

**The value of dihydrogen monoxide to a jumping mouse: habitat use and preference
in *Zapus princeps*.**

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ABSTRACT

The western jumping mouse, *Zapus princeps* is common in riparian habitat. There are multiple hypotheses (need for water, food type, or anti-predator/cover) for why this is. The objective of this project was to determine the use of mesic and adjacent drier habitats by *Zapus* using both a live-trapping study and a historical study using records of *Zapus* captures at three sites in the East River Valley, Gunnison, CO. I also conducted a test to determine if the presence of water vs. cover had a greater influence on *Zapus* habitat selection. I live-trapped individuals of *Z. princeps* in three different habitats: riparian, intermediate, and dry, replicated at three sites. I marked the mice uniquely to indicate the habitat in which they were first trapped. This allowed me to study frequency of recaptures both within and among habitat types. I also compared trapping success between two different microhabitats (wet/cover vs. dry/cover). The third study used historical trapping records on permanent grids to determine long-term patterns of *Zapus* captures with vegetation and proximity to water. *Zapus princeps* was captured more frequently in riparian areas. *Zapus* preferred to move within and between wetter habitats than the dry. The historical study showed a negative relationship between trap success and distance from water. The microhabitat experiment showed a trend but no overall significant difference in capture of mice between microhabitats of wet/cover and dry/cover.

INTRODUCTION

Riparian areas are acknowledged as areas of high biodiversity, richness and evenness for many different taxa (Soykan et al. 2012, Doyle 1990) and may act as source habitats (Doyle 1990) that maintain populations. The physical location of riparian areas creates an interface between aquatic and terrestrial ecosystems (Naiman et al. 1993), as well as providing a unique microclimate for organisms (Gregory 1991). It is likely riparian areas will be negatively affected both by climate-driven changes in the sources and abundance of water (Perry et al 2012) and continued human development.

The Western jumping mouse, *Zapus princeps*, is one species associated with these riparian areas. This mouse is a member of the Dipodidae family, featuring a tail up to 158 mm long and 30 mm long hind feet that allow them to leap up to two meters (Reid 2006). The species, like most within its genus, feeds on grass seeds, fungi and some insects (Reid 2006). However, the ecology of the Western jumping mouse is less understood

than the eastern species, such as the woodland jumping mouse or the meadow jumping mouse (Brown 1970). What research is available does indicate a preference for mesic environments, and at a rate higher than other comparable small rodents (Krutzsch 1954, Brown 1970, Hart et al. 2004). In 1990 Doyle studied small mammal use of riparian versus upland habitats in montane environments and found *Zapus trinotatus* occurred significantly more frequently in riparian areas than upland areas. While studying home ranges of *Zapus* spp., Brown (1970) found their home ranges rarely extended more than 30 meters away from a stream, despite that habitat not appearing to change as it extended away from the water. Densities of eastern species of jumping mice have been found to be almost three times higher in mesic areas than dry habitat (Brannon 2005). In contrast, other rodents commonly found in the same habitats as *Zapus* spp., such as *Peromyscus maniculatus*, generally prefer drier habitats or do not exhibit as strong habitat preference (Brannon 2005). These species share a similar diet and predators. Thus, the question becomes why is it that *Zapus* prefer the riparian habitat?

The habitat association of the jumping mouse and its form of locomotion is somewhat unusual. Other species of rodents that are bipedal, such as the kangaroo rat, seem to utilize bipedal locomotion in order to navigate open spaces, like deserts (Harris 1984). Harris (1984) compared a bipedal heteromyid and a quadrupedal cricetid's foraging behavior in different microhabitats. The heteromyids utilized open areas significantly more than the quadrupedal mouse. Thus, the dense willow and understory cover common in the riparian habitats *Zapus princeps* is associated with does not fit this theory. However, Harty (2010) proposes that the Pacific jumping mouse's (*Zapus trinotatus*) form of jumping is adapted to predatory evasion, as well as to its unique

habitat, “it may be that *Z. trinotatus* developed a preference for jumping because their more confined habitats did not promote a more ricochetal gait and bipedal stance” (pg 16). Thus, it’s possible the jumping mouse’s locomotion and the vegetation in its preferred habitat compliment each other.

While it is established *Zapus princeps* exists in riparian habitat, the extent to which it will utilize adjacent non-riparian habitat is not known. I sought to describe the distribution and habitat preference of *Zapus princeps*. This study also investigated movement between the habitats. I tested the hypotheses 1) that the jumping mice exhibit preference for riparian habitat, and 2) movement between proximal habitats occurs. The first hypothesis predicts the highest capture rates (animal densities) from transects in the riparian zone, followed by intermediate, and the least in the drier habitat. If the second hypothesis is supported, then mice will be recaptured in habitats that they were not originally captured and marked in.

In order to investigate habitat preference and association further, I conducted a historical study. Rosemary Smith’s lab contains over ten years of data detailing the capture of small rodents from permanent grids located in the East River Valley. The individual trap locations from these grids are identical over the years. These data were previously analyzed only for rodent biomass and population densities. I investigated the distance from every trap to the nearest riparian-associated plant and water source. I expected traps that caught *Z. princeps* to be closer to water or a riparian plant.

I conducted a microhabitat study to address why jumping mice prefer riparian areas. It is debated what habitat or physiological characteristic drives the association of the jumping mouse and wet environments. Brower & Cade 1966 concluded, “moisture is

not a critical limiting factor in the distribution of woodland jumping mice,” (p 46). Brannon (2005), as did several studies, found jumping mice do exhibit close associations with cool and wet environments, but speculates as to whether the water itself or the ground cover (and the potential anti-predator cover it provides) drives this association. I took advantage of a dry season at the Rocky Mountain Biological Laboratory (RMBL) in Colorado to analyze presence of *Z. princeps* between two different microhabitats. As a result of decreased precipitation, many small streams and creeks surrounded by this vegetation are dry. However, these dry sites still retain riparian vegetation, which is commonly dominated by *Salix* spp. and *Veratrum californicum* in RMBL. These circumstances allowed me to compare presence of *Z. princeps* between microhabitats alike in vegetative cover, but different in presence of water. I hypothesized that the presence of water is necessary for presence of these mice. If this is correct, microhabitat with water will have higher capture rates of *Z. princeps* than the dry microhabitat. If capture rates are similar, then cover may be more influential than the presence of water.

A more detailed understanding of *Z. princeps*' habitat use may benefit not only this species, but also others such as the federally endangered *Zapus hudsonious preblei* (USFWS 2012). These two species of jumping mice occur parapatrically; extensive understanding of their habitat use may aid in management and protection of them. Furthermore, any species utilizing riparian areas may face greater habitat loss in the near future, so a greater understanding of their habitat requirements is necessary for their management and protection.

METHODS

Study area

This study took place at the Rocky Mountain Biological Laboratory (hereafter RMBL) field station, in Gothic, Colorado. RMBL is located about 367 kilometers southwest of Denver, CO. The station consists of over 122 hectares, at a minimum altitude of 2895 meters. The area experiences hundreds of centimeters (up to 350 cm) of snow during the winter, typical mountain thunderstorms, and temperatures reaching 23 degrees Celsius in the summer (Rocky Mountain Biological Laboratory 2012). My sites were located within the East River valley, in three different locations (Table 1). All three replicates featured riparian habitat next to a water source dominated by *Salix* spp. and *Veratrum californicum*, which yielded to dry meadow habitat away from the water, dominated by grasses and forbs.

Live-trapping study of Z. princeps habitat association

I trapped small mammals in three replicate sites from 27 June until 02 August 2012. Each site consisted of three parallel transects (riparian, intermediate, or dry) placed approximately 20 meters apart, running parallel to a water source. Site A (the beaver ponds) was trapped for seven nights. Site B (the river meadow) and Site C (near Bellview mountain) were trapped for six nights. Each trapping transect consisted of 15 Longworth traps, spaced 10 meters apart. Traps were set at dusk, between 1900 and 2000, and checked at dawn, between 0530 and 0700. Each trap contained polyester bedding and bait to ensure animal survival. Bait consisted of a mixture of oats and peanut butter.

Successful traps were rebaited and any soiled or wet bedding was disposed of and replaced. When *Zapus princeps* was captured, data was collected and the mouse was released next to the trap. Data collection consisted of identification, sex, weight, date, trap number, weather and marking. I used Nyanzol D dye to mark the mice. A small dot

of the dye was placed on the ventral surface. The placement of the mark reflected where the mouse was first captured. Any non-target species that were caught were identified and released immediately. Sample size for this project was 120 mice.

Vegetative cover at each site

Initially, trapping transects were placed by visual assessment of difference in vegetation. Vegetative cover and height were later assessed using a line-intercept technique. However, at site C there was not a lot of dry habitat. Due to this, an unequal number of traps were placed in each transect at site C. Thus, I divided the number of mice caught in each habitat by the number of traps in it. To compare this to the other replicates, this number was then multiplied by fifteen.

For the line-intercept measurement, five random points were chosen on the 150 m long trap line. I measured the vegetation that intersected a meter tape extending one meter away in each direction from the center of each point. Additionally, the height of the tallest plant intersecting this two-meter length was recorded.

*Historical patterns of *Zapus* capture*

The historical study further investigated habitat preference by associating *Zapus* capture with the proximity to water and riparian vegetation. The existing census grids are 7 X 7 with traps spaced 10 meters apart. In the lab, I tallied the number of first captures and the number of recaps of *Z. princeps* in each trap for six years of data. In the field, I used the corner traps and the traps in the middle of each side of the square as sample points. I measured from these eight traps to the nearest riparian-associated plant (*Salix* spp. or *Veratrum tenuipetalum*) and nearest water source. I calculated the distance to each

plant/water source for the rest of the evenly spaced traps from these eight sample measurements.

Distinguishing the association: vegetative cover or water?

I conducted a limited three-night survey to distinguish microhabitat preference for vegetative cover versus water at two replicate sites. At each site, one transect was in a riparian area with cover consisting of *Salix* sp. and *Veratrum tenuipetalum* and a small stream running through the middle. The comparison transect was placed in a *Salix* and *Veratrum tenuipetalum* habitat that has running water in most years, but not in this year (2012). Each transect consisted of thirty traps, placed at fifteen spots, each in two transects. Due to the short period of trapping for this study I placed two traps at each spot in order to capture the maximum number of target species (*Zapus*). The first replicate used Sherman traps for both transects and the second replicate used Longworth traps for both transects. Trapping methods were the same as those of the primary experiment.

Analysis

To determine habitat preference and analyze movement in the primary experiment, I compared trap success between habitat type and microhabitat with a chi-squared analysis of covariance. Another chi-squared test was used to compare differences in distribution of plant types between habitats. The historical study was analyzed using a linear regression in order to investigate any relationship between the number of *Z. princeps* trapped and distance to water or the nearest riparian plant.

RESULTS

A total of 1080 trap-nights were conducted over a 35-day period, during which time 198 jumping mice were captured, with 120 individuals marked.

Initially, vegetative differences among the three habitats were initially assessed visually. My measurements of vegetative cover and height confirmed these differences. At Sites B and C, the average tallest height in the riparian habitat was significantly taller than in intermediate or dry. Site A, however, did not differ in height between the three habitats. Chi-squared analyses found a difference in the composition of vegetative cover among habitat type ($p < 0.001$) (Figure 1). Shrub cover only existed in riparian habitats. In riparian habitats the highest percentage of cover was from tall forbs (such as *Heracleum maximum* and *Veratrum tenuipetalum*) or grass. Drier habitats were dominated by shorter forbs or grass.

Population estimates were calculated for each site using the Schnabel method. Site A's estimate was 61.78, site B's was 24.6 and Site C' was 26.3. Chi-squared analyses found a difference in the distribution of *Z. princeps* among habitat type in two out of three replicates (Figure 2). Riparian habitats captured two to three times more mice than intermediate and dry habitats at site A and B ($p < 0.001$). The difference in the distribution of *Z. princeps* at site C was not significant ($p = 0.097$).

A chi-squared analysis did not find a significant difference in distribution of the number of movements between the habitats in site A, B or C ($p = 0.25$, $p = 0.87$, $p = 0.58$) (Figure 3). Nor was there a significant difference in distribution of the number of mice caught between the wet/cover and dry/cover microhabitats (replicate 1, $p = 0.317$, replicate 2, $p = 0.07$). (Figure 4).

The historical study revealed a negative relationship between distance from water and number of first captures of mice between all three sites ($r^2 = 0.295$, $p < 0.001$) (Figure 5). Maxfield was the only site with a significant relationship when analyzed

individually ($r^2 = 0.260$, $p < 0.001$) (Figure 6). No relationship existed between distance from nearest riparian vegetation and number of first captures between all three sites. Again, Maxfield was the only site with a significant relationship when analyzed individually ($r^2 = 0.396$, $p < 0.001$).

DISCUSSION

My results support the hypothesis that *Z. princeps* is more abundant in riparian habitat and that it does not utilize the nearby (40 m away) drier habitat to the same extent. This is similar to previous studies of jumping mice habitat choice. For instance, in 2005 Brannon found 71 out of 115 individual woodland jumping mice preferred wet habitat. Brown (1970) and Hart (2004) found similar patterns in their studies of the western jumping mouse. However, there were differences among my replicates in population size. In this sense, the replicates were not identical to one another.

The statistical analysis suggested that movement between adjacent habitats occurs randomly and is driven by local animal density rather than habitat preference. While the mice were not marked individually, there still appeared to be a pattern indicating a preference for the wetter habitat. For example, at Site A the largest “movement” was to not leave the riparian transect (12 recaptures) and more movements occurred from riparian to intermediate than between any other two habitats. Theoretically the same mouse may have been recaptured in riparian three times and also recaptured in intermediate. Yet the drier habitat was only 40 meters from the riparian and the mice almost never moved within it or to it, which emphasizes *Zapus*’ patten of preferring mesic habitat. In future experimental designs, marking mice individually and recording sex of dispersers could reveal more detail about patterns of movements between habitats. Many

mammals, including small rodents such as *Tamias* spp. and *Spermoophilus lateralis*, exhibit sex-biased dispersal (Chamber & Garant 2010), but this is not well documented in *Z. princeps*.

The historical study indicated that in some sites (Maxfield) one is unlikely to capture a mouse if the trap is more than 80 meters away from water. Interestingly, the Bellview grid did not follow this pattern. At Bellview, jumping mice were captured up to 110 meters away from water. At both Maxfield and Kettle Ponds, the riparian habitat is linear. However, the riparian habitat at site C is non-linear in that it is surrounded by a water source on three sides. Thus, it is possible there is no location within this meadow that is “too far” from water for a jumping mouse to travel through. This unique orientation of riparian habitat may also explain why mice didn’t prefer the riparian habitat to the drier habitats. The home range of jumping mice is usually elongated to parallel a stream, and often extends 175 meters long (Brown 1970). In further studies, it would be interesting to know if home range is affected by non-linear riparian habitat.

The result from the microhabitat secondary experiment suggests the presence of tall riparian cover is more influential than water for a jumping mouse. According to Harty (2010), *Zapus*’ ricochetal jumping ability may allow it to evade predators, and then utilize the tall, dense riparian cover to hide in. However, the lack of preference for permanent water could be due to a small sample size. In both replicates, a trend appeared, for I caught more mice in the wet microhabitat. Extending this study either in number of replicates or trap nights could indicate *Z. princeps* prefers habitat with water, not just riparian cover. If this is the case, the next question is why water is influential for *Z. princeps* but doesn’t appear to be other mice, such as *P. maniculatus*. Throughout my

trapping studies, there were a total of 71 deer mice captures in riparian, compared to 107 deer mice captures in drier habitats. It is possible that vegetative cover and water are both influential in habitat preference, that their importance changes temporally, or that *Zapus* outcompetes other rodents, thereby preventing them from utilizing riparian habitat.

The diet of the western jumping mouse has not been studied thoroughly enough to determine if this is an influential factor of habitat preference. However, in 1980 Vaughan & Weil determined arthropods were a larger and more important part of *Z. princeps*' diet than had originally been thought. Notably, they found that arthropods were particularly important early in the summer, before forb seeds were abundant. *Zapus* hibernates for most of the year, unlike many small rodents. Thus, upon emergence, a food source such as arthropods may be particularly important for replenishing depleted fat stores. If arthropod density is higher or more accessible for the mouse near water, they may be more likely to select riparian habitat.

Repeating the objectives of Vaughan & Weil's study now, 30 years later, could yield verification of this difference in diet. Comparing *Z. princeps*' diet in dry/cover areas to wet/cover areas may confirm if the presence of water is linked to a larger arthropod food source and use for the mouse, and thus offer insight into the reasons for its habitat preference. Alternatively, utilizing stable isotope analysis to compare presence of an aquatic food source between deer mice and jumping mice may also provide evidence for this hypothesis.

It is worth noting that during the course of this study, both Longworth and Sherman traps were used (for the primary and secondary objectives, respectively). For studies of *Zapus*, Longworth traps may be more appropriate, as Sherman traps showed a

tendency to catch long tails in the door as it snapped shut. Although the injury was generally minor, this stress and discomfort can be avoided by using a Longworth trap.

Understanding the drivers of habitat preference offers valuable insight into the importance of different habitat types, as well as management strategies for the organism. In the case of the western jumping mouse, their preferred habitat is one housing important biodiversity. Riparian habitat is also an ecosystem under threat from multiple sources, including climate change and human development. Further research into these intricate habitats and the diverse organisms that depend on it may be critical.

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Table 1. Description of the three sites used during the 2012 summer study of *Zapus princeps* habitat preference.

Site	UTM	Distance from townsite (mi)	Elevation (m)	Water source
A	327360 E 4314164 N	0	2909	Beaver ponds
B	327228 E 4314722 N	0.5	2919	East river
C	324936 E 4318875 N	3.5	3086	East river and beaver ponds

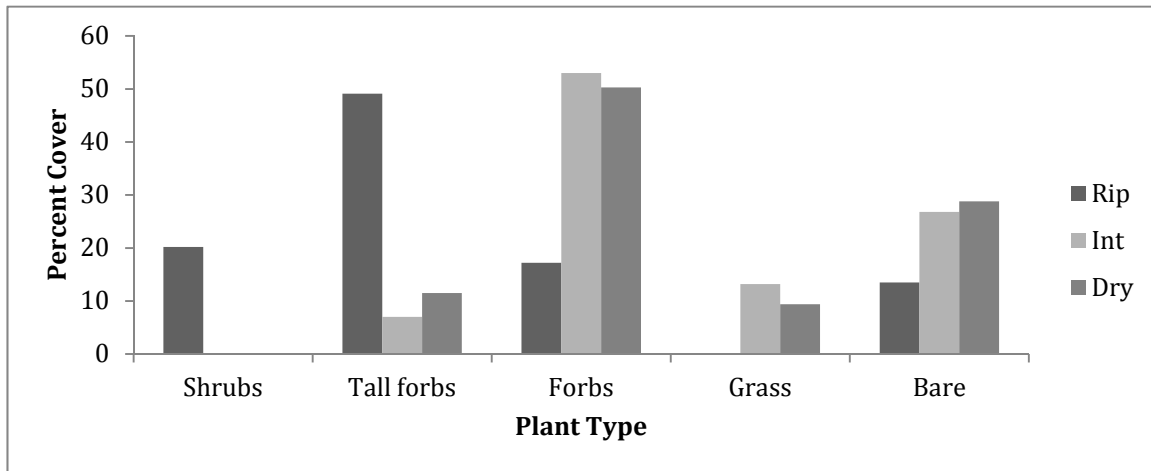


Figure 1. Comparison of percent cover among plant types in three different habitats, riparian, intermediate and dry.

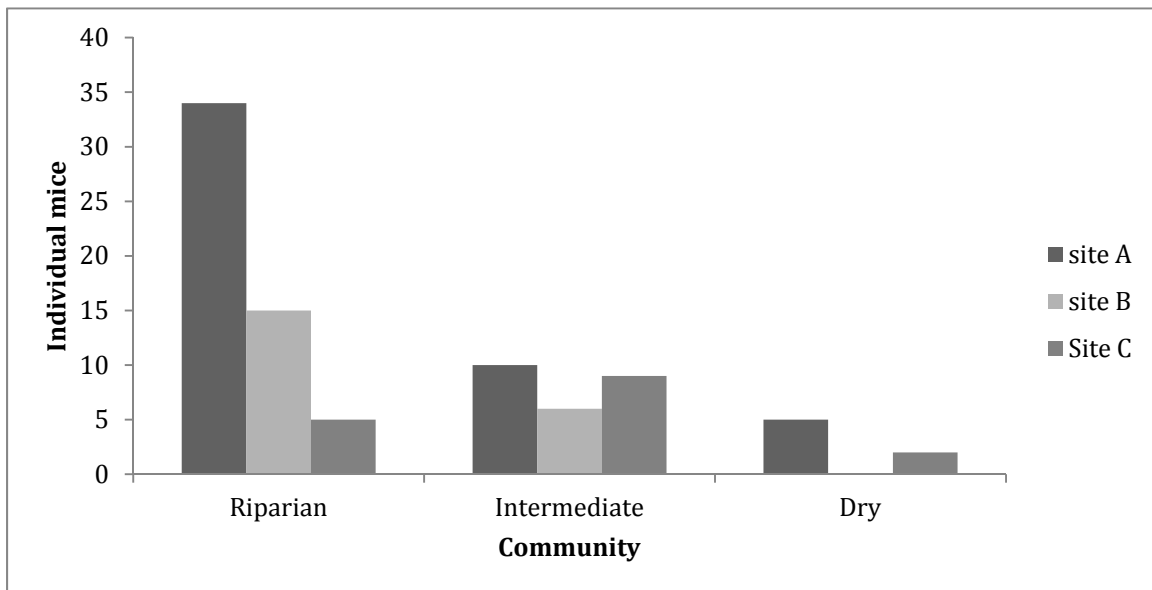


Figure 2. Comparison of the distribution of individual *Z. princeps* captures among habitat type between three research sites.

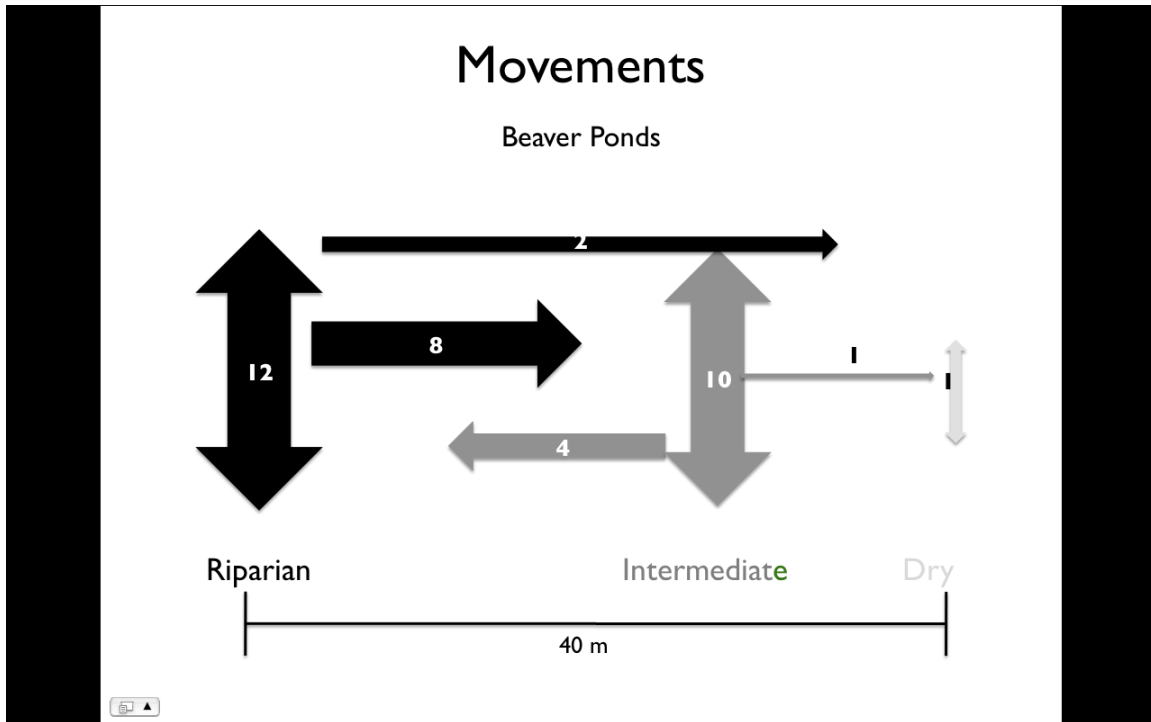


Figure 3. An example of movement patterns between three different habitat types. Vertical arrows represent movement within the same habitat. Horizontal arrows represent movement between two habitats. Numbers indicate the number of recaptures for that type of movement.

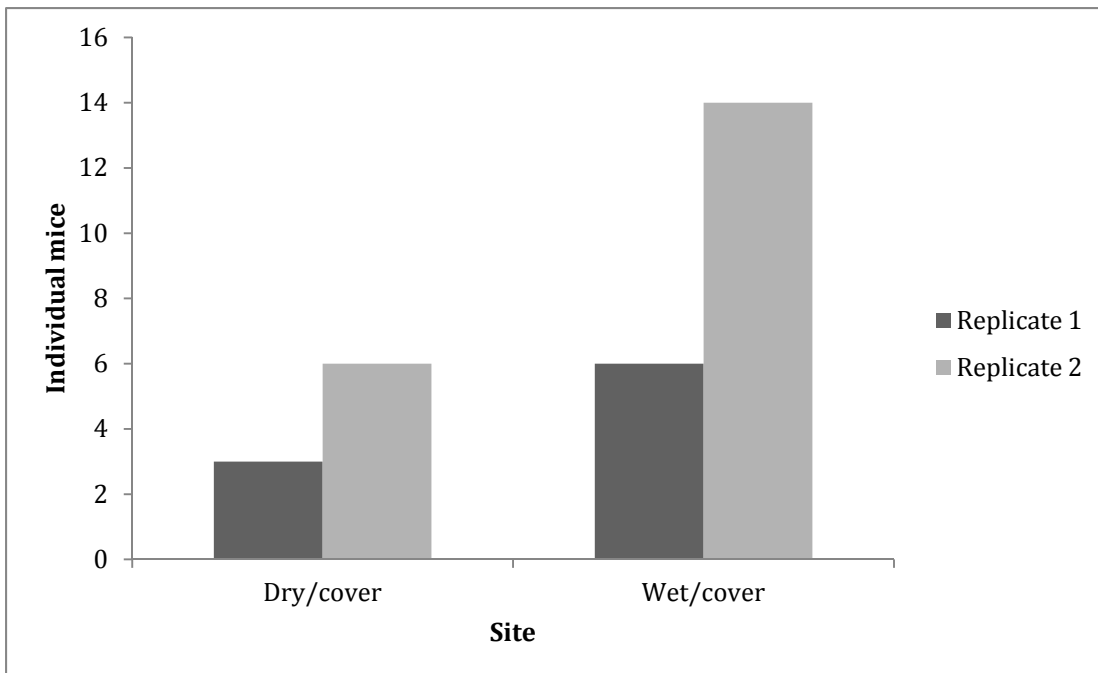
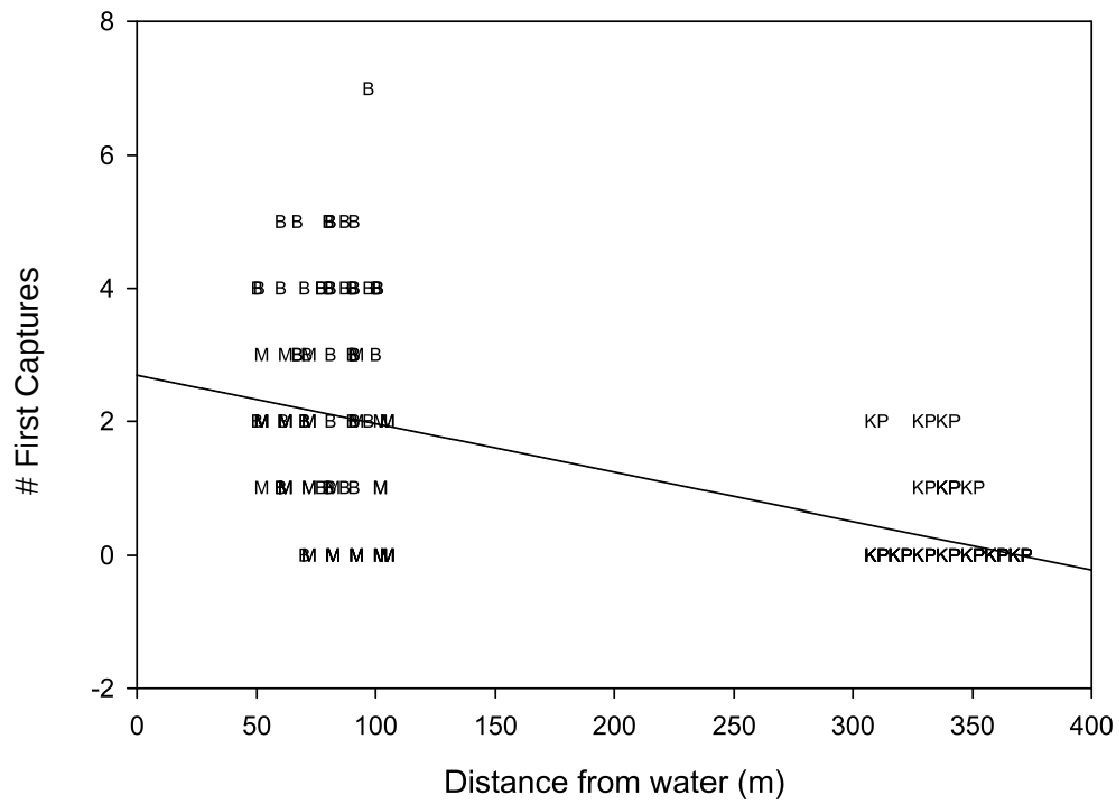


Figure 4. Comparison of number of individual mice captured between two different microhabitats, for both replicates.



Maxfield

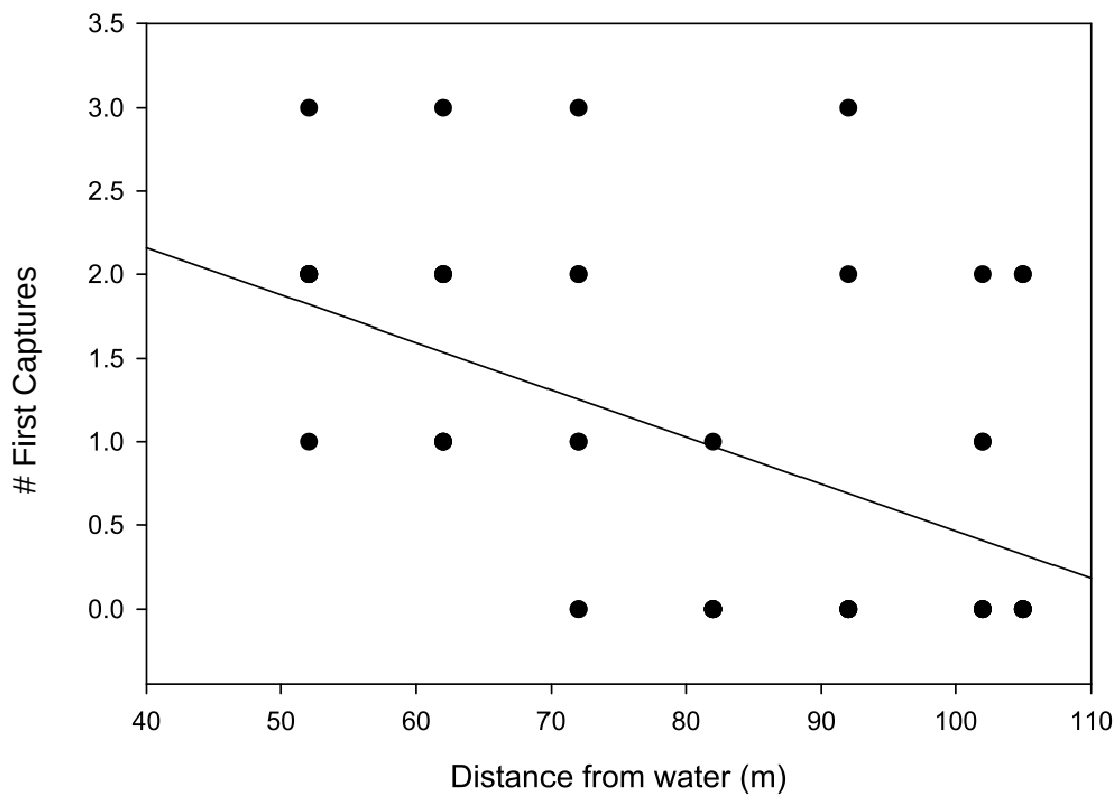


Figure 6. Number of first captures as a function of distance from water at the Maxfield site.