THESIS

# Abundance, Distribution, and Dispersal of the Ogden Rocky Mountain Land Snail, *Oreohelix peripherica wasatchensis*


Submitted by

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In partial fulfillment of the requirements for the
Thesis in Zoology
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## Weber State University

We hereby recommend that the thesis prepared under our supervision by Melinda R. Morin entitled "Abundance, Distribution and Dispersal of the Ogden Rocky Mountain Land Snail, *Oreohelix peripherica wasatchensis*" be accepted as fulfilling partial requirements for the thesis in Zoology.

Thesis Committee

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Advisor

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**Abundance, Distribution and Dispersal of the Ogden Rocky Mountain Land Snail,** ***Oreohelix peripherica wasatchensis***

## *INTRODUCTION*

Many of the areas in the Rocky Mountains are considered relatively uninhabitable to most land snails, due to the lack of moisture and extreme seasonal variation in temperature and weather (Ports 1996). The one taxon that is a major exception to this pattern is the genus *Oreohelix*, a group of relatively large-bodied land snails. *Oreohelix* includes approximately 24 living species, seven of which are found in Utah (Clarke 1993; Pilsbry 1939). Henderson and Daniels (1917) noted that occasionally this genus is found in unexpected places such as areas with poor vegetative cover or steep and eroding slopes. Most often these areas are so isolated that little information exists on those populations. Ports (1996) points out that when larger snails appear in areas which are thought to be unfavorable, they tend to occur only on the western slopes of canyons. This may be the result of at least three factors. First, large amounts of snow tend to accumulate on the western slopes, keeping the areas cool and moist. Second, western slopes benefit from the rainshadow effect, which also helps add to the moisture of the area. Finally, the rock types typically present on the slopes retain water, thus allowing a more favorable environment for the snails due to the increase of vegetation and overall species richness.

The success of the few *Oreohelix* species that have been studied in these higher and colder elevations, *O. strigosa* and *O. subrudis*, can be attributed partly to their physiological specializations (Rees and Hand 1993). Both snails are able to aestivate during periods of hot, cold, and dry conditions thereby minimizing water loss (Rees and Hand 1990). Within a few days after the beginning of aestivation, they are able to reduce their respiration by more then 80 percent, and decrease their oxygen consumption by 83 percent (Rees and Hand 1990). Aestivation usually lasts until conditions are favorable again, even a few years in some non-oreohelicids (Rees and Hand 1990). Owing to the continuous use of carbohydrates during aestivation, the duration of aestivation may be shortened as a result of urea accumulating in the snails' tissues. High levels of urea can even be fatal due to the lack of detoxifying chemicals (Rees and Hand 1993). *O. strigosa* and *O. subrudis* can also lower their pH by 0.4 to 0.5 units during aestivation (Rees et al. 1991). Dropping pH levels may actually aid in suppressing the aerobic metabolism of the snail, thus increasing the duration of aestivation (Rees and Hand 1990).

Aside from *O. strigosa* and *O. subrudis*, other Oreohelices have been poorly studied beyond taxonomic descriptions and scattered ecological censuses. One such example is the endemic subspecies, the Ogden Rocky Mountain land snail (*Oreohelix peripherica wasatchensis*), from northern Utah. The only descriptions for this subspecies are by W.G. Binney (1886), and taxonomic collections by Henderson and Daniels (1917) which were later revised by Pilsbry (1939). This subspecies is morphologically distinct from other snails due to its high spire, keeled periphery, and coarse shell texture. *O. p. wasatchensis* is an official U.S.F.W.S. candidate endangered subspecies, which is found in a 40-acre area located in the Wasatch Mountains less than 1.6 km south of the mouth of Ogden Canyon. During 1992 and 1993, Clarke (1993) surveyed Ogden Canyon for *O. p. wasatchensis*. Based on this survey, he estimated this population to range from 10,000 to 100,000 living snails. No other studies exist for this subspecies.

Due to its conservation status, and the lack of information about it, it is necessary to begin a baseline study of *O. p. wasatchensis* to determine if measures need to be taken to ensure its survival. Since these snails are found in such a limited area and are only abundant within small patches of bigtooth maple trees (*Acer grandidentatum*), it should be useful to study their abundance and distribution in more detail.

The area of maple trees in which these snails are found is bisected by two dirt roads and numerous trails. These roads may be causing this snails' habitat to be fragmented by creating barriers to its movement (e.g., Baur and Baur 1990). In land snails, dispersal is achieved through small-scale movements that are influenced by daily activity patterns (Baur and Baur 1995). Because snails are not able to fly or jump over intolerable or fragmented habitat, their daily activity patterns are usually confined to more favorable or connected areas (Baur and Baur 1993). Aside from habitat fragmentation, movement and dispersal have considerable influence on the extinction or colonization of a species and the size of its gene pool; both movement and dispersal are crucial factors that deserve attention when studying an endangered species (e.g., Baur and Baur 1995). Therefore, it is important to assess the ability of the snails to move across these barriers. In addition, because the maple trees which form their main habitat occur in isolated patches, estimates of movement rates should be helpful in determining the amount of isolation due to habitat patchiness.

My goal was to establish baseline information for *O. p. wasatchensis*, making possible further study and monitoring. I focused on the abundance and distribution of this subspecies in order to determine the population size and density, and the relation between density and habitat type and composition. I also studied its movement and dispersal, concentrating on directional preference and the relationship between movement and factors such as size, time and behavior. The results of this work may enable us to understand more about these animals and provide information on how to preserve this unique subspecies.

## *METHODS*

### *Study Site*

*O. p. wasatchensis* has only been observed in a 16 hectare (40-acre) area in the Wasatch Mountains, 1.6 km south of the mouth of Ogden Canyon, in Ogden, Utah (41° 14' N, 111° 55 ' W; altitude 1372 to 1890m). This area is easily accessible from the U.S. Forest Service Indian Trail trailhead and a nearby access road for public utilities, and is frequented by walkers, joggers, and mountain bikers (Fig. 1). The vegetation on this western slope consists of short grasses, sage (*Artemisia* spp.), small shrubs, scrub oak (*Quercus gambeli*) and bigtooth maple trees (*Acer grandidentatum*). Both the grassy areas, and the areas under the trees are littered with quartz and limestone rocks ranging in size from pebbles to boulders. The bigtooth maples are concentrated in an east to west draw that runs through this area. The habitat of *O. p. wasatchensis* seems to consist of maple leaf-litter or quartzite boulders and less commonly includes limestone (Binney 1886; Clarke 1993; Henderson and Daniels 1917).

### *Abundance and Distribution*

To estimate the abundance and distribution of these snails, 33 transects, approximately 15-20 meters apart, were used, running from north to south in the snails' range, and were categorized as areas above, between, and below the two dirt roads. The length of each transect was dependent on the habitat in the area, but transects generally extended at least 100 meters on either side of the main draw. Every 3 to 5 meters along the transect, a 0.25 $m^2$ quadrat was searched for snails. For each quadrat, the number of live and dead snails and the percent of microhabitat composition within the quadrat was recorded. The data on live and dead snail density by location, which included isolated areas of maple trees and open areas, were analyzed using one-way ANOVA. The maximum shell diameter of each live snail was measured to the nearest 0.1 mm using calipers, and these data were used to create a size-frequency histogram. Habitat composition encompassed the following microhabitat types: maple, oak or mixed leaf litter, tree bark/small branches, grass, herbs/shrubs, quartz or limestone rocks, pebbles and soil. A stepwise multiple regression (F to enter or exit = 4.0) was used to determine which microhabitat variables were significantly correlated with snail density. Since few snails were found outside the maple groves, only quadrats from within the maple groves were used in this analysis. Data from the transects were later used to estimate the snail densities in each habitat area and microhabitat use. Population size was estimated from the figures on snail density and habitat size.

To access the snail density under rocks in the open areas, rocks were randomly sampled and categorized as limestone or quartz. The surface area of the rock covering the ground was measured with a clear plastic sheet graduated to 50 $cm^2$. All live and dead snails were counted under each rock. The density of live and dead snails was compared between quartz and limestone rocks using a one-way ANOVA.

***Movement and Dispersal***

Two sites within the main bigtooth maple tree habitat of *O. p. wasatchensis* were chosen for this part of the study, based on habitat fragmentation concerns and snail distributions and densities from the above survey. Site 1 was located under a patch of maple trees less then three meters east from the upper dirt road while site 2 was located 30 meters west of the second dirt road (Fig. 1). At each site a 10 $m^2$ area (5 x 2 m) was marked off using flags on thin metal stakes to form a grid of 1x1 m squares which made up both of the 10 $m^2$ sites. The size of these sites was based on the size of sites from similar studies of movement patterns in other species of land snails (Baur 1986; Baur and Baur 1990; 1993; 1995). Each 10-meter site was searched for live snails. When a live snail was found, its position was recorded to the nearest cm (using X and Y coordinates within the 10 $m^2$ grid area), the snail was measured for maximum diameter, marked, and returned to the exact location it was found (Baur and Baur 1993; Paul 1978). Initially, the snails at the upper site were marked using India ink directly on the shell, but since this was not long lasting, this method was later replaced by numbered waterproof paper strips, approximately 4 x 5 mm, superglued to the dorsal body whorl (Baur 1986; 1993). Movement was again recorded by measuring X, Y coordinates one week and one month following the initial marking. Size was measured on the one month recapture date to obtain growth estimates. The time between the initial capture and the first recapture may increase the accuracy of the data if it is over a few days long, since movement has been shown to increase for a few days after marking in other species of land snails (Cameron and Williamson 1977).

Collecting and marking at site 1 began on March 25, 1998 and on April 24, 1998 at site 2. For the movement and dispersal data, the distances moved at each site were compared with collection periods, and the size and behavior at initial capture. The snails' behavior upon collecting was classified as active or dormant. Dormant snails have a dried mucus film covering the aperture (the epiphragm), or they cover the aperture by attaching to rocks or leaves. Snails that are actively moving, or have a foot and/or head partially out of the shell were considered active. The data from the above variables were analyzed using one-way ANOVA to determine if the sites differed significantly in snail movement. Directional patterns were determined graphically.

## *RESULTS*

### *Abundance and Distribution*

A total of 603 quadrats were sampled in the 33 transects. 83 live snails were found under maple trees while only two were found in the open habitats. More snails were found under the maple trees in the leaf litter then out in the open area ($F_{5,584} = 33.86$, $p < 0.05$)(Fig. 2). Density did not differ significantly within the maple areas above, between, or below the roads, or within the different types of areas in the open habitat (grass, or boulders of quartz and limestone)($p > 0.05$ using Tukey's pairwise comparisons for each set). A total of 297 rocks (limestone = 113; quartz = 184) were sampled in the open area. Only two live snails were found in the areas with quartz, and one in the areas with limestone ($F_{1,295} = 1.22$, $p > 0.05$). The average density of snails under the maple trees was 2.96 snails/$m^2$, and 1.1 snails/$m^2$ under the rocks. Based on density and habitat size, the estimated population ranges from 4,200 to 12,000 individuals. The range was determined from the 95% confidence interval from the density estimates and extrapolations using the measured area of the habitat.

The percentage cover of both maple leaf litter and bark/small branches was positively correlated with live snail density (bark : $t = 3.72$, $p < 0.05$; maple: $t = 2.22$, $p < 0.05$; log(live snails + 1) = 0.054 + 0.003 x maples + 0.042 x bark, $R^2 = 0.15$). Maple leaf litter made up 75 to 90 percent of the microhabitat in the ground surface survey; only a few percent of the coverage came from pebbles, bark, soil and grass.

***Movement and Dispersal***

A total of 191 snails were marked, 77 at site 1 and 114 at site 2. At site 1 the rate for the first recapture was 27.2 % and 15.5 % for the second recapture. At site 2 the rates were higher: 32.5 % were caught on the first recapture and 21.1 % on the second recapture. No marked snails were found to cross either of the dirt roads. Movements and dispersal of snails did not show any directional preference at either site (Fig. 3).

Although there was no pattern of directional preference, there was a difference in the distance moved between the two sites in relation to collection dates. The average distance moved over the first week at site 1 was significantly different from the distance moved over one week at site 2 ($\bar{x}$'s: site 1 = 29.5, site 2 = 62.9 cm)($F_{1,56} = 9.81$, $p < 0.05$). However, the overall distances moved between site 1 and 2 over one month did not vary significantly ($F_{1,34} = 0.24$, $p > 0.05$)(Fig. 4).

The size of these snails ranged from 4.0 mm to 18.0 mm, with most of the population falling in the 14 mm to16 mm range (Fig.5). Snail diameter did not have any significant influence on the overall distance moved ($F_{1,34} = 0.27$ , $p > 0.05$)(Fig. 6). However, snail diameter did vary significantly between site 1 and site 2 ($\bar{x}$'s: site 1 = 15.53 mm, site 2 = 14.43 mm; $F_{1,101} = 8.40$, $p < 0.05$) (Fig. 7). It is important to consider if the sizes at recapture are an accurate representation of the initial marked group. A bias in the movement results could occur if the sizes being recaptured varied significantly over time. To check for this, the shell size in relation to collection times (initial capture, and first and second recapture) was analyzed with a one-way ANOVA for each site. There was no significant change in size among initial capture and first and second recapture at each site ($F_{2,106} = 0.01$, $p > 0.05$)(Fig. 7).

Snail activity or dormancy at initial capture did not show any significant relationship with the overall distance moved (from both sites combined)($F_{1,34} = 0.09$, $p > 0.05$)(Fig. 8). The percent of snails active on the different collection dates ranged from 83.3 % to 100 % (Table 1).

## *DISCUSSION*

### *Abundance and Distribution*

It is unusual that this subspecies was found mostly under maple trees since snails from this genus are generally associated with oak trees (Clarke 1993; Henderson and Daniels 1917). Based on similar studies, snail abundance and distribution are primarily influenced by drainage, soil pH, and calcium carbonate content (Paul 1978). If calcium carbonate is not found in the soil, it can be found in the leaf litter (Paul 1978). This may explain why the distribution of *O. p. wasatchensis* is associated with maple leaf litter. Other studies have found higher non-oreohelicid snail densities under trees such as maple than in more open areas (Ports 1996). Leaves of ash (*Fraxinus* ), elm (*Ulmus*), and maple (*Acer*) are good sources of calcium for snails, since it is readily available and more alkaline then what is found in other leaf sources such as oak (*Quercus*) (Paul 1978). Because the calcium salts in maple leaves are more alkaline they may make some areas more tolerable by altering the pH of the soil at the surface (Paul 1978).

*Oreohelix* has also been found in areas with quartzite or granite, but is less frequently associated with limestone (Clarke 1993; Henderson and Daniels 1917; and Ports 1996). This relationship to quarzite or granite may be important, due to the non-porous nature of these rock types, which may facilitate water retention in this area.

The correlation between live snail density and maple leaf litter and bark/small branches was low but significant ($R^2 = 0.15$). This result must be looked at subjectively since density depends on many factors. It is possible the association of this subspecies with bark and small tree branches may provide both suitable moisture and food resources for the snails. No comparable studies are available on specific microhabitat associations.

***Movement and Dispersal***

In comparison to a related study (see Baur 1986), our percent of recaptures (27.2 % to 32.5 % after the first week; 15.5 % to 21.1 % after one month) was average. Most rates are 23% to 40% the day after marking, and after one month the averages are close to 29% (see Baur 1986). The fact that *O. p. wasatchensis* did not display directional preference in its movement is supported by the work of Baur and Baur (1993), which did not indicate any pattern in the direction of movement in land snails.

When looking at the distance traveled in relation to that of other land snails, this subspecies moved shorter distances over a one month period. This difference may be due to the fact that these snails are smaller than the other species that have been examined (see Baur and Baur 1993; Cowie 1980). Baur and Baur (1993) found the daily movements of the 16 to 22 mm land snail, *Arianta arbustorum*, to range from 0 to 4.44 m in a forest clearing, but in tall grass and ditches this distance drops to 0 to 1.57 m . In a

30-day period, this same species covered distances ranging from 0.77 to 6.28 m (Baur and Baur 1989; 1993). Cowie (1980), found that the maximum distances moved by two land snails (*Cernuella virgata* and *Candidula intersecta*) during a 24-hour interval were 300 cm and 120 cm, respectively.

Contrary to my research, Baur and Baur (1995) found that snail size can influence daily movement, but like our results, they also found that over long periods of time the average overall distance is not influenced by size. Baur (1986) found that daily movement does not usually differ from adults to smaller subadults, even though the subadults do tend to be active longer then the adults, who hibernate earlier in the fall and leave hibernation later in the spring than the subadults.

The significantly larger size of the snails at site 1 verses site 2 could be the result of three things. First, the snails at site 1 may have a lower mortality rate then those at site 2. Second, due to the lower densities at site 1, the snails here are able to grow faster then the snails at site 2, whose growth may be slowed by intraspecific competition. Thus, the snails at site 1 are able to attain a larger size. Baur and Baur (1990), found this to be true for the land snails *Chondrina clienta* and *Balea perversa*. Third, the quality of the environment may not be similar at both sites, thereby preventing the snails at site 2 from reaching their maximum growth potential. Because no data have been collected to answer this question, it is not yet possible to distinguish between the above possibilities.

The most significant aspect regarding snail size was that the shells we measured did not exceed 18 mm. This size is smaller than earlier collections which included individuals up to 23 mm (Clarke 1993). This may mean an overall decrease in the shell size of this subspecies has occurred in the last 80 years. The pattern revealed by the size frequency histogram suggests that the average life span is 2 to 3 years (Fig. 5). There are no comparative data from other oreohelicids.

Although it was interesting to see what influence snail behavior had on overall distance moved at the initial capture, there are no related studies with which to compare these results. Cameron and Williamson (1977), did mention that snail movement was primarily determined by rainfall and soil moisture. This may also apply to *O. p. wasatchensis* since when collecting during rainfall, more snails seemed to be active. But, since this study did not include weather as a factor, further research would be needed to determine if such a correlation does exist.

***Conservation and Management Implications***

The most alarming result of this study is the decrease in density that has occurred between 1993 and 1998. In 1993, the density estimated by Carke (1993) was 8.37 snails per $m^2$ in the maple leaf litter, while this study estimates the population to be 2.96 snails per $m^2$. Furthermore, this present study estimated the population size of this snail to range from 4,200 to 12,000 individuals, which is a drop from the estimate of 10,000 to 100,000 living snails by Clarke (1993). This is despite the fact that the distribution results in this study for *O. p. wasatchensis* are wider than Clarke's (1993) initial estimate (D. Meadows, personal communication). Clarke (1993), estimated the range of the species to be 4 hectares, but we now know it is approximately 16 hectares. There is reason, however, to question the original estimate by Clarke (1993), because he surveyed the area for less then five hours spread over three non-consecutive days. Because the area of habitat used to estimate the population size was not even measured, more weight is given to Clarke's (1993) density estimate than his population size estimate.

Some explanations for this possible decline in snails may involve the direct influence of habitat degradation and fragmentation. Habitat degradation is evident in many ways. First, the area in which these snail are found contains a substantial amount of litter, such as car tires, buckets, cans, and scraps of metal. This litter may be altering the movement or dispersal of these snails. It is also possible that these items may affect the microclimate in the maple patches by altering drainage patterns or decomposition rates. The trash may also increase intraspecific competition by making favorable areas uninhabitable. Second, the roads and trails which bisect the habitat are more frequently used by people. Lastly, new houses are being built less then 1.6 km away from this snails' habitat. Although the impacts of these factors has not been established, they need to be studied further since the alteration of natural habitats can lead to isolation, inbreeding, or decreasing population sizes in land snails (Baur and Baur 1990).

Because of the relatively small scale movements of these snails, habitat fragmentation may have a detrimental impact on their survival. First, dirt roads increase the edge effect by fragmenting the main maple area. The microclimate near the edge of the maple patches will be less favorable, since it is drier, sunnier and warmer than the center of the habitat (Kapos 1989, Saunders, et al. 1991). Therefore, only a portion of the maple patches may be considered habitable to these snails. Second, other studies have shown that roads act as barriers for snails (Baur and Baur 1989). It has been shown that even if the snail is capable of crossing the width of the road, they will move parallel to the road instead (Baur and Baur 1989). In the case of *O. p. wasatchensis*, the dirt roads are narrow, but the snails still do not appear to be crossing them. The same may be true of the smaller width trails, but I have no data on this point. Aside from crossing the road to disperse, the only other option would be to move into the grassy areas surrounding the maple patch. Baur and Baur (1995), discovered that even a 40 cm wide grassland may inhibit snail dispersal. Therefore, the roads and trails, as well as the patchiness of the maples, may be isolating these snails and influencing the amount of genetic diversity within the population, or the size of its gene pool (e.g., Baur and Baur 1989).

In conclusion, it is important to continue monitoring the dispersal and distribution of these snails. Many factors which this study overlooked deserve attention in future studies such as the role of precipitation, humidity, and temperature, all of which may play an important role in the movement and distribution of this subspecies. Another important concern for future research is the amount of snail genetic diversity existing among the maple patches. Furthermore, the size differences that exist between the two sites should be examined more broadly. As more research is carried out with *O. p. wasatchensis*, it may become necessary to minimize the impact of humans in the area. Many impact minimization options exist, such as restricting any further development close to the snails, fencing off the maple area or roads and trails to eliminate bike and foot traffic, or creating corridors making dispersal across the dirt roads possible. If future research indicates the populations are declining, primarily due to fragmentation, my recommendation would be to implement the use of corridors. Placing corridors underneath the roads and trees and leaf litter to connect the maple patches could increase the area available for movement and dispersal by reducing the amount of isolation, thus increasing population growth for this candidate endangered subspecies.

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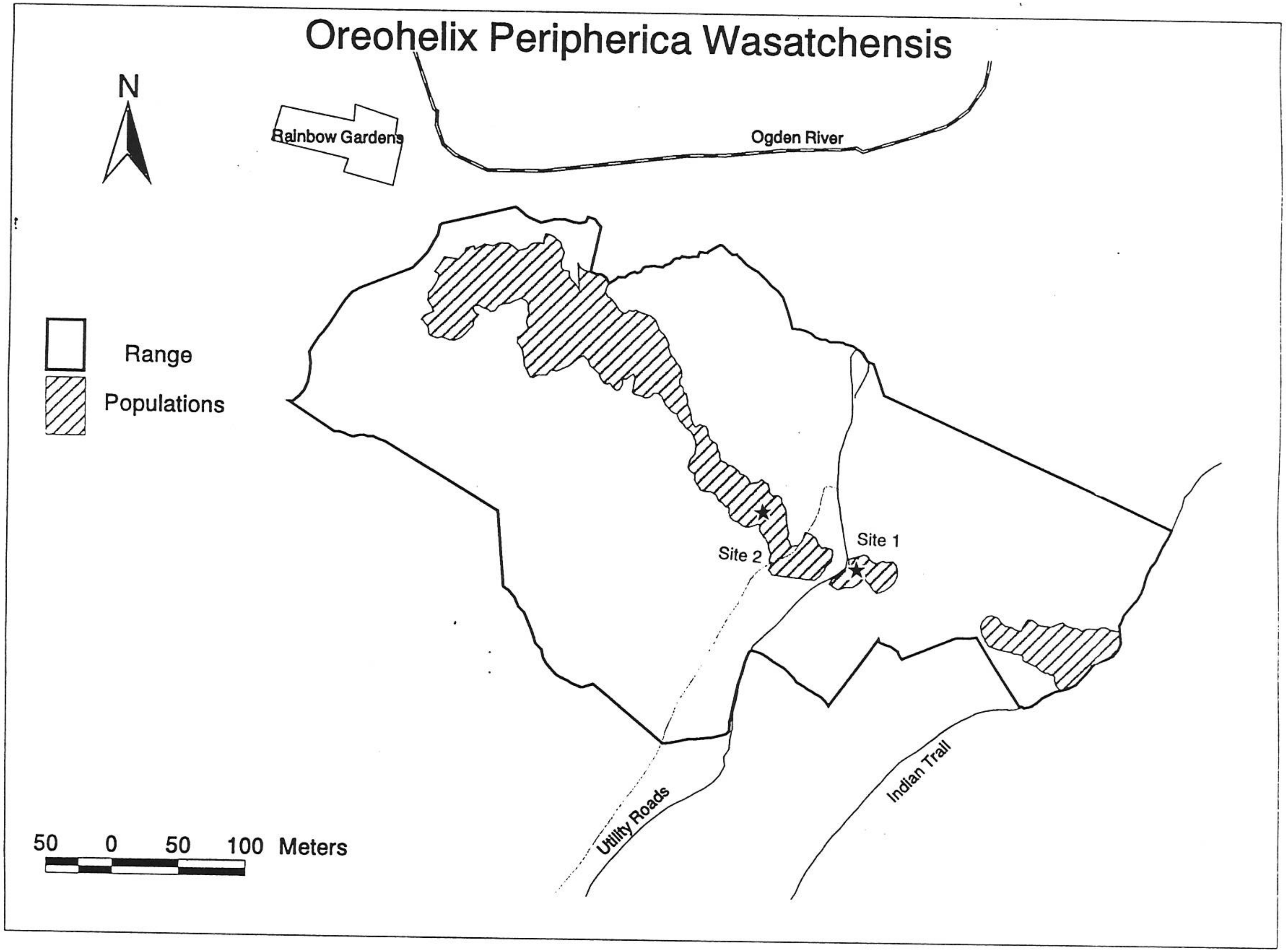



Fig. 1. Map of subspecies distribution including main populations of live snails under maple tree patches (crosshatched area) and total range based on dead snail distribution. Main human impacts are centered around the utility roads and the Indian Trail. Sites for movement study are labeled.

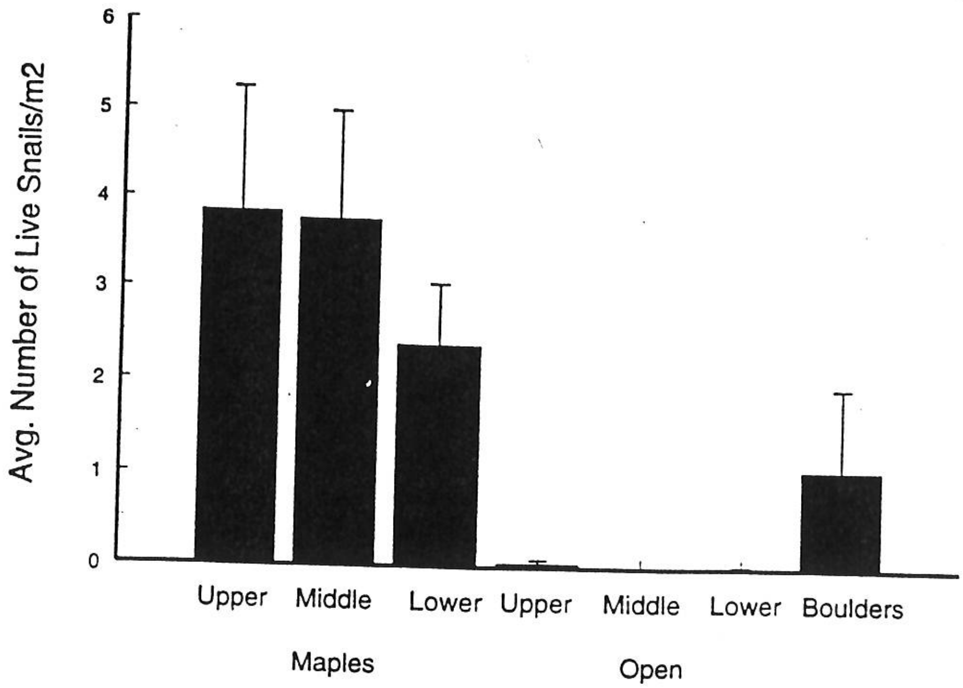



Fig. 2. Density of live snails/m$^2$ found in maples, open areas and boulders. Error bars on this and subsequent figures are 2 s .e .

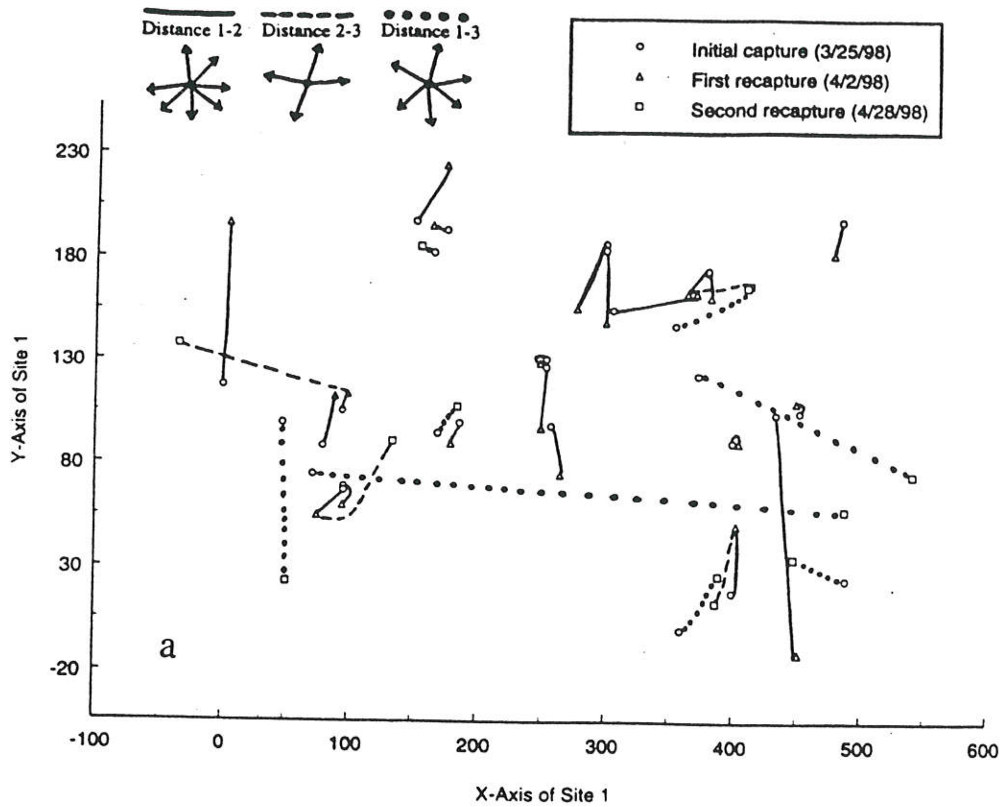
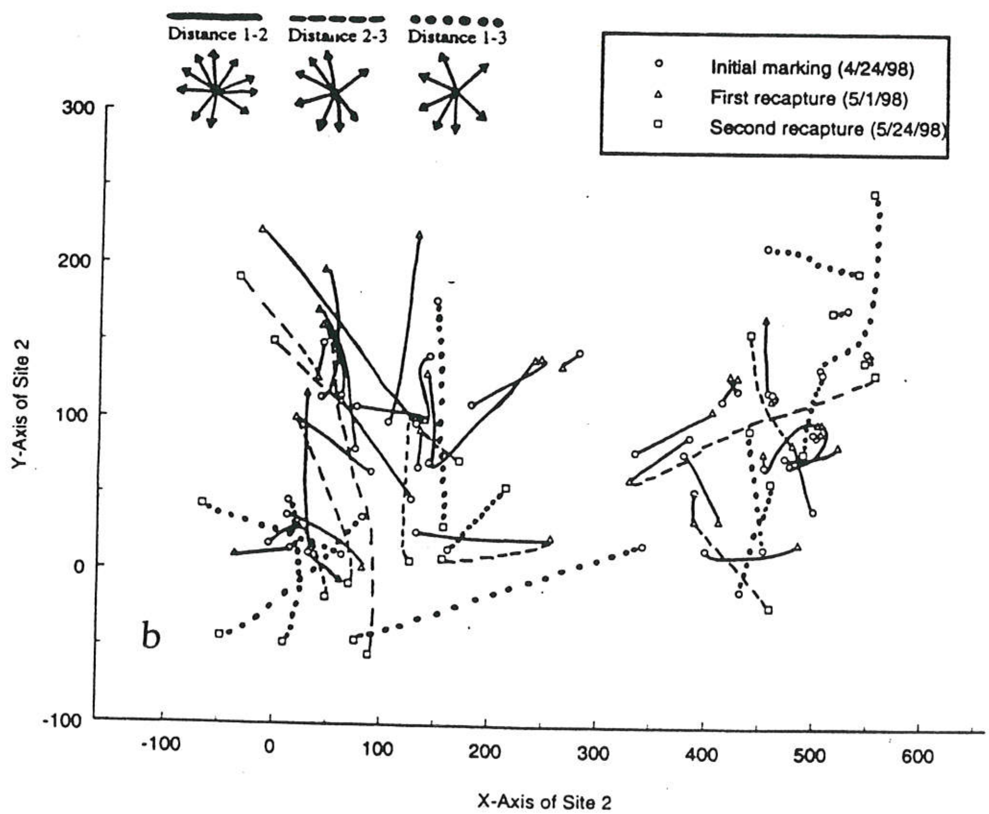



Fig. 3. Representative movement tracks of individual *O. p. wasatchensis* at (a) Site 1 and (b) Site 2. Symbols indicate the snails positions on sampling dates and the direction moved during the sampling period labeled in the key.



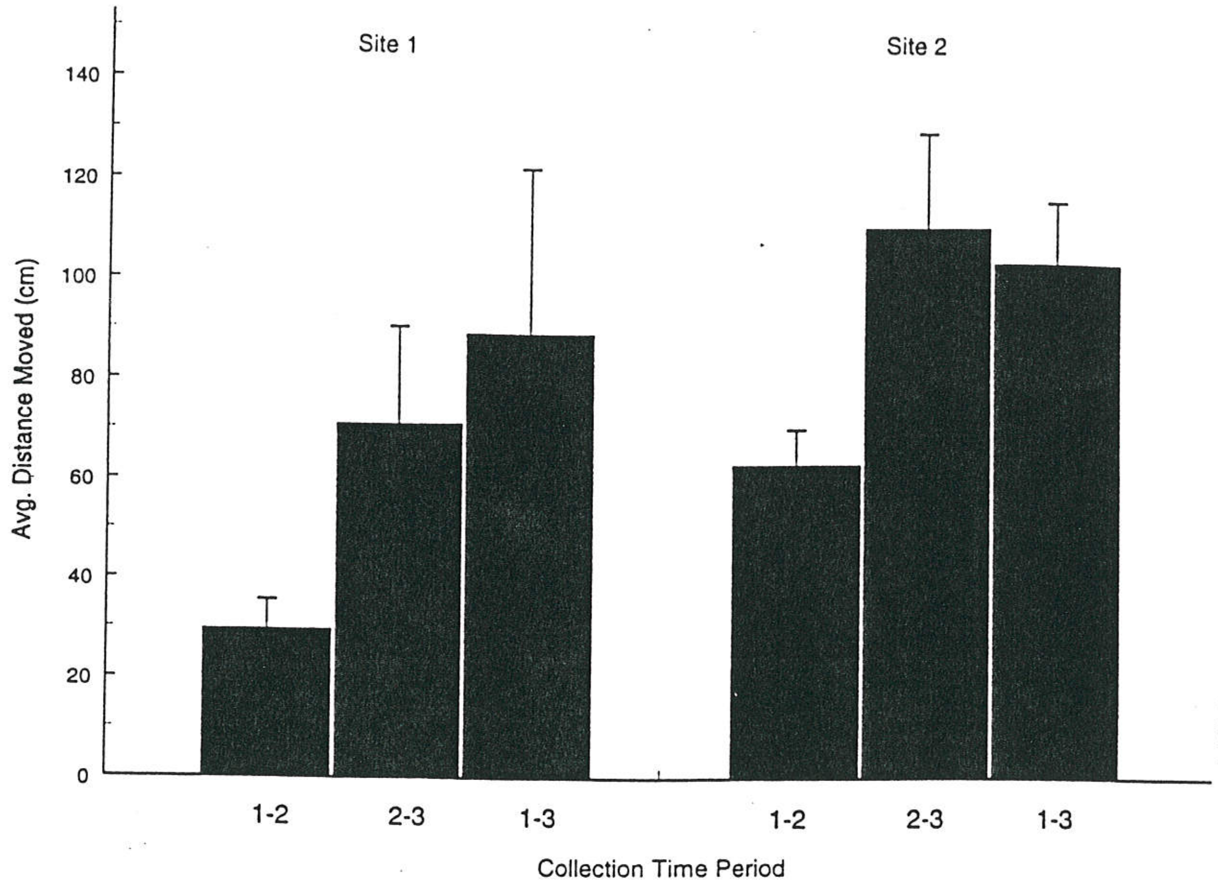



Fig. 4. Average distances moved between sampling dates for initial capture to first recapture (1-2), first recapture to final recapture (2-3), and initial capture to final recapture (1-3) at site 1 and site 2.

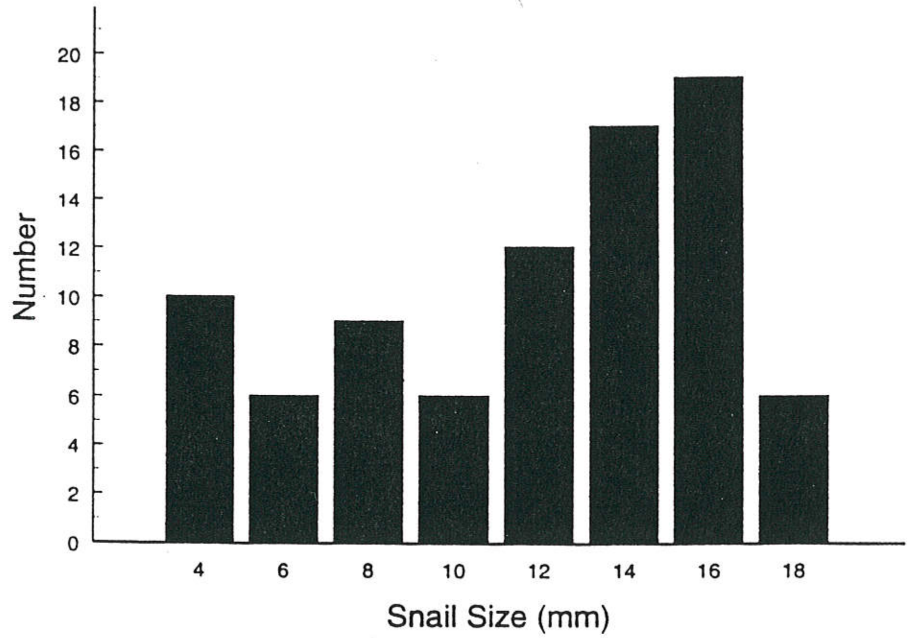



Fig. 5. Size frequency histogram for live snails found under maples and boulders (n = 85).

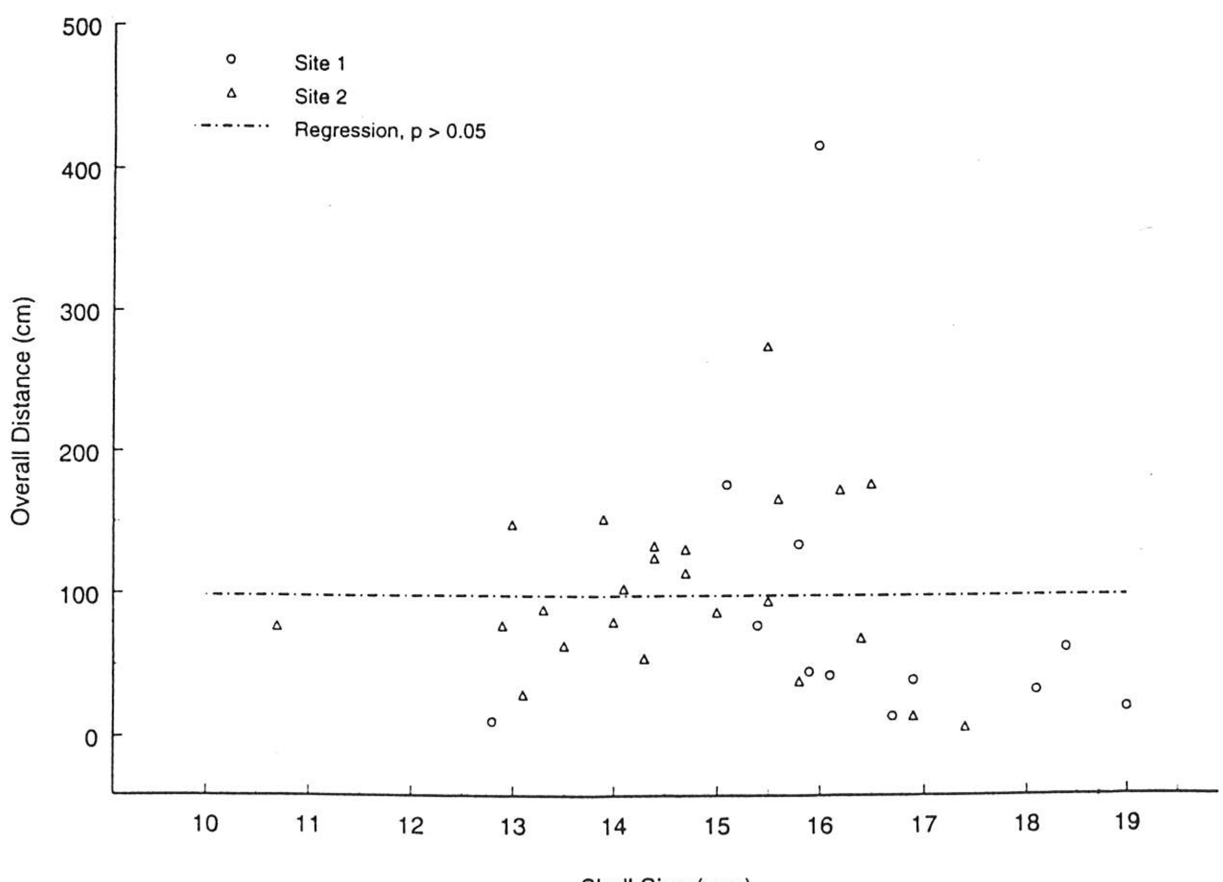



Fig. 6. Shell diameters for individual snails recorded on final recapture date at site 1 (O) and site 2 (Δ). Regression (•–•–•) is $y = 4.1\,x + 161$, slope = 0, $p = 0.608$.

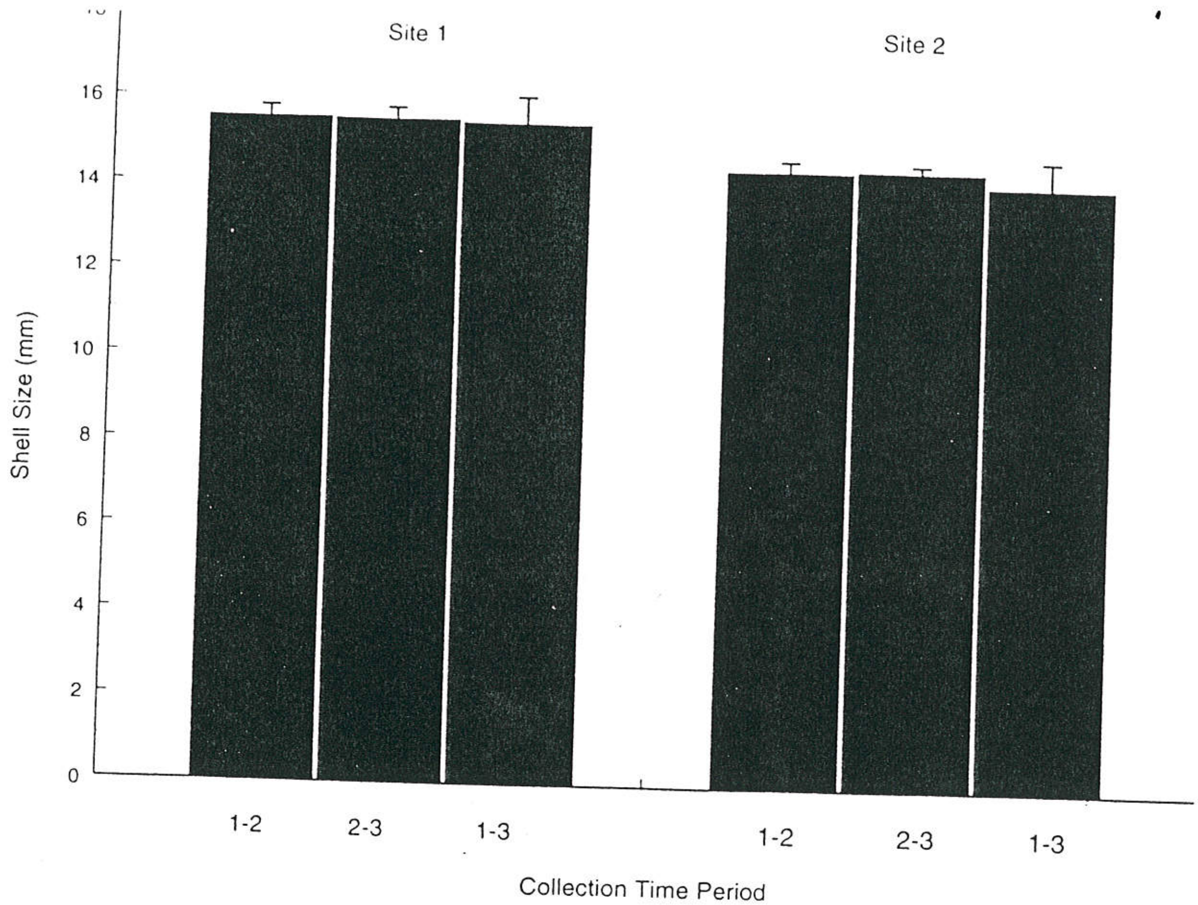



Fig. 7. Average shell size at site 1 and site 2 at initial capture (1-2), first recapture (2-3), and final recapture (1-3).

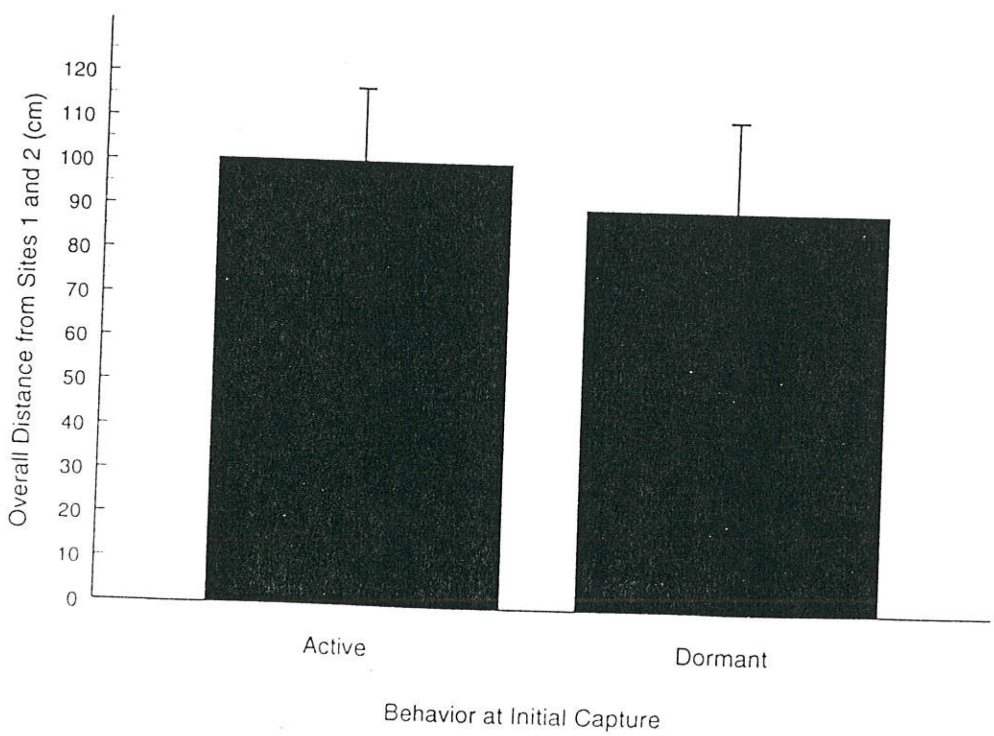



Fig. 8. Overall distance moved at site 1 and site 2 combined, for snails classified as active or dormant at initial capture.

Table 1. Percent of snails active at each site for all collection dates.

| | | | |
|---|---|---|---|
| **Site #1** | **3/25/98** | **4/02/98** | **4/28/98** |
| | 82.6% | 100% | 83.3% |
| **Site #2** | **4/24/98** | **5/01/98** | **5/24/98** |
| | 81.6% | 71.1% | 96% |