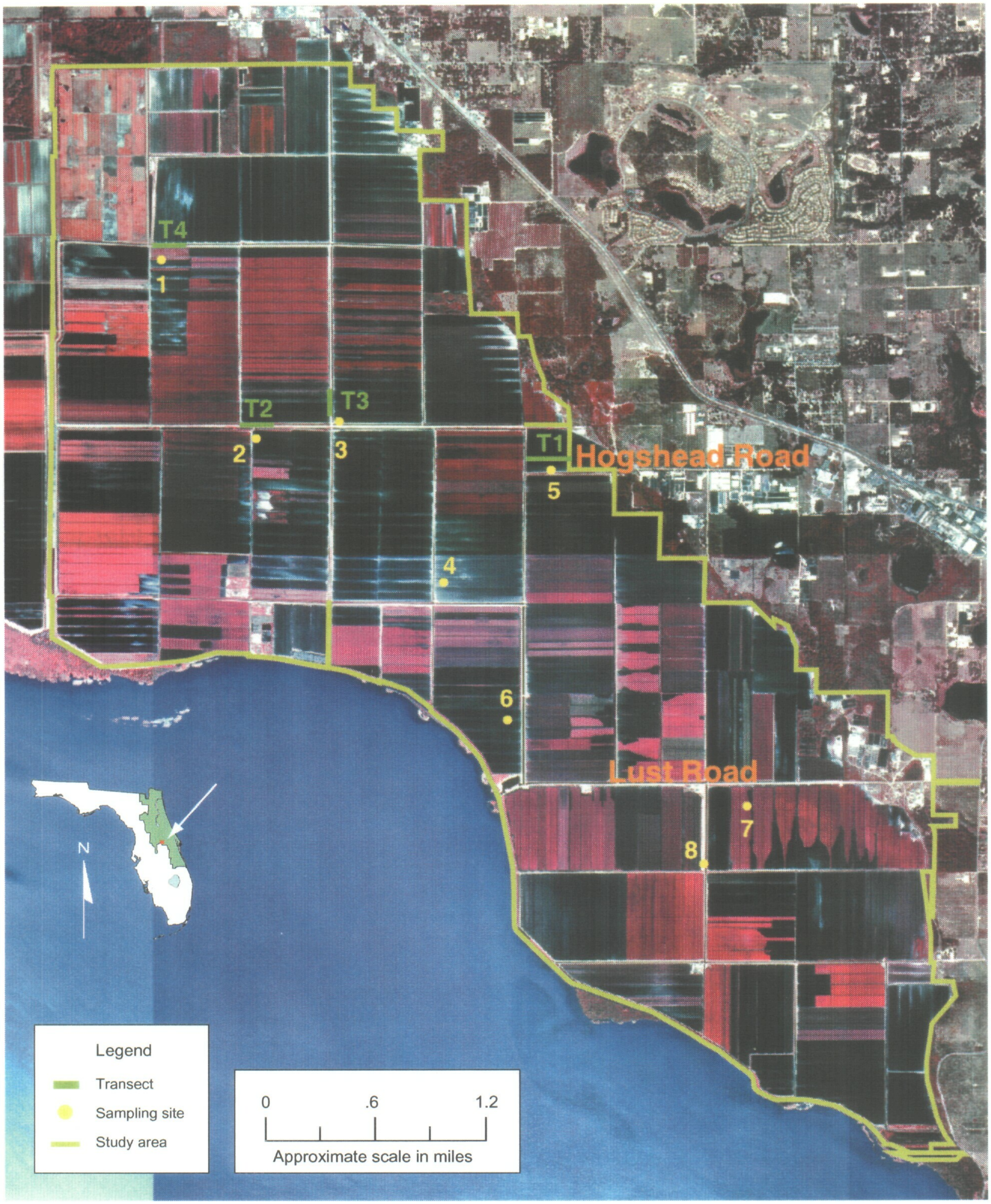


Figure 1. Location of eight small mammal trapping grids and transects in fallow fields within the North Shore Restoration Area, Lake Apopka, Florida. *Sampling was conducted in November and December 1999.*

grasses, sedges, and herbs. The only woody vegetation present was to be found near canals where water-primrose (*Ludwigia peruviana*) had spread into the fields. Vegetative cover tended to be very patchy, with single species dominance alternating from patch to patch. Patches were 3–8 meters (m) or slightly greater in width, and bare ground was generally not present.

Plants were identified according to Stucky et al. 1981, Murphy et al. 1979, and Tobe et al. 1998. The groundcover of the study sites included the following plants: cattail (*Typha* spp), nightshade (*Solanum* spp.), dogfennel (*Eupatorium capillifolium*), bedstraw (*Galium aparine* and *G. tinctorium* ), water-primrose (*Ludwigia peruviana* and *L. leptocarpa*), morning glory (*Ipomoea* sp.), spreading dayflower (*Commelina diffusa*), sedges (*Cyperus* spp.), guineagrass (*Panicum maximum*), vaseygrass (*Paspalum urvillei*), knotroot foxtail (*Setaria geniculata*), spiny amaranth (pigweed) (*Amaranthus spinosus*), common beggarticks (*Bidens alba*), eclipta (*Eclipta alba*), curly dock (*Rumex crispus*), false-willow (*Baccharis angustifolia*), saltbush (*Baccharis halimifolia*), and sea-purslane (*Sesuvium portulacastrum*). Many additional plants were not identified because of various conditions, but mostly herbaceous species dominated the study sites.

# Methods

## Study Approach

One sampling site was randomly selected within each of the eight units (grids) prior to going into the field. Once the sites were located in the field (locations given in appendix), the exact position of sampling sites was moved, in some cases as much as 200 m, to accommodate access and logistics. Once sampling areas in the fallow fields were established, nearby levee habitat was selected for study. Buildings within the study area at the Hogshead Road entrance were sampled.

Each of eight fallow field sampling sites consisted of one grid. Six grids contained 49 trap stations (7 rows, 7 columns). Two grids deviated from this configuration due to local land features, namely, grid 5 (5 rows, 10 columns) and grid 4 (10 rows, 5 columns). Stations were 10 m apart. A single Sherman live trap baited with large sunflower seeds was placed at each trap station. Traps remained in place on the grids for the duration of the study.

Sampling was conducted from November 6 to December 9, 1999. Traps were set in the late afternoon and checked the following morning. House mice were ear-tagged on all the study grids. Males were recorded as abdominal or descended with respect to the position of the testes. Females were examined for signs of lactation, pregnancy, or reproductive inactivity. Body weights of house mice were determined. Trap location was recorded for all individuals, and all captures were released at the site of capture as soon as processing was completed. Rodent captures other than house mice on grids 1–8 were recorded by species, age class, and site of capture, and released alive. In addition, all captures of small mammals on grid 8 were ear-tagged.

Trappings at levees and canal banks and at buildings followed a slightly different protocol. Canal levees were sampled by transects (linear trap lines) of at least 25 Sherman traps at 10-m intervals for two successive days. Size and configuration of buildings determined the number and arrangement of Sherman traps within them. Trappings at buildings were conducted during three successive days.

## Data Analysis

Data reduction was done at the grid level. House mouse capture success per grid was expressed in terms of captures per trap night. Minimum numbers alive were used as a conservative estimate of abundance based on marked animals and their frequency of recapture. Population estimates were computed using the Lincoln Index when recaptures were available (Krebs 1999). Calculations were based on the following formula:

$$N = M C / R$$

where

N = population estimate
M = number of marked individuals released in the first sample
C = number of marked and unmarked individuals caught in the second sample
R = number of marked individuals from the first sample caught in the second sample

Trapping was done in four cycles associated with these dates: cycle 1 (November 6–8), cycle 2 (November 13–15), cycle 3 (November 19–22), and cycle 4 (December 4–9). Trap cycles 1, 2, and 3 were used as the mark phase of the population estimation procedure and cycle 4 as the recapture phase.

Densities were extrapolated from population estimates where available. Area of the grids was calculated with a border strip added to represent half the distance between trap stations, that is, 5 m. The use of a border strip approach was developed from the assumption that the traps were sampled from a larger area than that defined by the trap stations' corners (Krebs 1999). Densities were based on numbers per hectare (10,000 square meters) and acres (1 acre = 2.47 ha).

All the trapping results were entered into a spreadsheet format for the collection of summary statistics. Central tendency and variation were expressed as sample means with standard deviations when appropriate. Using the chi-square test, sex ratios of house mice were tested for departure from a 50:50 ratio. Correlation and regression were used to examine trap success and habitat features; the program InStat was used to compute these statistics.

# Results

## Rodent Captures in Grids

Capture success in grids within the former muck farms was about 46 rodents per 100 trap nights (1,319 captures per 2,856 trap nights = 0.4618). Capture success varied among the eight grids, with the lowest success in grid 7 (0.1088) and the highest success in grid 6 (0.6939) (Table 1).

Table 1. Total number of small mammal captures and captures per trap night by grid on the North Shore Restoration Area during November and December 1999

| Grid No. | Total Captures | Captures per Trap Night |
|---|---|---|
| 1 | 162 | 0.4723 |
| 2 | 172 | 0.5015 |
| 3 | 207 | 0.6035 |
| 4 | 118 | 0.3073 |
| 5 | 161 | 0.4025 |
| 6 | 272 | 0.6939 |
| 7 | 32 | 0.1088 |
| 8 | 195 | 0.5462 |
| Total | 1,319 | |
| Overall trap success = 1,319/2,856 = 0.4618 | | |

These numbers reflect the relative number of trappable rodents and not the absolute number of rodents because individuals might be recaptured on more than one trapping date.

Cotton rats were the most frequently captured rodent in five of the eight grids, often by overwhelming numbers (Table 2). Cotton rats made up 70.05% of the 1,319 captures. Cotton rats and house mice were nearly equal in frequency of capture in grids 4 and 5 (Table 2).

Table 2. Composition of small mammal captures on grids on the North Shore Restoration Area during November and December 1999. Totals may include recaptures of individuals on successive nights

| Grid No. | House Mice | Cotton Rats | Rice Rats |
|---|---|---|---|
| 1 | 37 | 124 | 1 |
| 2 | 37 | 134 | 1 |
| 3 | 12 | 188 | 7 |
| 4 | 56 | 54 | 8 |
| 5 | 73 | 85 | 3 |
| 6 | 45 | 227 | 0 |
| 7 | 23 | 8 | 1 |
| 8 | 66 | 104 | 25 |
| Total | 349 | 924 | 46 |
| Overall total = 1,319 | | | |

House mice were present in all eight grids. They represented 26.46 % of the captures (Table 3). House mice were the dominant capture in grid 7, the grid with the fewest captures (32) over the period of study (Table 1). The greatest number of captures of house mice occurred in grid 5 (73).

Table 3. House mouse abundance on grids within the North Shore Restoration Area during November and December 1999

| Grid No. | Grid Area (in ha) | Mean No. of House Mice per Trap Night | Lincoln Index Population Estimation | Density (no. per ha) |
|---|---|---|---|---|
| 1 | 0.49 | 0.094 | 74.6 | 152.3 |
| 2 | 0.49 | 0.091 | 42.5 | 86.7 |
| 3 | 0.49 | 0.031 | — | — |
| 4 | 0.48 | 0.143 | 41.4 | 86.3 |
| 5 | 0.50 | 0.175 | 127.5 | 255.0 |
| 6 | 0.49 | 0.102 | 55.0 | 112.2 |
| 7 | 0.49 | 0.051 | 45.0 | 91.8 |
| 8 | 0.49 | 0.160 | 58.8 | 122.5 |

The rice rat was a relatively minor component of the rodent assemblage in seven of the eight grids. Twenty-five captures were made in grid 8 and this represented 12.82% of the captures at that site (Table 2). Across all the grids, the rice rat made up 3.49% of the captures over the period of study.

## Rodent Captures in Transects

Transect sampling revealed that trappable numbers of rodents varied widely in the landscape. Transect 1, immediately south of Hogshead Road and north of grid 5, yielded 21 captures or 0.0933 captures per trap night. North of Hogshead Road a transect in a mowed strip between the muck farms and private land produced no captures of rodents in 50 trap nights.

Transects 2, 3, and 4 were located on levees or elevated land used as roadways. Captures per trap night were transect 2 (0.6200), transect 3 (0.6800), and transect 4 (0.3733). These results were comparable or slightly higher than the average trap success on the grids (0.4618). Species composition and relative abundance of captures on transects tended not to reflect the grids they were near. The ratio of house mouse to cotton rat captures was 0.0877 for transect 2 and 0.2761 for grid 2. The ratio for transect 3 was 0.4667, whereas for grid 4 it was 1.0371. Transect 4 had a ratio of 0.4737, while for grid 1 the ratio was 0.2984. In contrast to the other transects, transect 1 registered 10 captures of house mice and 11 captures of cotton rats (ratio = 0.9090), which was in close agreement with grid 5 (20 m distant; ratio = 0.8588).

In summary, house mouse captures from transects on levees were slightly greater (mouse:cotton rat ratio = 0.4333) than from grids in the fallow fields (ratio = 0.3777).

## House Mouse Abundance by Grid

A total of 234 individual house mice were tagged and released in the eight grids. The average number of mice released per grid was 29.25 (SD = 15.03). Of 233 individuals for which sex was determined, 146 were males and 87 were females. A chi-square test based on the hypothesis that the sex ratio was even yielded a value of 14.939. This was significant at $p < 0.01$ and suggested more males that females existed in the trappable population.

### Grid 1

From grid 1, 25 individual house mice were captured 33 times. The recapture success was 0.3684, based on 20 individuals marked in the first six trapping events. The mark-recapture estimate was 74.6 individuals in the population. Estimated house mouse population density was 152.3 per ha, or 61.6 per acre. Among the marked individuals, 15 were males and nine were females; one individual was not sexed.

### Grid 2

From grid 2, 23 individual house mice were captured 32 times. The recapture success was 0.2381, based on 21 individuals marked in the first six trapping events. The mark-recapture estimate was 42.5 individuals in the population. Estimated house mouse density was 86.7 per ha, or 35.1 per acre. Fourteen males and nine females were marked.

### Grid 3

From grid 3, 11 house mice were marked and released. None was recaptured. No house mice were captured on November 6 or 7, and single captures were registered on November 14 and 21. Three mice were marked on November 22, five on December 5, and one on December 6. Six males and five females were marked and released.

### Grid 4

From grid 4, 32 individual mice were marked and released. The probability of recapture was 0.448. Mark-recapture estimate of the population was 41.42 mice. This density extrapolated to 86.3 per ha, or 34.9 per acre. Twenty-two males and 10 females were in the marked population.

### Grid 5

From grid 5, 58 mice were tagged and released. This was the largest number of animals released among the grids. The probability of recapture was 0.155 and represented the lowest likelihood of recapture observed, with the exception of grid 3. The population was estimated to be 127.5 individuals. This population density was estimated to be 255.0 per ha, or 103.2 per acre. Thirty-four males and 24 females were marked and released.

### Grid 6

From grid 6, 25 mice were tagged and released. The probability of recapture was 0.4091. The population was estimated to be 55.0. Estimated density was 112.24 per ha, or 45.44 per acre. The marked population included 19 males and six females.

### Grid 7

From grid 7, 17 mice were tagged. The probability of recapture was 0.2727. The population was estimated to be 45.0. Estimated population density was 91.83 per ha, or 37.1 per acre. The trapped population consisted of eight males and nine females.

### Grid 8

From grid 8, 43 mice was tagged. The probability of recapture was 0.2619. The population estimate for the grid was 58.80. Estimated population density was 122.5 per ha, or 49.59 per acre. The marked population consisted of 28 males and 15 females.

## House Mouse Captures Relative to Vegetation

The grids were markedly different in terms of the exact plant species composition and in the extent of cover made up by the various species. Field observations suggested that the nature of the plant cover, particularly the height of the vegetation, might have influenced the capture success. The relationship between the average height of the vegetation at the trap sites (grid average) and the trap success for house mice (grid average) was examined by correlation. The correlation coefficient (R) was 0.6468 and suggested 41.8% of the variation in trap success was explained by variation in vegetation height. However, a regression analysis of capture success on vegetation height did not yield a significant relationship. That is, the slope was not significantly different from zero ($F = 4.3148$, $p = 0.0831$, 7 df). Thus, plant cover appears to have influenced the capture success of house mice, but a more detailed study of horizontal and vertical structure of the vegetation will be necessary to discern the details necessary to make predictions.

# Discussion

## Overview of House Mouse Population Behavior and Dynamics

Feral house mice have been introduced into nearly every environment occupied by mankind. The mouse plagues of Australia are perhaps the most widely reported and studied population outbreaks in agricultural landscapes (Brown and Singleton 1999). These plagues occur at intervals of one to seven years with an average of four years between events for any particular region. Plagues occur in different years within the agricultural regions of southern and eastern Australia. Economic loss in 1993 was estimated at AUD (Australian dollars) $64.5 million. House mice remained in the agricultural lands between plagues, but at much lower abundances.

Rather detailed studies of house mice in wheat fields in Australia have been reported over the years. Newsome (1969a) found the mice did not abandon the fields after harvest and drought associated with the typical rainfall patterns of his study areas. Mice bred to the limit of their food supply, and when breeding ceased the populations tended to crash. Mice lived in reed beds (*Phragmites communis*) near the wheat fields and re-invaded the superior habitat as the wheat crop developed (Newsome 1969b). Newsome induced a mouse plague with food supplementation. He concluded shelter and food were key to the plague events.

Outbreaks of house mice in Australia are not always associated with wheat fields. Newsome and Crowcroft (1971) provided details on a plague that occurred in 1965 in South Australia. An area of about 515 square kilometers of wheat field was involved. In addition, a pine plantation was destroyed by a local outbreak. An isolated wheat stack (identified as four years old) supported >500 mice based on individual captures. In spite of abundant food, mice in the wheat stack had ceased to reproduce.

Newsome and Corbett (1975) claimed that favorable conditions for plant growth set the stage for house mice population eruptions in Australia. Regardless of plant growth, they found that the density and biomass of house mice declined as density and biomass of native rodents increased in four habitats under study.

Experiments in arid regions where food and water were provided resulted in large increases of house mouse populations, but a decline occurred in spite of the supplemental feeding (Newsome et al. 1976). Other rodents apparently did not play a role in the decline. Bomford (1987b) used supplementary feeding to stimulate breeding in spring when controls without extra food did not breed.

Brown and Singleton (1999) provided a definition of mouse plagues in Australia as follows:

- Populations increase in density and spread into new habitats (places where they were absent or unrecorded).
- The population increase is synchronous over a large area (>50,000 ha).
- During plagues, house mouse densities exceed 500 individuals per ha and typical densities exceed 1,000 per ha.
- Plague conditions may exist for one to two years before declines or crashes occur.

The scientific literature on feral house mice in the United States is somewhat limited relative to that of other regions, such as Australia. No literature exists that reports comparable population behavior in the United States or, indeed, elsewhere in the world. The private lands in Zellwood and Plymouth, Florida, associated with high densities of house mice, represented only 6,477 ha.

Sizable populations of house mice have been encountered in natural and disturbed habitats in California. Lidicker (1966) studied house mice on an island (22.26 ha) in San Francisco Bay. He observed the population decrease from about 121 per ha to extinction. The extinction occurred over a 14-month period and no one factor could account for the decline. DeLong (1966) worked nearby on the mainland in the same time period as Lidicker. He reported evidence that the survival of young house mice was apparently reduced by the presence of

California voles (*Microtus californicus*). DeLong was interested in the factors (extrinsic or intrinsic) that regulated house mice on the mainland. Based on six populations under study, he concluded that house mice were not limited by external factors. Rather, he stressed that intrinsic factors or mechanisms limited house mice populations.

Feral house mice in Maryland occupied corn-wheat-hay fields that existed in a habitat mosaic (Stickel 1979). These populations increased through the summer as breeding occurred from May to October. Live trapping revealed that the mice tended to live less that five months. Stickel (1979) claimed the mice moved within the habitat mosaic as crops were harvested. House mice in Virginia moved into old field habitat when the resident population was removed (Staples and Terman 1977).

Bronson (1979) summarized information on house mice, with an emphasis on their reproductive ecology. He recognized two categories of house mice populations. First, feral populations were associated with natural and disturbed habitats where the numbers of individuals tended to be variable in time and space. Second, commensal populations were found associated with buildings and other man-made structures. Commensal populations exhibited more population stability that the feral populations. Available evidence was interpreted to indicate that male house mice forced the dispersal of young. Rapid colonization of all suitable habitats could result from this behavior. For example, of more than 3,000 house mice tagged and released on a 100 ha Welsh island, >20% bred in areas distant from where they were born (Berry and Jakobson 1974).

## Behavior and Dynamics of Local House Mice

Layne (1997) found the first recorded evidence of house mice in Florida occurred in 1894; however, he suggested the animals have been in the state since the colonial period. The presence of stable house mice populations in native habitat is not commonly reported, but presence of house mice in disturbed habitats and coastal dunes is frequently reported.

Rodents were common to abundant on all the trapping grids established in the area of former muck farms along the northeast shore of Lake Apopka. Trap success was about 46% over the course of the brief study. Typical trap success in native Florida vegetation (habitats) may be expected to vary from 1–10% with occasional trapping events yielding 30–60% success (Stout, personal observations since 1973). B. Toland (cited as personal communication in Layne 1997) has reported a 60% trap success for house mice in open weedy-grassy habitat trapped on reclaimed phosphate-mined land in Polk County, Florida.

Cotton rats were the most frequently trapped rodents on the majority of the grids. House mice were the second most frequently captured species. House mice were present on all the grids. However, considerable variation in abundance was documented over the complete study area. Rice rats were present in extremely low numbers. Perhaps the most common native Florida small mammal in many habitats, namely, the cotton mouse, was not observed in the study.

Mark-recapture methods were used to estimate the abundance of house mice on the eight grids. Two-hundred and thirty-four house mice were ear-tagged and released alive on the study grids.

Recapture success averaged 0.2691 across the grids and varied from 0–40% among grids. For example, no marked animals were recaptured on grid 3. Mark-recapture estimates such as the Lincoln Index carry several assumptions (Krebs et al. 1994, Krebs 1999). One of these assumptions is that an equal probability of capture exists between tagged and untagged individuals. This assumption was most likely not met by the data presented here. The sex ratio of trapped mice favored males ($p < 0.05$) as found by most other workers, for example, Drickamer et al. (1999). Prior studies have reported recapture rates of marked house mice to range from 0–20% (Krebs et al. 1994). Exceptions to the low recapture success pattern do exist. For example, DeLong (1967) reported recapture rates of 75–100% at two-week intervals in annual grasslands in California.

Krebs et al. (1994) radio tracked house mice to determine the reason or reasons low recapture rates are observed. Their results suggested that during periods of reproduction, breeding individuals remained fairly restricted to home ranges but were not very trappable. During the nonbreeding season, nomadic movements reduced the likelihood of recaptures. Other studies have shown that trappability declined from adults to subadults to juveniles (Drickamer et al. 1999). It was not clear if these results applied to the data collected on the muck farms. These data represented a nonbreeding season sample. Thus, nomadic movements might account for the low trappability. However, with the exception of grid 3, where no recaptures were observed, the grid populations appeared to be resident as opposed to transient in behavior.

House mice captures per trap night provided a standardized index for comparisons among the grids. Trap success showed that grid 3 had the fewest captures (3 per 100 trap nights), followed closely by grid 7 (5 per 100 trap nights). In contrast, grids 5 (17 per 100 trap nights) and 8 (16 per 100 trap nights) had the highest success among the grids. The only grid with poor trap success for house mice (5 per 100 trap nights) and poor trap success overall (10 per 100 trap nights) was grid 7.

The density estimates of house mice for the grids indicated the degree of variation that existed among the study sites. The estimates are undoubtedly inflated because of the small number of recaptures. Drickamer et al. (1999) suggested that data generated by live trapping must be interpreted with caution and reservation. Alternative methods for computing population sizes and densities are available, but could not be applied in the time available to prepare this report (Pollock 1982). These alternative methods will be applied to the data in the future.

Some patterns appeared to emerge based on past land use and known locations of abundant house mice populations west or north of the muck farms. Grid 1 was in the northwest portion of the study area and near sites that had remained in agriculture through the growing season of 1999. The Lincoln Index estimate for grid 1 was the second highest among the grids. Grid 2 was relatively near grid 1, but the house mouse population was estimated to be about half as large as the one associated with grid 1. Grids 3 and 4 were more interior in the muck farm area relative to the offsite uplands where house mice were known to very abundant. Very few house mice were trapped on grid 3, and numbers on grid 4 were similar to those estimated for grid 2. Grid 5 was adjacent to Hogshead Road and near private homes and businesses. This grid had the highest trap success for house mice and the highest population estimate. Modest numbers of house mice were captured on transect 1, located to the north of grid 5. Interestingly, only one house mouse moved from grid 5 to transect 1; this suggested that the mice were resident during the period of study as opposed to being prone to dispersal. Farther south within the study area, grids 6 and 8 were relatively isolated from the uplands, but supported relatively high numbers of house mice. In contrast, grid 7 near Lust Road had the second lowest trap success for house mice (5 per 100 trap nights) and trailed grids 6 and 8 in terms of population estimate and density. Large populations of house mice were known to exist along Lust Road beyond the muck farms to the east.

Local variation in the abundance of house mice within the area of former muck farms may be expected due to the natural variation in populations in local habitats. Many potential variables may be linked with the explanation for this variation. Vegetation as a source of food and as cover from predators may be important (Newsome and Corbett 1975). In Australia, Brown and Singleton (1999) found populations increased following high rainfall and decreased following low rainfall. Plant growth providing food and cover should be correlated with rainfall. Because rainfall variation has been somewhat atypical in central Florida over the last two to three years, it may prove useful to examine these patterns relative to house mouse abundance.

Local predation pressure may have played a role in suppressing or releasing the rodent populations. Based on the general lack of sign (tracks and scat), medium-sized mammals appeared to be very uncommon on the muck farms (Stout and Clerico, personal observations). In contrast, avian predators were common to abundant during October, November, and December 1999. For example, migrating Northern Harriers (*Circus cyaneus*) were very abundant in early November. An American kestrel (*Falco sparverius*) was observed holding a house mouse (Stout and Clerico, personal observation). Relatively few snakes were observed during this study, but the time of year may explain the lack of sightings.

The presence of large numbers of cotton rats in all the fallow fields that were trapped suggests food and shelter were abundantly available for use by herbivorous rodents. House mice feed on plant parts, seeds, and insects and other invertebrates (Bomford 1987a). Simple observation suggested an abundance of food for a rodent that is omnivorous, such as the house mouse. Thus, interactions between the cotton rat and the house mouse would be more likely to involve competition for space rather than food supply.

Interactions of house mice with the cotton rats should be examined, however. Further study of the existing data on site of capture may reveal some relationship at the grid level. On Virginia barrier islands, house mice occurred in mixed habitats of grassland and shrub-dominated areas. Scott and Dueser (1992) found the house mice in grasslands whereas deer mice (*Peromyscus leucopus*) inhabited the shrub thickets. Reciprocal-removal experiments did not result in significant habitat shifts by either species. Layne (1997) reported very few captures of house mice in native habitats at the Archbold Biological Station, Highlands County, Florida. He noted, however, that the house mice captures tended to coincide with periods of low abundance of native mice.

Ants, including the imported fire ant (*Solenopsis invicta*), are extremely common on the study areas. Young of some mammals are killed by fire ants while they are confined to nests on the ground. A question arose as to why this source of mortality did not limit numbers of cotton rats and house mice.

The working hypotheses of the study were not rejected. House mice were controlled in the buildings available for study, yet mice were still present. House mice were apparently as numerous on levees and roadsides as in the fallow fields. However, house mice were not uniformly abundant in any of the habitats sampled. The results do suggest that levees may have served as a source habitat (refuge) for house mice that now occupy the fallow fields. This argument must assume that even with flooding, some of the levees remained as suitable habitat.

Recommendations for management of house mice in the muck farms cannot be offered at this time. A study currently under way may provide practical answers for this unique ecological problem.

# References Cited

Berry, R.J., and M.E. Jakobson. 1974. Vagility in an island population of the house mouse. *Journal of Zoology* 173:341–354.

Bomford, M. 1987a. Food and reproduction of wild house mice I. Diet and breeding seasons in various habitats on irrigated cereal farms in New South Wales. *Australian Wildlife Research* 14:183–196.

———. 1987b. Food and reproduction of wild house mice II. A field experiment to examine the effect of food availability and food quality on breeding in spring. *Australian Wildlife Research* 14:197–206.

Bronson, F.H. 1979. The reproductive ecology of the house mouse. *The Quarterly Review of Biology* 54:265–299.

Brown, P.R., and G.R. Singleton. 1999. Rate of increase as a function of rainfall for house mouse *Mus domesticus* populations in a cereal-growing region in southern Australia. *Journal of Applied Ecology* 36:484–493.

DeLong, K.T. 1966. Population ecology of feral house mice: interference by *Microtus*. *Ecology* 47:481–484.

Drickamer, L.C., G.A. Feldhamer, D. G. Mikesic, and C.M. Holmes. 1999. Trap-response heterogeneity of house mice (*Mus musculus*) in outdoor enclosures. *Journal of Mammalogy* 80:410–420.

Krebs, C.J. 1999. *Ecological Methodology.* 2nd edition. Menlo Park, Calif.: Addison Wesley Longman, Inc.

Krebs, C.J., G.R. Singleton, and A. J. Kenney. 1994. Six reasons why feral house mouse populations might have low recapture rates. *Wildlife Research* 21:559–567.

Layne, J.N. 1997. Nonindigenous mammals. *Strangers in Paradise*. Pp. 157–186. D. Simberloff, D.C. Schmitz, and T.C. Brown, editors. Washington, D.C.: Island Press.

Lidicker, W.Z., Jr. 1966. Ecological observations on a feral house mouse population declining to extinction. *Ecological Monographs* 36:27–50.

Murphy, T.R., D.L. Colyin, R. Dickens, J.W. Everest, and D. Hall. 1979. Weeds of southern turfgrasses. SP-79. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Newsome, A.E. 1969a. A population study of house-mice temporarily inhabiting a south Australian wheat field. *Journal of Animal Ecology* 38:341–359.

———. 1969b. A population study of house-mice permanently inhabiting a reed-bed in south Australian. *Journal of Animal Ecology* 38:361–377.

Newsome, A.E., and L.K. Corbett. 1975. VI. Outbreaks of rodents in semi-arid and arid Australia: Causes, preventions, and evolutionary considerations. *Rodents in desert environments*. Pp. 117–153. I. Prakash and P.K. Ghosh, editors. The Hague, Netherlands: Dr. W. Junk.

Newsome, A.E., and P. Crowcroft. 1971. Outbreaks of house-mice in South Australia in 1965. *CSIRO Wildlife Research* 16:41–47.

Newsome, A.E., R.C. Stendell, and J.H. Myers. 1976. Free-watering a wild population of house-mice—a test of an Australian hypothesis in California. *Journal of Mammalogy* 57:677–686.

Pollock, K.H. 1982. A capture-recapture sampling design robust to unequal catchability. *Journal of Wildlife Management* 46:752–757.

Scott, D.E., and R.D. Dueser. 1992. Habitat use by insular populations of *Mus* and *Peromyscus*: What is the role of competition? *Journal of Animal Ecology* 61:329–338.

Staples, P.P., and C.R. Terman. 1977. An experimental study of movement in natural populations of *Mus musculus*, *Microtus pennsylvanicus*, and *Microtus pinetorum*. *Researches on Population Ecology* 18:267–283.

Stickel, L.F. 1979. Population ecology of house mice in unstable habitats. *Journal of Animal Ecology* 48:871–887.

Stucky, J.M., T.J. Monaco, and A.D. Worsham. 1981. Identifying seedling and mature weeds common in the southeastern United States. The North Carolina Agricultural Research Service and the North Carolina Agricultural Extension Service, North Carolina State University, Raleigh.

Tobe, J.D., K.C. Burks, R.W. Cantrell, M.A. Garland, M.E. Sweeley, D.W. Hall, P. Wallace, G. Anglin, G. Nelson, J.R. Cooper, D. Bickner, K. Gilbert, N. Aymond, K Greenwood, and N. Raymond. 1998. *Florida wetland plants: An identification manual*. Tallahassee, Fla.: Florida Department of Environmental Protection.

# Appendix

Location of eight study areas in the former muck farms of the North Shore Restoration Area, Lake Apopka, Florida

| Grid No. | Degrees | Minutes | Seconds | Direction |
|---|---|---|---|---|
| 1 | 28 | 42 | 40 | N |
| | 81 | 37 | 29 | W |
| 2 | 28 | 41 | 48 | N |
| | 81 | 36 | 58 | W |
| 3 | 28 | 41 | 53 | N |
| | 81 | 36 | 31 | W |
| 4 | 28 | 41 | 06 | N |
| | 81 | 35 | 57 | W |
| 5 | 28 | 41 | 39 | N |
| | 81 | 35 | 22 | W |
| 6 | 28 | 40 | 26 | N |
| | 81 | 35 | 36 | W |
| 7 | 28 | 40 | 01 | N |
| | 81 | 34 | 18 | W |
| 8 | 28 | 39 | 44 | N |
| | 81 | 34 | 32 | W |