ECOLOGY OF THE PREDATOR ASSEMBLAGE AFFECTING NEST SUCCESS OF PASSERINES IN SIERRA NEVADA, CALIFORNIA

A Thesis

by

MARIA CONSTANZA COCIMANO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2009

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Michael L. Morrison
Committee Members,	Roel R. Lopez
	Georgianne W. Moore
Head of Department,	Thomas E. Lacher, Jr.

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ABSTRACT

Ecology of the Predator Assemblage Affecting Nest Success of Passerines in Sierra Nevada, California. (May 2009)

Maria Constanza Cocimano, B.S., Universidad Nacional de Tucuman, Argentina

Chair of Advisory Committee: Dr. Michael L. Morrison

The endangered willow flycatcher (*Empidonax traillii*) breeds in mountain meadows in the Sierra Nevada, which have been intensively modified, especially reducing meadow wetness, which favors easy access for mammalian predators to reach nesting areas in the meadow interior. High nest predation frequency is one of the main factors for willow flycatcher and other passerines' populations decline. I conducted trapping in wet and dry areas on 10 meadows in May–August of 2007 and 2008 to identify the assemblage of potential mammalian nest predators. I compared the predator activity between wet and dry areas of the meadows and determined the relationship between predator activity with vegetation and hydrology of the meadows. In 2008, I used radio-telemetry on deer mice (*Peromyscus maniculatus*) and yellow-pine chipmunks (*Tamias amoenus*) to determine their movement patterns across wet and dry areas, and between forest and meadow. My results showed that chipmunks' and squirrels' activity was restricted almost to dry areas. The activity of yellow-pine chipmunks was 96% and 97% higher in dry versus wet areas in 2007 and 2008, respectively. Voles, mice, and shrews were active in both site types. Voles (*Microtus* spp.) and shrews (*Sorex* spp.) were in general more active in wet areas versus dry areas in 2007. Deer mice were equally active in both site types in 2007 and more active in wet areas in 2008. Between years, predators were 68% more active in wet areas in 2007 compared to 2008, and similarly 52% more active in dry areas. Radio-tagged deer mice used the forest and the meadow and were more common in dry areas, whereas yellow-pine chipmunks used more the forest than the meadows and were active only in dry areas. Passerines nesting in drier areas are exposed to a larger assemblage of potential predators and are more likely to be predated. My results suggest that increasing the proportion of inundated areas in the meadows would help reduce predator activity (especially chipmunks and squirrels) and consequently nest predation, helping increase flycatcher numbers. In addition, wetter conditions will favor an increment in food availability for flycatchers and an increment in willow cover, which consequently will provide more nesting substrate and will help increase nest concealment.

DEDICATION

To mom and dad

To Hernan

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Michael Morrison, for giving me this opportunity and for his guidance throughout my research. In addition, I would like to thank my committee members, Dr. Georgianne Moore and Dr. Roel Lopez, for their guidance and support.

I would like to thank professors, friends, and fellow graduate students who helped in so many different ways: discussing ideas, giving suggestions, or just listening. Especially I would like to thank Bob McCleery, Lisa Vormwald, Heather Mathewson, Helen Loffland and Kathi Borgman, Jerrod Butcher, Andy Campomizzi, Shannon Farrell, Chris Lituma, Julie Groce, Terri Pope, and Anna Knnips, along with Tara, Ardath, Melissa, Mike, Jessica, Kati, Mark, Haemish, and Melanie. The willow flycatcher crews of 2007 and 2008 assisted with field work, especially Kristin Comolli, Amber Wiewel, and Joe Connery.

The staff of the Department of Wildlife and Fisheries Sciences assisted with logistics, especially Vicki Buckbee, Desiree Wooten, Kristi Smith, Shirley Konecny, and Melissa Rubio. Funding for my research was provided by USDA Forest Service, Region 5 and Animal Behavior Society.

The most special thanks go to my husband, Hernan Molina, and my parents, Maria del Carmen and Jorge Cocimano. Their constant support and encouragement were most significant in my career.

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INTRODUCTION

Different species of passerines have experienced continual population declines in the last decades (Ricklefs 1969, Martin 1992, Michaud et al. 2004). Habitat degradation and alteration and the consequent loss of breeding areas, and the increase in brood parasitism and nest predation frequencies, have all led to a decrease in reproductive success. One of the consequences of nest predation is the reduction in juvenile recruitment for the next breeding season. Thus, a decrease in juvenile recruitment is a major contributor to observed population declines (Wilcove 1985, Green et al. 2003).

Numerous studies have documented the effect of nest predation on birds' fitness (e.g., Martin 1992, 1995). Studies in the Sierra Nevada have shown that predation by terrestrial vertebrates significantly reduces nest success of the endangered willow flycatcher (*Empidonax traillii*), and other species such as yellow warbler (*Dendroica petechia*) (Cain et al. 2003) and dusky flycatcher (*Empidonax oberholseri*) (Cain and Morrison 2003). For instance, a long term demography and monitoring study of the willow flycatcher found percentages of predated nests ranged from 45% (n = 49) in 2000 (Morrison et al. 2000) to 71% (n = 24) in 2007 (Mathewson et al. 2007).

The willow flycatcher is a neotropical migrant that was originally distributed throughout the western USA, but it has been experiencing a continual decline in the past five decades (Green et al. 2003). There are five subspecies (*Empidonax traillii traillii, E. t. extimus, E. t. campestris, E. t. adastus, and E. t. brewsteri*) of willow flycatcher that breed across the United States (Unitt 1987, Browning 1993). Three of the subspecies of

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This thesis follows the style of The Journal of Wildlife Management.

willow flycatcher are present in California, and were all listed as state endangered by the California Department of Fish and Game in 1990 (Green et al.2003). Two of the subspecies (*E. t. adastus* and *E. t. brewsteri*) are present in the Sierra Nevada region (Unitt 1987, Browning 1993); the southwestern subspecies (*E. t. extimus*) is present in southern and Baja California (Unitt 1987). The southwestern subspecies reached such critical level that was listed as federally endangered in 1995 (USFWS 1995).

Grinnell and Miller (1944) described the distribution of willow flycatchers (including the southwestern subspecies) in California as present in all areas where preferred vegetation, especially willow thickets, were present associated with some kind of water body, and ranging from 100–2,400 m above sea level. Today, the distribution of the Sierra Nevada subspecies of the willow flycatcher has been restricted to wet mountain meadows, mostly ranging from 1,200–2,500 m above sea level (Green et al. 2003). However, most of the studies carried out until now had focused on willow flycatcher demography (Green et al. 2003, Mathewson et al. 2007), but little has been done regarding the predators affecting nest success, and ultimately leading to population decline.

The meadows inhabited by willow flycatchers have been intensively modified by livestock grazing, road construction, timber harvesting, and recreational activities (Green et al. 2003). Road construction is particularly important as roads were placed along and through meadows, and structures to maintain roads without water were constructed (i.e., gullies) that intercept water flow. Decrease in meadow wetness favors the establishment and expansion of lodgepole pine (*Pinus contorta*) further into the meadows. Also, a decrease in water levels leads to a reduction in willow (*Salix lemmonii* and *S. geyeriana*) cover, which is the substrate for willow flycatcher nests. The presence of water is considered a characteristic of suitable habitat for willow flycatchers, as successful territories (fledged ≥1 young) are associated with the presence of water (standing or flowing water, or highly saturated soils) (Green et al. 2003). Restoration of the water level may inhibit some predators to reach the nests, create the conditions for increase of willow cover and improve habitat for passerines prey (wasps, flies, moths, caterpillar, and bees) (Cain et al. 2003, Green et al. 2003, Mathewson et al. 2006).

Some habitat alterations have favored an increase in abundance and activity of nest predators. Cain et al. (2003) studied the relationship between predator activity and nest success of willow flycatcher and yellow warbler (*Dendroica petechia*) in the Sierra Nevada, and the relation with meadow characteristics. Their results indicated that certain habitat characteristics (meadow wetness, meadow size, amount of edge, distance to isolated trees, and distance to forest edge) are related to predator activity. Bombay (1999) found that successful willow flycatcher territories had 20% greater water depth than unsuccessful territories. Different wetness conditions may be related to different frequencies of predator activity and ability to enter the willow clumps. Cain et al. (2003) found that meadow wetness would be beneficial for willow flycatcher nesting success, because the presence of water may prevent some predators (i.e., Douglas' squirrels, [*Tamiasciurus douglassi*]) to reach the nests. Such relationships have been found in other species such as prothonotary warblers (*Protonotaria citrea*) (Hoover 2006). In addition, Picman et al. (1993) found lower predation rates in higher water depth in a marsh in Ontario, Canada, in comparison with shallow areas of the marsh. They also found that the assemblage composition and the number of species of predators changed with changes in water depth.

Cain et al. (2003) recorded different species of potential nest predators in the meadows. Among mammals they found, Douglas squirrel, lodgepole chipmunk (*Tamias speciosus*), and deer mouse were photographed predating abandoned yellow warbler nests baited with eggs. They also recorded in the meadows, long-tailed weasel (*Mustela frenata*), short-tailed weasel (*Mustela erminea*), Allen's chipmunk (*Tamias senex*), yellow-pine chipmunk (*T. amoenus*), long-eared chipmunk (*T. quadrimaculatus*), western-harvested mouse (*Reithrodontomys megalotis*), montane vole (*Microtus montanus*), long-tailed vole (*Microtus longicaudus*), western aquatic garter snake (*Tamnophis couchii*), western terrestrial garter snake (*Tamnophis elegans*), and common garter snake (*Tamnophis sirtalis*).

I focused on squirrels, chipmunks, and mice. The activity of short-tailed weasels' did not appear to be influenced by amount of water in Cain et al. (2003). Moreover, snakes and weasels are considered very good swimmers (King 1983, Sheffield and Thomas 1997, Ernst and Ernst 2003) and the presence of water may not represent a barrier that prevents them to reach the nesting areas. However, Cain et al. (2003) found that squirrels and chipmunks' activity decreased as the mean percent of water cover in the meadows increased, and that the nest success of passerines nesting in the meadows was negatively related with chipmunks and squirrels' activity. Chipmunks and squirrels are associated with the forest interiors and forest edge (Sutton 1992, Steele

1999) and constitute one of the most important predators of nests located in drier areas of the meadows, and close to the forest edge (Cain et al. 2003). On the other hand, species of mice and shrews (*Sorex* spp.) present in the meadows are associated with both wet and dry environments (Smolen and Keller 1987, Sullivan 1995, Sera and Early 2003, Blake Hart et al. 2004, Gillihan and Foresman 2004). Although we know, based on natural history of the different groups of small mammals present in the meadows, that we could expect to find a higher activity of chipmunks and squirrels (known nest predators, see Cain et al. 2003) in drier areas of the meadows, whereas mice and shrews could be equally active on both site types, we need to quantify how individual species of small mammals respond to different wetness conditions at a local (meadow) scale. Overall, there is little information on small mammal ecology in wet meadows (Austin and Pyle 2004).

My goal was to evaluate aspects of the ecology of squirrels, chipmunks and mice, and how they might influence reproductive success of passerines that breed in meadows in the Sierra Nevada. My objectives were to: 1) determine the relative abundance, activity and distribution of squirrels, chipmunks, and mice in meadows; 2) determine the relation between the predator assemblage composition, abundance and activity with characteristics of the habitat (wetness condition, vegetation structure and plant species composition); and 3) provide management recommendations for the implementation of restoration practices oriented to improve meadow conditions for passerines such as the endangered willow flycatcher. I predicted that the abundance and activity of nest predators such as chipmunks and squirrels will be lower in areas with wetter conditions and that the composition of the predator assemblage will be different at different water levels and inundated soils among the study areas.

STUDY AREA

My study areas are part of a long-term demography monitoring program of willow flycatchers that started in 1997 and include areas managed by the U. S. Forest Service, California Department of Fish and Game, California Department of Parks and Recreation, and private land (Mathewson et al. 2006). During this demography study 21 meadows were surveyed since 1997 (15 from 1997 to 2006, plus 6 added in 2003).

My study areas were located in montane meadows in central Sierra Nevada, California, USA, including El Dorado, Placer, Nevada, and Sierra counties. The area presents a mountainous topography and a naturally fragmented landscape. There are different types of meadows: meadows associated with streams and small headwater rivers; meadows located in ponds and lakes margins; and those associated with springs and seeps (Ratliff 1982, Bombay et al. 2003). Meadows are surrounded by lodgepole pine forest, and different herbaceous plants (*Carex* spp. and *Juncus* spp.) and willows conform the main vegetation. Willows constitute the riparian shrub community and are distributed along streams and in clumps scattered throughout the meadows (Bombay et al. 2003, Cain et al. 2006). In addition, these meadows are considered wet meadows for their high water saturation throughout the year. Meadow areas range from 24.5–103 ha, and elevations range from 1,900–2,700 m. Temperatures in the summer range from an average of 3^{o}C to 26^{o}C (Western Regional Climate Center 2008).

METHODS

Study Site Selection

I selected study areas (meadows) that have willow flycatchers or have historically supported populations of willow flycatchers. In each of the meadows selected as study sites I determined wet and dry areas, where wet areas were those with a combination of highly saturated soils and standing water (inundated). I only considered an area to be wet if at least 60% of the line intercept was wet (with saturated and inundated soils). My study areas included: South and Central Perazzo meadows (SPZZ and CPZZ, respectively), Little Perazzo (LTP), Independence (IND), Little Truckee 1 and 2 (LT1 and LT2, respectively), Tallac (TA), Truckee marsh (TRM) and South Bog and East Corral (SB and EC, respectively) (Table A-1). Once I selected my study areas, I randomly selected the order in which each one would be sampled.

Mammal Sampling

To evaluate the predator abundance and activity in different wetness conditions across the meadows, I carried out mammal trapping in the summers (May–August) of 2007 and 2008 in wet and dry areas of the meadows. In previous studies in the area, short-tailed weasel, long-tailed weasel, Douglas' squirrel, and different species of chipmunks, mice and voles were detected in the area (Cain et al. 2003) and constitute potential nest predators.

Of the 421.7 hectares of meadows included in this study, only 59.3 ha (14.1%) were dominated by willow (Bombay 1999, Mathewson 2009). Of this willow-covered area, approximately 30 ha (7.1%) were excluded from trapping due to the presence of willow flycatcher territories (Table A-2). All remaining willow areas were sampled as follows. In each of the wet and dry areas in the meadows I set Sherman live traps (extra large 7.6 × 9.5 × 30.5 cm and large 7.6 × 8.9 × 23.5 cm) 10–15 m apart from each other, within patches of vegetation (willow clumps). The number of traps in each meadow was related to the availability of areas of the meadow covered by willows, and with the availability of wet areas. As I located traps in meadows with willow flycatcher territories, and considering this is an endangered species, and that traps have to be checked several times a day, I located the traps ≥30 m from known willow flycatcher territories, or known nesting areas, to reduce disturbance that could lead to nest failure. I sampled each wet and dry area only once each summer, except Truckee Marsh, which I sampled twice (with 1 month separation) in 2008 and considered the 2 trapping sessions as 1 sample.

I baited traps with oatmeal and peanut butter, supplied the traps with polyester filling to provide insulation and checked traps 2–3 times a day, during 4 consecutive nights in each of the wet and dry areas in each meadow. Because recapture rates were low (~50%), I tested to determine if increasing the trapping period would increase the recapture rate. To do this I set the traps as explained above and trapped for 7–8 total days. After this preliminary sampling period, however, recaptures rates remained at ~50%. Because there was no substantial difference in capture rate between 4–7 days, I used a trapping session of 4 nights, to maximize the number of locations sampled. Also, 3–4 nights of trapping is the most commonly used trapping session in most of the studies with small mammals trapping. I calculated an overall index of predator activity (IA) for wet and dry areas in each meadow, and a species IA as a ratio between total number of captures (of all the species together and for each species) and total number of trap nights (trapping effort) multiplied by 100 (IA = [no. of captures/no. of trap nights] × 100). I also calculated the abundance of each species in each meadow, and in dry and wet areas within each meadow. Because the number of traps in wet and dry areas in the meadows was different, I calculated and index of relative abundance (RA) as the number of first individuals captured for each species divided by the number of trap nights, per 100 (RA = [no. of first individuals of sp_x captured/no. of trap nights] × 100), corrected for closed but empty traps (see below). Because I did not mark shrews (*Sorex* spp., see below), to calculate their relative abundance I used a conservative method and counted all the individuals (dead and alive) captured during the first night, and for the subsequent nights I subtracted from the total captures for each night the cumulative number of shrews found alive in the previous nights, to avoid double counting individuals that could have been recaptures.

When checking the traps, I used a Ziploc plastic bag to take the animals from the trap and identified, sexed, aged and fur-clipped captured animals, and released them at the capture site. Due to their small size and high mortality rates, I did not fur-clip shrews and released them without marking at the capture sites. In inundated areas, considering the presence of water and changes in water level, I provided the traps with a floating structure made of Styrofoam (30 × 60 × 3.5 cm for extra large traps, and 30 × 30 × 3.5 cm for large traps) attached at the bottom of each trap and tied to the surrounding vegetation. In dry areas I set traps directly on the ground, without additional floating structures. I placed the traps on the ground within the vegetation, covered on the sides and on the top for protection and insulation with soil, moss or woody debris.

To calculate trapping effort I multiplied the number of traps that were active each night, at each wet and dry area in my study sites (TTN = no. of nights × no. of traps − 0.5 CBE). Where TTN represents total trap-night, no. of nights is the duration of the trapping session at each site (e.g., 4 nights), no. of traps is the number of traps that were used at each site, CBE is the number of traps that were found closed but empty, and this is used as a correction factor (Nelson and Clark 1973).

Hydrologic and Vegetative Characteristics

To evaluate the hydrologic and vegetative characteristics of wet and dry areas in each meadow, I established transects along the lines of mammals traps. I used the line intercept method (Bonham 1989), using a pole (200 cm tall × 1.25 cm diameter). I took measurements every 3 meters, including vegetation type, as each species of plant that touched the pole (willow, other shrub species, grass/forbs, aspen, alder, coniferous), vegetation height category (0–50, 51–100, 101–200, >200 cm), soil surface moisture (dry, saturated, inundated), and water depth. I considered other shrub species (referred as “other shrub” species hereafter), those that were not willow, including sagebrush (*Artemisia tridentata*), gooseberries and currant (*Rebis* spp.), and any unidentified species. I sampled a different number of points at each site proportional to the size of the available areas at each of the meadows (Table A-2). Smaller areas with fewer traps had fewer sampled points.

I evaluated the hydrologic and vegetative characteristics at the end of each trapping session, at each of my dry and wet sampling areas. I calculated the overall percentage of inundated soils and mean water depth for each wet and dry areas in each meadow. For the percentage of inundated soils, I calculated the number of points along the line intercept that had water, in wet or dry areas and divided this by the total number of points along the sampling line in that wet or dry area. I evaluated soil saturation by pressing on the ground and if water seeped, I considered that a saturated soil. I calculated the percentage of vegetation cover for each vegetation type (willow, other shrub species, grass/forbs, aspen, alder and coniferous) in each wet and dry area of each meadow. To calculate the percentage of cover of each vegetation type I divided the number of points where I recorded each vegetation type by the total number of points sampled for that wet or dry area.

Movement Patterns of Small Mammals

In 2008, I used radio-telemetry on deer mice and yellow-pine chipmunks to determine their movement patterns across wet and dry areas in the meadows. I used 2 types of transmitters: 0.60-gr BD-2NC collar transmitters and 0.70-gr BD-2 glue-on transmitters (Holohil Systems, Carp, Ontario, Canada), that were <10% of the animal's mass (Koehler et al. 1987). To attach the glue-on transmitters I shaved an area (1×2 cm) on the back of the individual, between the shoulder blades, using a battery-powered moustache trimmer, and glued the transmitter on the back of each individual with eyelash cement. To follow the signal of the transmitters I used a TRX-1000s receiver, and a 3-element Yagi antenna (Wildlife Materials, Carbondale, Illinois).

I determined the location of radio-tagged animals by homing in on the animal location (White and Garrot 1990). I tried to relocate each individual every 30 minutes, during 4–7 nights. For each individual relocated I recorded the position of every location with a GPS, and determined the type of habitat where the animal was located (dry or wet, forest or meadow).

Data Analyses

Prior to statistical analyses, I tested the data for normality and homogeneity of variances. I used scatter-plots to examine trends in the data and used Spearman correlations (Zar 1984:318–320) to test for relationships between the small mammal dependent variables (index of activity and relative abundance) and to check for correlations among the independent variables (vegetative and hydrologic variables). Because relative abundance and activity of small mammals were highly correlated ($P < 0.05$, $r_s > 0.5$) for both wet and dry areas during 2007 and 2008 (Table B-1) I chose to use the index of activity alone when testing for differences between wet and dry areas, and between years, because the index of activity could be a better predictor of the probability of nests to be predated, in comparison with the index of relative abundance (Cain 2001). Passerines nesting in areas with higher predator activity (predators spending more time foraging in these areas) are more likely to be predated than those in areas with lower activity (Cain et al. 2003).

To meet objective 1 I used the Mann-Whitney test (Zar 1984:139–141) to compare the small mammal variables 1) between years for wet (saturated + inundated) and dry areas and 2) between wet and dry areas each year. I also used the Mann-

Whitney test to compare the wetness conditions and vegetation characteristics 1) between years for wet and dry areas and 2) between wet and dry areas each year. To meet objective 2 I used Spearman correlations to determine if there were relationships between the dependent variables and the independent variables, and to identify the variable or set of variables that could predict changes in the small mammal variables. To determine significance of movement patterns of radio-tagged individuals, I used a Chi-square analysis (Zar 1984:400–401), to test for differences in the proportions of locations in which I found the rodents. For all analyses I set alpha at 0.05, and used SPSS 14.0 (SPSS Inc., Chicago, Illinois, USA) statistical package.

RESULTS

Mammal Sampling

I used 1,097 traps for a cumulative sampling effort of 4,278.5 trap-nights between 2007 and 2008 (Table 1). The high numbers of CBEs at IND and TRM in 2007 and at TRM in 2008 were due to bear (*Ursus americanus*) and possibly coyotes (*Canis latrans*) moving traps.

During 2007 and 2008 I obtained 880 captures and 534 individuals of 12 species: long-tailed vole (*Microtus longicaudus*, MILO), montane vole (*Microtus montanus*, MIMO), short-tailed weasel (*Mustela erminea*, MUER), deer mouse (*Peromyscus maniculatus*, PEMA), vagrant shrew (*Sorex vagrans*, SOREX), California ground squirrel (*Spermophilus beecheyi*, SPBE), yellow-pine chipmunk (*Tamias amoenus*, TAAM), Douglas' squirrel (*Tamiasciurus douglassi*, TADO), shadow chipmunk (*Tamias senex*, TASE), lodgepole chipmunk (*Tamias speciosus*, TASP), and jumping mouse (*Zapus princeps*, ZAPR).

Small mammal distribution and composition.— In 2007, I captured 9 species in wet areas and 10 species in dry areas; whereas in 2008 I captured 6 species in wet and 7 species in dry areas (Table 2). Of the species in wet areas, I captured 6 of them (MILO, MIMO, PEMA, SOREX, TAAM, ZAPR) in both years and 3 (MUER, TASE, TASP) only in 2007. In dry areas I captured 6 species (MILO, PEMA, SOREX, SPBE, TAAM, ZAPR) in both years and 4 species (MIMO, MUER, SOPA, TASE) only in 2007 and 1 species (TADO) only in 2008 (Table 2).

Table 1. Number of traps used at each site (NT), number of traps found closed but empty (CBE) and total trap-night (TTN) as the number of traps that were active each night multiplied by the number of nights and minus a half of the traps found closed but empty, at each wet and dry area at each study site for 2007 and 2008.

	2007						2008					
	Wet			Dry			Wet			Dry		
Site	NT	CBE	TTN	NT	CBE	TTN	NT	CBE	TTN	NT	CBE	TTN
CPZZ	12	0	48	28	2	111	na	na	na	na	na	na
EC	24	3	94.5	22	0	88	na	na	na	na	na	na
IND	25	4	98	40	17	151.5	35	4	138	35	9	135.5
LT1	13	0	52	57	4	226	19	1	75.5	51	5	201.5
LT2	39	9	147.5	25	1	99.5	18	0	72	75	10	282
LTP	na	na	na	na	na	na	37	7	144.5	28	2	111
SB	14	2	55	15	0	60	na	na	na	na	na	na
SPZZ	na	na	na	60	0	240	4	0	16	69	15	268.5
TA	43	7	168.5	50	3	198.5	35	6	137	40	4	158
TRM	31	8	120	39	19	146.5	28	14	105	86	29	329.5
total	201	33	783.5	336	46	1321	176	32	688	384	74	1486

Table 2. Species presence in wet and dry areas of the meadows in 2007 and 2008. An X indicates presence.

	2007		2008	
Species	Wet	Dry	Wet	Dry
MILO	X	X	X	X
MIMO	X	X	X	0
MUER	X	X	0	0
PEMA	X	X	X	X
SOREX	X	X	X	X
SOPA	0	X	0	0
SPBE	0	X	0	X
TAAM	X	X	X	X
TADO	0	0	0	X
TASE	X	X	0	0
TASP	X	0	0	0
ZAPR	X	X	X	X

Among meadows, only SOREX was present in all sites in both years (Table 3). PEMA was present in 8 (89%) sites in 2007 and only 1 (14%) site in 2008; MILO was present in 7 (78%) sites in 2007 and in 4 (57%) in 2008; TAAM was present in 6 (67%) sites in 2007 and 6 (86%) sites in 2008; ZAPR and MIMO were present in 5 (56%) of the sites in 2007, and 4 (57%) and 1 (14%) respectively in 2008. The remaining species (MUER, SOPA, TASE, TASP, only in 2007; TADO only in 2008; and SPBE, in both years) were present in ≤3 (Table 3).

Table 3. Species presence in each site, in 2007-2008. No. SP indicates number of sites present and % SP indicates the percentage of sites present.

	Species/Site	CPZZ	EC	IND	LT1	LT2	LTP	SB	SPZZ	TA	TRM	no. SP	%SP
2007	MILO	0	X	X	X	0	na	X	X	X	X	7	78
	MIMO	0	0	0	X	X	na	X	X	0	X	5	56
	MUER	0	X	0	0	0	na	0	0	0	0	1	11
	PEMA	0	X	X	X	X	na	X	X	X	X	8	89
	SOREX	X	X	X	X	X	na	X	X	X	X	9	100
	SOPA	0	X	0	0	0	na	0	0	0	0	1	11
	SPBE	X	0	0	X	0	na	0	X	0	0	3	33
	TAAM	X	0	X	X	X	na	0	X	0	X	6	67
	TADO	0	0	0	0	0	na	0	0	0	0	0	0
	TASE	0	0	0	0	0	na	0	0	X	0	1	11
	TASP	0	X	0	0	0	na	0	0	0	0	1	11
	ZAPR	0	0	X	X	X	na	0	X	X	0	5	56
2008	MILO	na	na	X	X	0	0	na	0	X	X	4	57
	MIMO	na	na	0	0	0	X	na	0	0	0	1	14
	MUER	na	na	0	0	0	0	na	0	0	0	0	0
	PEMA	na	na	0	0	0	0	na	0	0	X	1	14
	SOREX	na	na	X	X	X	X	na	X	X	X	7	100
	SOPA	na	na	0	0	0	0	na	0	0	0	0	0
	SPBE	na	na	0	0	0	0	na	0	0	X	1	14
	TAAM	na	na	X	X	X	X	na	X	0	X	6	86
	TADO	na	na	0	0	0	0	na	0	0	X	1	14
	TASE	na	na	0	0	0	0	na	0	0	0	0	0
	TASP	na	na	0	0	0	0	na	0	0	0	0	0
	ZAPR	na	Na	X	0	X	X	na	X	0	0	4	57

Small mammal abundance and activity.— In 2007 in wet areas, MILO was the most abundant species, followed by SOREX, PEMA and MIMO. MILO was also the most abundant species in dry areas for the same year, followed by TAAM and PEMA (Table 4). In 2008, SOREX was the most abundant species in wet areas followed by ZAPR and MILO. In dry areas, TAAM was the most abundant species followed by MILO and ZAPR (Table 4).

Table 4. Mean relative abundance (no. of individuals/100 trap-nights) of each small mammal species in wet and dry areas in 2007 and 2008.

	2007		2008	
Species	Wet	Dry	Wet	Dry
MILO	7	4.9	1.1	2.2
MIMO	2.8	1.2	0.1	0
MUER	0.1	0.1	0	0
PEMA	3	3	0.1	0
SOPA	0	0.1	0	0
SOREX	4.5	2.5	2.5	1
SPBE	0	0.2	0	0.1
TAAM	0.2	3.2	0.1	3.3
TADO	0	0	0	0.1
TASE	0.1	0.1	0	0
TASP	0.4	0	0	0
ZAPR	1.6	0.8	1.3	1.5

I compared the differences in activity between wet and dry areas for each small mammal species. In 2007, 6 (55%, n = 11) species (MILO, MIMO, MUER, SOREX, TASP, ZAPR) were more active in wet areas, 1 (9%) species (PEMA) was equally active in both site types, and 4 (36%) species (SOPA, SPBE, TAAM, TASE) were more active in dry areas (Figure 1; Table 5). The only species that presented a significant difference in activity between the 2 site types were SOREX (P = 0.021) and TAAM (P = 0.015) (Table C-1). SOREX was 58% more active in wet than in dry areas, whereas TAAM was 96% more active in dry areas versus wet areas, with only 1 record in wet areas (LT1). The activity of the rest of the species was not statistically different between dry and wet areas.

In 2008, 3 (38%, n = 8) species (MIMO, PEMA, and SOREX) were more active in wet areas than in dry areas, 4 (50%) species (MILO, SPBE, TAAM, TADO) were more active in dry areas and 1 (13%) species (ZAPR) was equally active in dry and wet areas (Figure 2; Table 5). Only TAAM presented significant (P = 0.008) differences in activity between wet and dry areas (Table C-2), with 97% more activity in dry areas compared to wet areas.

Table 5. Mean index of activity (no. of captures/100 trap-nights) of each species in wet and dry areas of the meadows and the difference (%) between site types, for 2007 and 2008.

	2007			2008		
Species	Wet	Dry	Difference	Wet	Dry	Difference
MILO	10.3	7.91	23.2	2.07	2.71	23.6
MIMO	3.82	1.49	61	0.3	0	100
MUER	0.26	0.13	50	na	na	na
PEMA	5.24	5.22	0.4	0.54	0.04	92.6
SOPA	0	0.13	100	na	na	na
SOREX	9.2	3.84	58.3	5.25	1.59	69.7
SPBE	0	0.44	100	0	0.3	100
TAAM	0.24	6.09	96.1	0.2	6.1	96.7
TASE	0.07	0.11	36.4	na	na	na
TASP	0.4	0	100	na	na	na
TADO	na	na	na	0	0.13	100
ZAPR	2.18	1	54.1	1.92	1.89	1.6

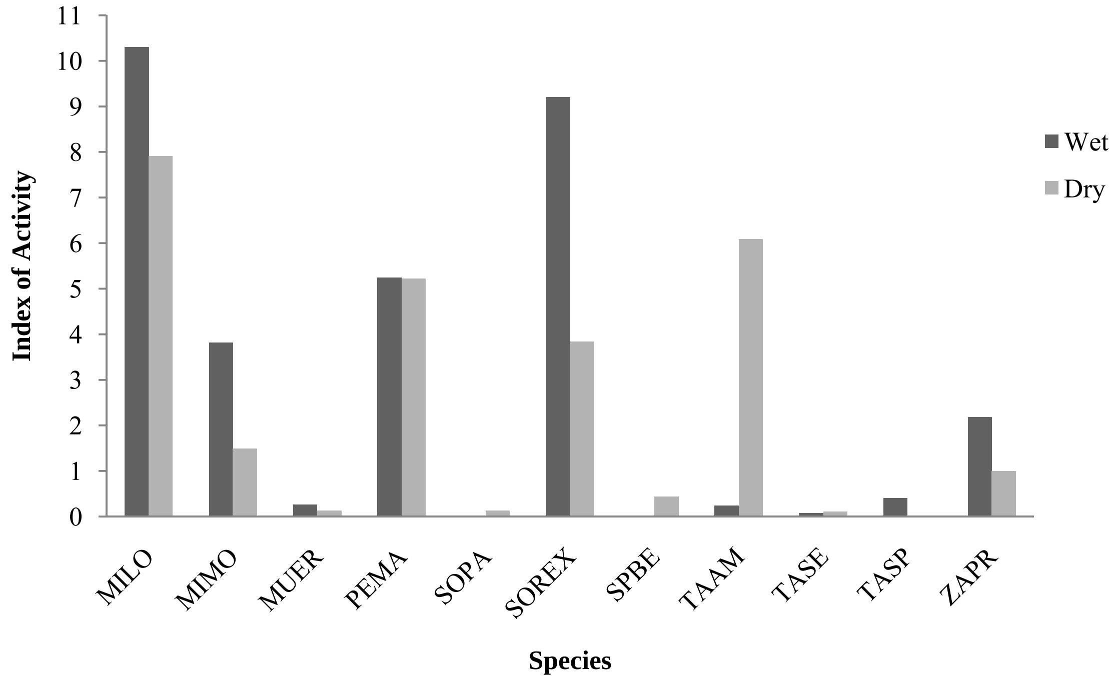

Figure 1. Index of activity of each species of small mammal (number of captures of each species per 100 trap-nights) between wet and dry areas for 2007.

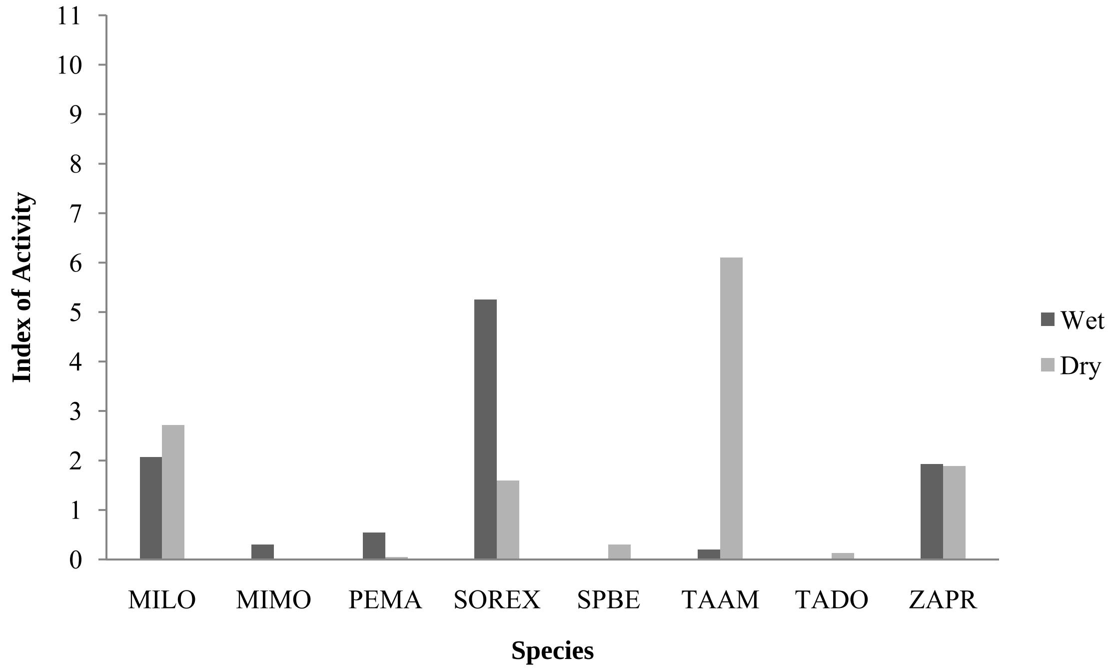

Figure 2. Index of activity of each species of small mammal (number of captures of each species per 100 trap-nights) between wet and dry areas for 2008.

I compared the index of activity for each species between years, for wet and dry areas. I only considered those species that were present in both years. For wet areas, 3 species (MUER, TASE, and TASP) were only present in 2007. In general, the different species were more active during 2007 (Figure 3); 3 species (MIMO, PEMA, and MILO) were >50% more active and 3 species (SOREX, TAAM, and ZAPR) were <50% more active in 2007 compared to 2008 (Table C-3). However, only the differences for 2 species were statistically significant: PEMA was 90% (P = 0.033) more active in 2007 and MILO was 80% (P = 0.031) more active in 2007 (Table C-4).

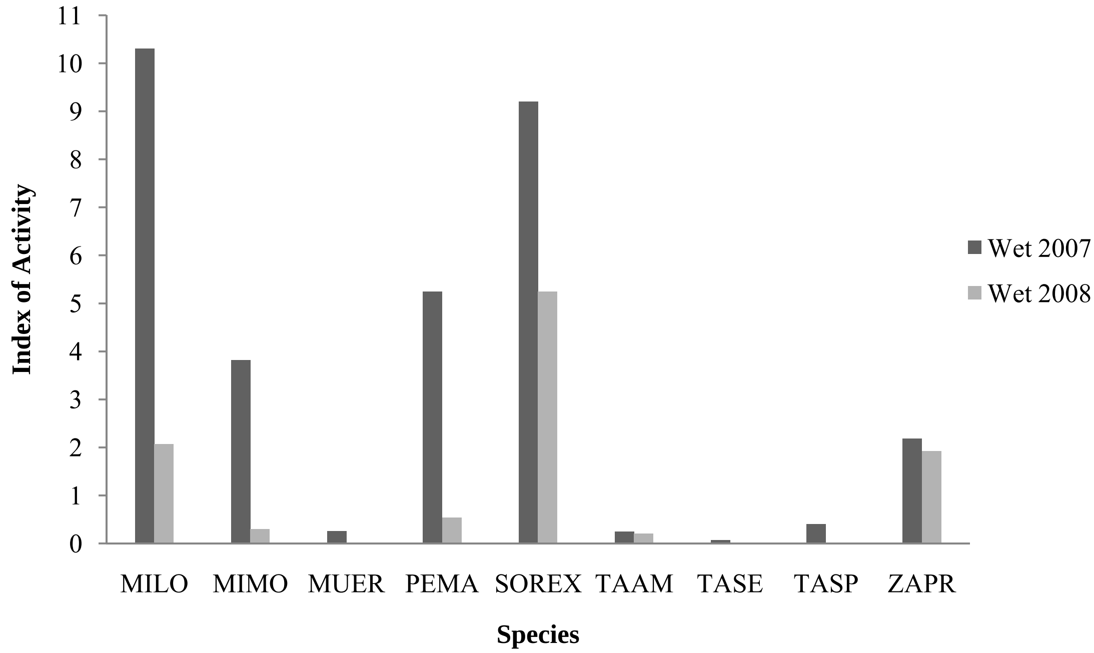

Figure 3. Index of activity of each small mammal species (number of captures of each species per 100 trap-nights) between 2007 and 2008 for wet areas.

For dry areas, 4 species (MIMO, MUER, SOPA, and TASE) were present only in 2007 and 1 species (TADO) was present only in 2008. In general, the different species were more active during 2007, except TAAM that was equally active in both years and ZAPR that was more active in 2008 (Figure 4). Three species (PEMA, MILO, SOREX) were >50% more active in 2007, and the rest of the species presented <50% difference between years (Table C-3). However, only the difference for 1 species was statistically significant: PEMA was 99% (P = 0.002) more active in 2007 than in 2008 (Table C-5).

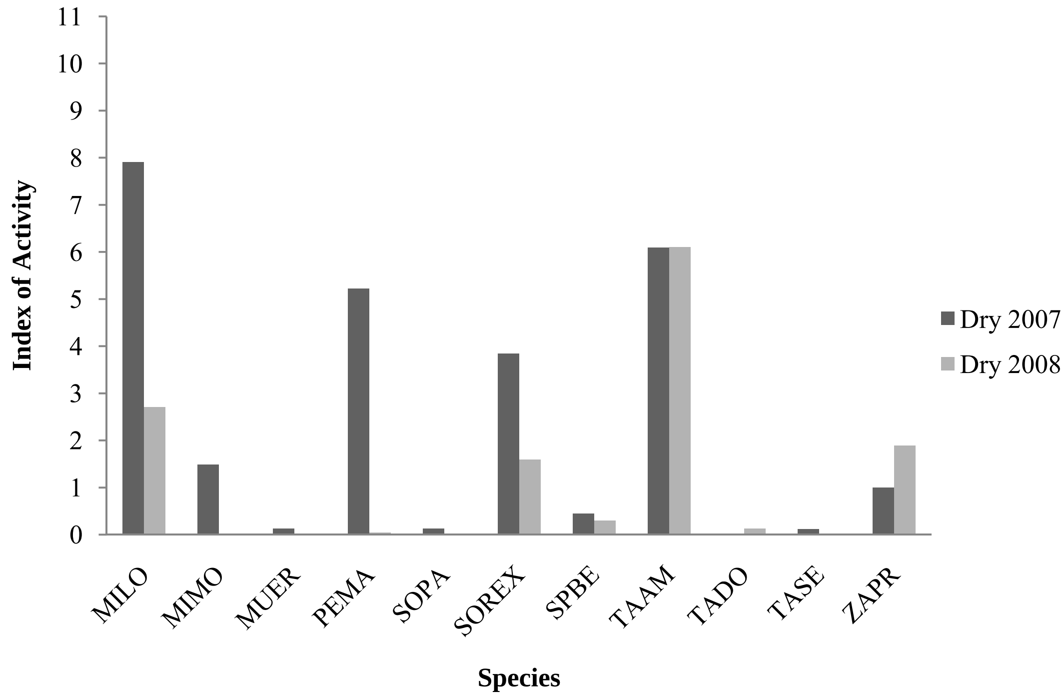

Figure 4. Index of activity of each small mammal species (number of captures of each species per 100 trap-nights) between 2007 and 2008 for dry areas.

MILO was the species with the highest mean index of activity ($\bar{x}$ = 10.3, SE = 3.3) in 2007 in wet areas, followed by SOREX ($\bar{x}$ = 9.2, SE = 1.6) and PEMA ($\bar{x}$ = 5.2, SE = 2.2). In dry areas in 2007, the species with the highest mean index of activity were MILO ($\bar{x}$ = 7.9, SE = 3.6), TAAM ($\bar{x}$ = 6.1, SE = 3.2), and PEMA ($\bar{x}$ = 5.2, SE = 1.1). In 2008 for wet areas, SOREX had the highest mean index of activity ($\bar{x}$ = 5.3, SE = 1.7), followed by MILO ($\bar{x}$ = 2.1, SE = 1.1) and ZAPR ($\bar{x}$ = 1.9, SE = 1.1). For dry areas in 2008, TAAM had the highest mean index of activity ($\bar{x}$ = 6.1, SE = 2.5), followed by MILO ($\bar{x}$ = 2.7, SE = 1.5), ZAPR ($\bar{x}$ = 1.9, SE = 1.0) and SOREX ($\bar{x}$ = 1.6, SE = 1.0).

The overall index of activity was different between 2007 and 2008, for both wet (P = 0.011, n = 15) and dry (P = 0.030, n = 16) areas; the mean overall index of activity was 68% higher in 2007 versus 2008 in wet areas (Figure 5), whereas in dry areas the mean index of activity was 52% higher in 2007 than in 2008 (Figure 6). Between wet and dry areas in 2007 the mean index of activity was 17% higher in wet ($\bar{x}$ = 31.7, SE = 6.5, n = 8) versus dry areas ($\bar{x}$ = 26.4, SE = 6.6, n = 9) (Figure 7), but this difference was not statistically significant (P = 0.386). In 2008 the mean index of activity was 20% higher in dry areas ($\bar{x}$ = 12.8, SE = 3.3, n = 7) versus wet areas ($\bar{x}$ = 10.3, SE = 2.1, n = 7) (Figure 8), but this difference was not statistically significant (P = 0.949).

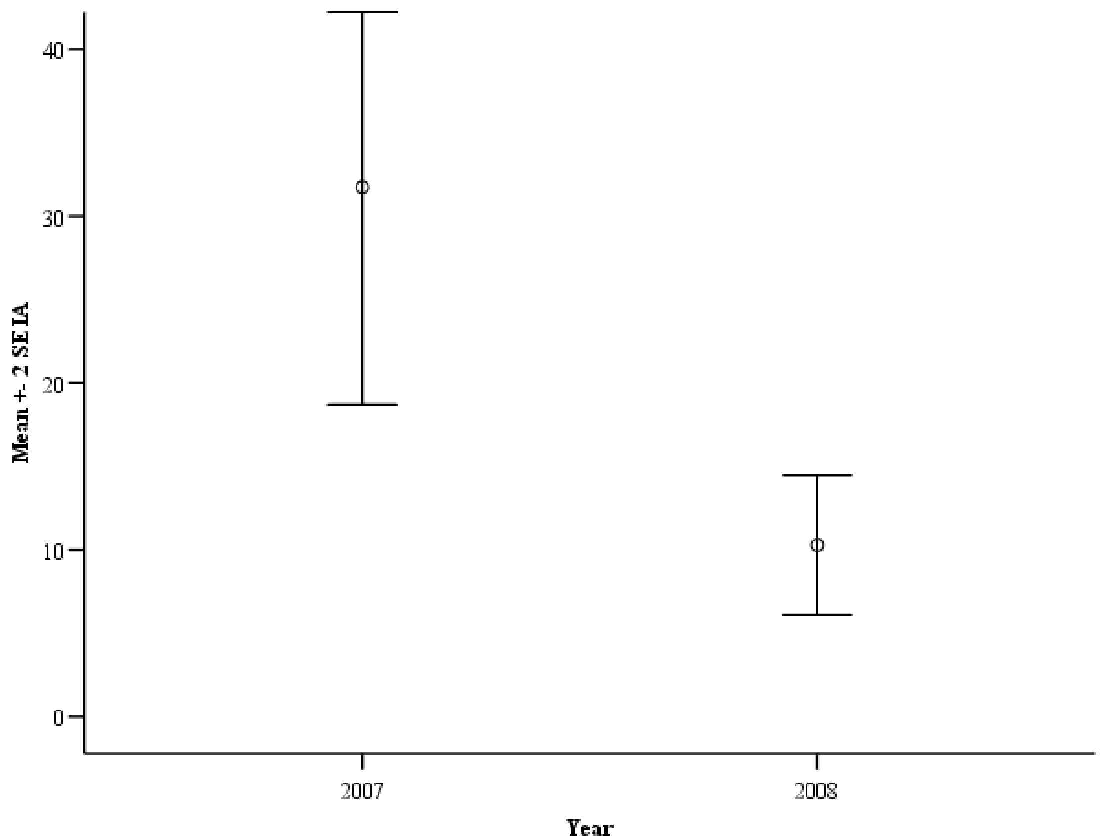

Figure 5. Error bars (± 2SE) showing the differences in mean index of activity of small mammals between years (2007-2008) for wet areas. IA (index of activity) represents number of captures of small mammals per 100 trap-nights.

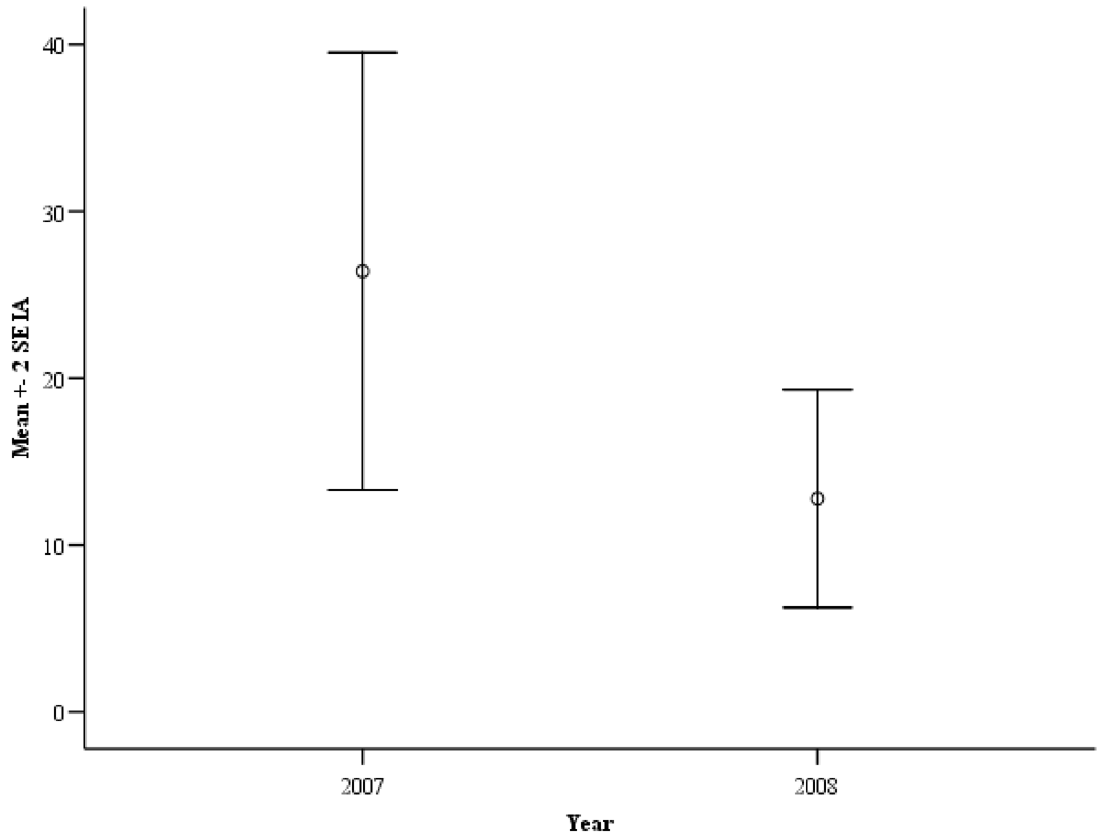

Figure 6. Error bars (± 2 SE) showing the differences in mean index of activity of small mammals between years (2007-2008) for dry areas. IA (index of activity) represents number of captures of small mammals per 100 trap-nights.

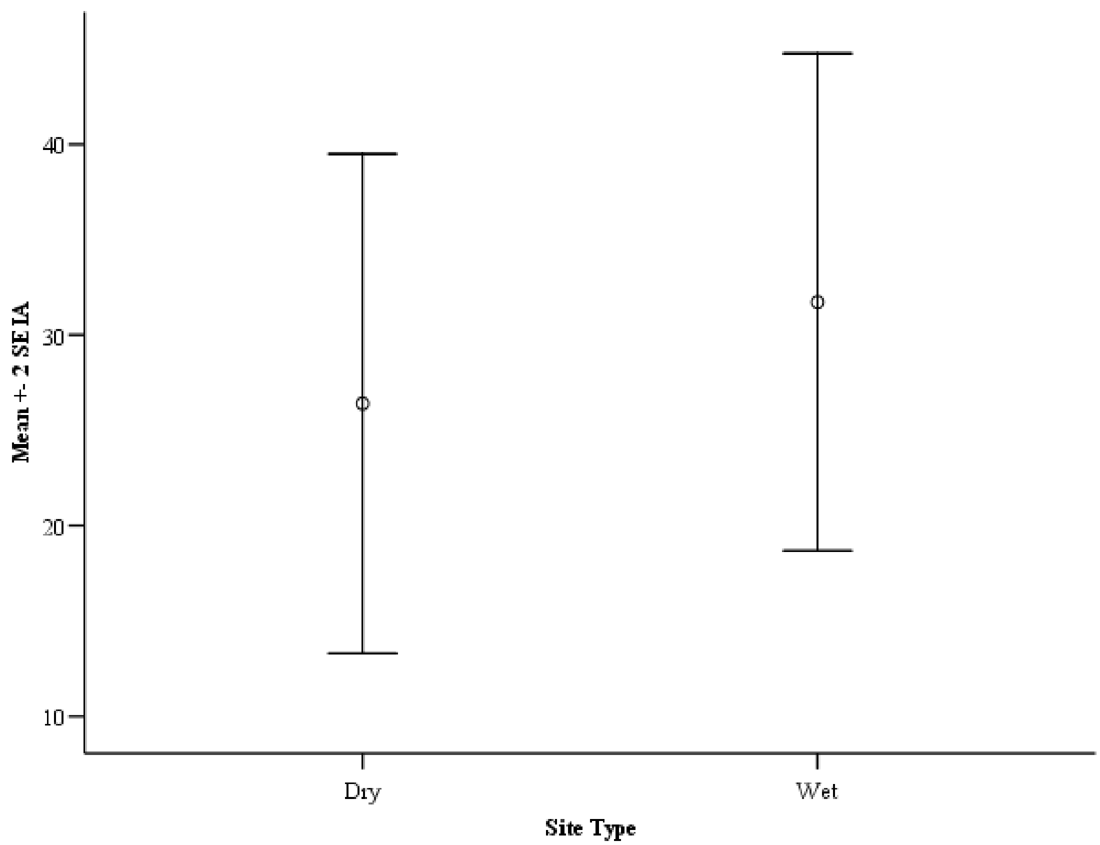

Figure 7. Error bars (± 2SE) showing the differences in mean index of activity of small mammals between wet and dry areas for 2007. IA (index of activity) represents number of captures of small mammals per 100 trap-nights.

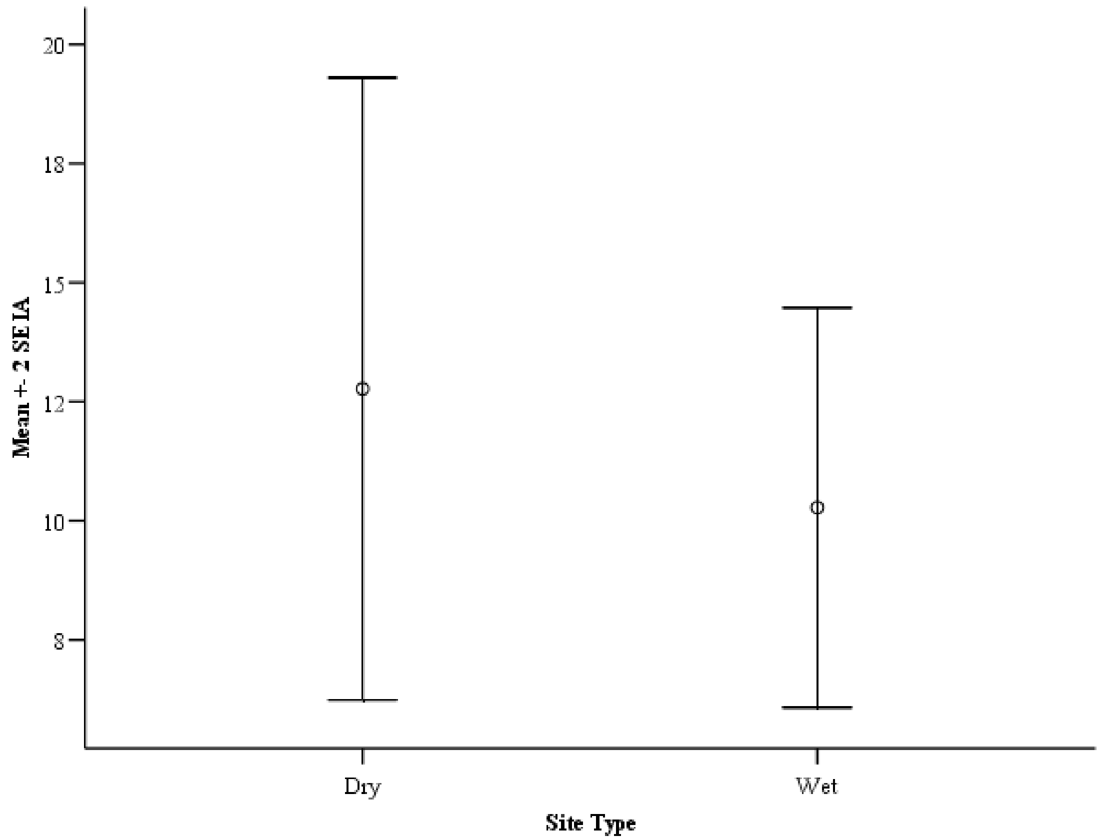

Figure 8. Error bars (± 2SE) showing the differences in mean index of activity of small mammals between wet and dry areas for 2008. IA (index of activity) represents number of captures of small mammals per 100 trap-nights.

Hydrologic and Vegetative Characteristics

Overall, there were not significant differences in vegetation or hydrology between both years of my study. Between wet and dry areas, the differences in vegetation were mainly due to a higher abundance of willows in wet areas, and higher abundance of coniferous in dry areas closer to the meadow edge, although some scattered pines were also found in the meadow interiors.

In 2007, percentage of inundated soils was positively correlated with percentage of saturated soils ($P = 0.030$, $r_s = 0.526$) and mean water depth ($P = 0.009$, $r_s = 0.610$) and negatively correlated with percentage of dry soils ($P \leq 0.001$, $r_s = -0.936$). Dry soils were negatively correlated with mean water depth ($P = 0.003$, $r_s = -0.672$) and percentage of saturated soils ($P = 0.001$, $r_s = -0.740$) (Table D-1). Willow cover was negatively correlated with coniferous cover ($P = 0.046$, $r_s = -0.490$) and alder cover ($P = 0.001$, $r_s = -0.719$), and these last 2 were positively correlated with grass/forbs cover ($P = 0.011$, $r_s = 0.600$, and $P = 0.020$, $r_s = 0.556$; respectively). Alder and coniferous cover were positively correlated ($P = 0.034$, $r_s = 0.515$) (Table D-1). Mean water depth was negatively correlated with percentage of other shrub cover ($P = 0.047$, $r_s = -0.488$).

In 2008, the percentage of dry soils was negatively correlated with percentage of inundated soils ($P \leq 0.001$, $r_s = -0.947$) and saturated soils ($P = 0.011$, $r_s = -0.653$). Percentage of coniferous cover was negatively correlated with percentage of willow cover ($P = 0.002$, $r_s = -0.757$) and positively correlated with other shrub cover ($P = 0.035$, $r_s = 0.566$). Percentage of dry soil cover was positively correlated with percentage of coniferous cover ($P = 0.005$, $r_s = 0.7090$) and other shrub cover ($P = 0.001$, $r_s = 0.806$), and negatively correlated with willow cover ($P = 0.006$, $r_s = -0.697$) (Table D-1).

Hydrology.— Overall, the wetness conditions of my study sites were not significantly different between years. For wet areas, the percentage of inundated soil was 10% higher in 2008 versus 2007 (Figure 9), the percentage of saturated soils was 20% higher in 2007 compared to 2008 (Figure 10), and the mean water depth was 22% higher in 2007 versus 2008, although none of the differences were statistically significant (*P* = 0.355, *P* = 0.817, and *P* = 0.355 respectively) (Table E-1).

Dry areas also had some percentage of inundated soils and saturated soils, but because these wet areas were isolated points I did not consider them as a barrier for small mammal movements. For dry areas, the percentage of inundated soils was 6% higher in 2008 compared to 2007, the percentage of saturated soils was 42% higher in 2007, and the mean water depth was 30% higher in 2008 than 2007. Again, the differences were not statistically significant (*P* = 0.958, *P* = 0.788, and *P* = 0.315, respectively) (Table E-1).

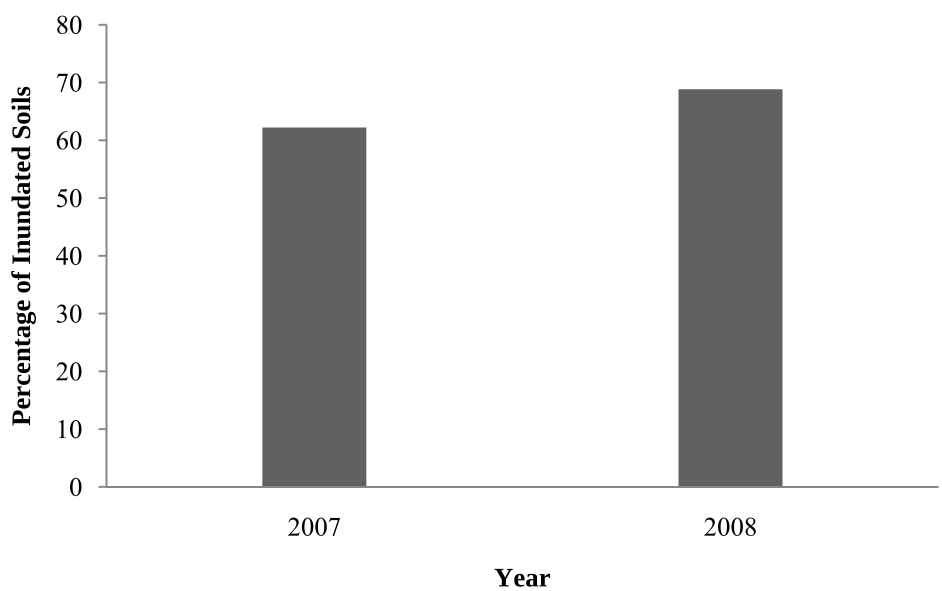

Figure 9. Percentage of inundated soils in wet areas of the meadows for 2007 and 2008.

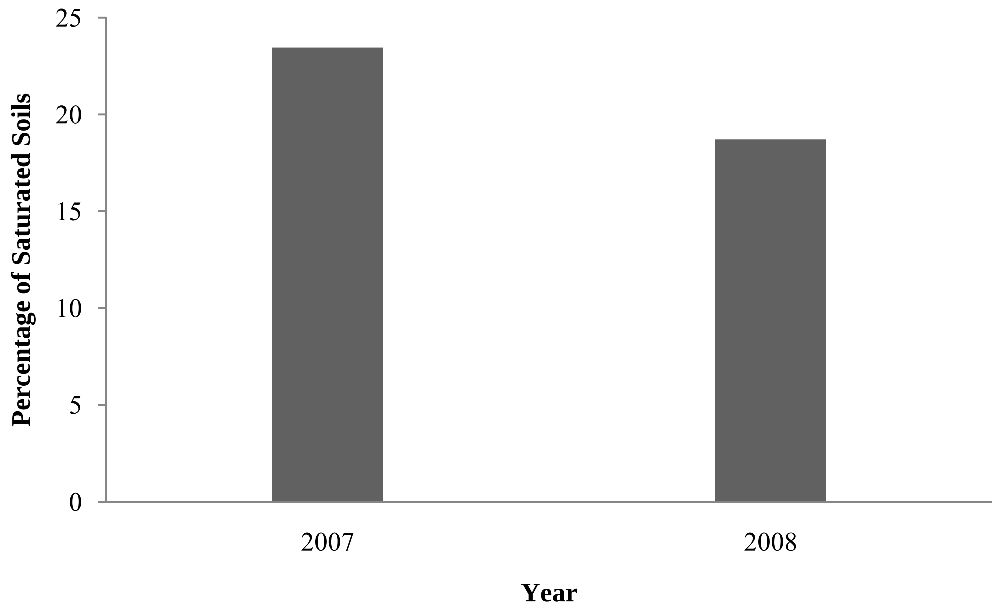

Figure 10. Percentage of saturated soils in wet areas of the meadows for 2007 and 2008.

When comparing the wetness conditions between wet and dry areas for each year, in 2007 wet areas had on average: 96% more inundated soils than dry areas, 72% more saturated soils (Figure 11) and 55% higher water depth. The differences in wetness conditions between wet and dry areas were statistically significant for the 3 variables; percentage of inundated soils (P = 0.001), percentage of saturated soils (P = 0.025), and mean water depth (P = 0.004) (Table E-2). In 2008, wet areas had on average: 96% more areas with inundated soils than dry areas, 77% more saturated soils (Figure 12) and 18% higher water depth. The differences in wetness conditions between wet and dry areas for 2008 were significantly different for 2 of the variables: percentage of inundated soils (P = 0.002) and percentage of saturated soils (P = 0.025) (Table E-2).

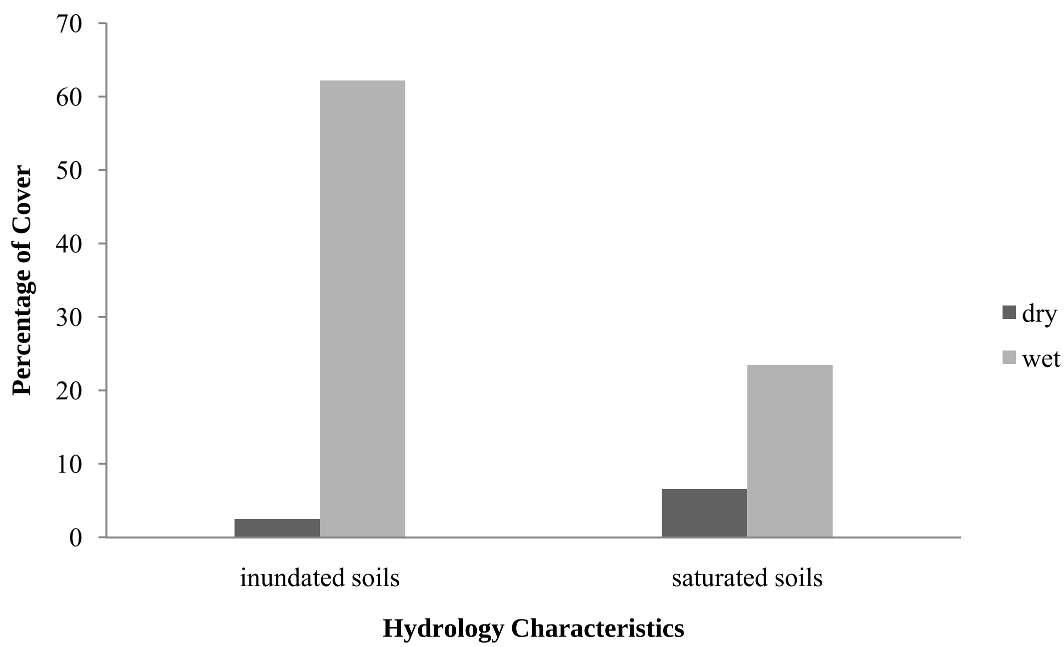

Figure 11. Percentage of cover of inundated and saturated soils in wet versus dry areas for 2007.

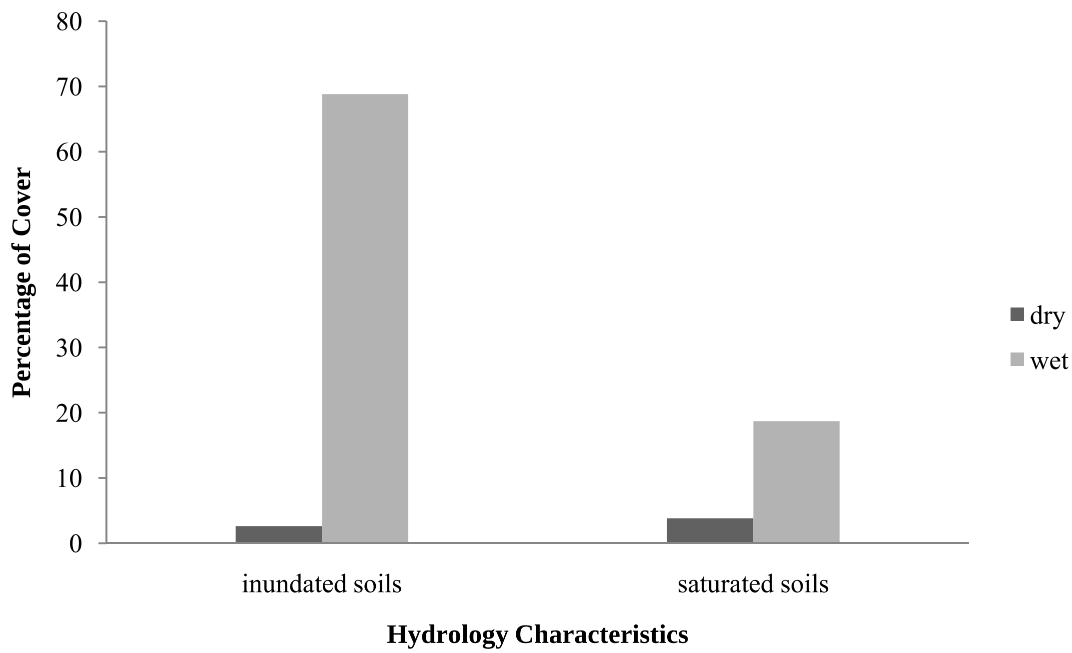

Figure 12. Percentage of cover of inundated and saturated soils in wet versus dry areas for 2008.

Vegetation.— There were not statistically significant differences in the vegetation characteristics between years for both wet and dry areas (Table E-3). In dry areas, the percentage of difference between 2007 and 2008 remained relatively low (ranging from 0.5 to 9.4) for percentage of grass/forbs cover, other shrub cover, and willow cover. In 2008, the percentage of coniferous cover was higher (43%) due to trap allocation at the forest edge in 2008. In addition, aspen was only present in 2008, due to trap allocation at the forest edge. In 2007, the percentage of alder cover was 86% higher than in 2008, due to higher presence of alders in 2 of the sites (EC and SB) sampled in 2007 only

(Figure 13). For wet areas, there were not statistically significant differences between years. And the percentage of differences remained low (ranging from 4 to 8%) too, for percentage of willow cover (higher in 2008) and grass/forbs cover (higher in 2007). Aspen was not present in wet areas in either year and other shrub species were only present in 2007. Coniferous cover and alder cover were both 57% higher in 2007 (Figure 14), and were represented by scattered trees within the meadows.

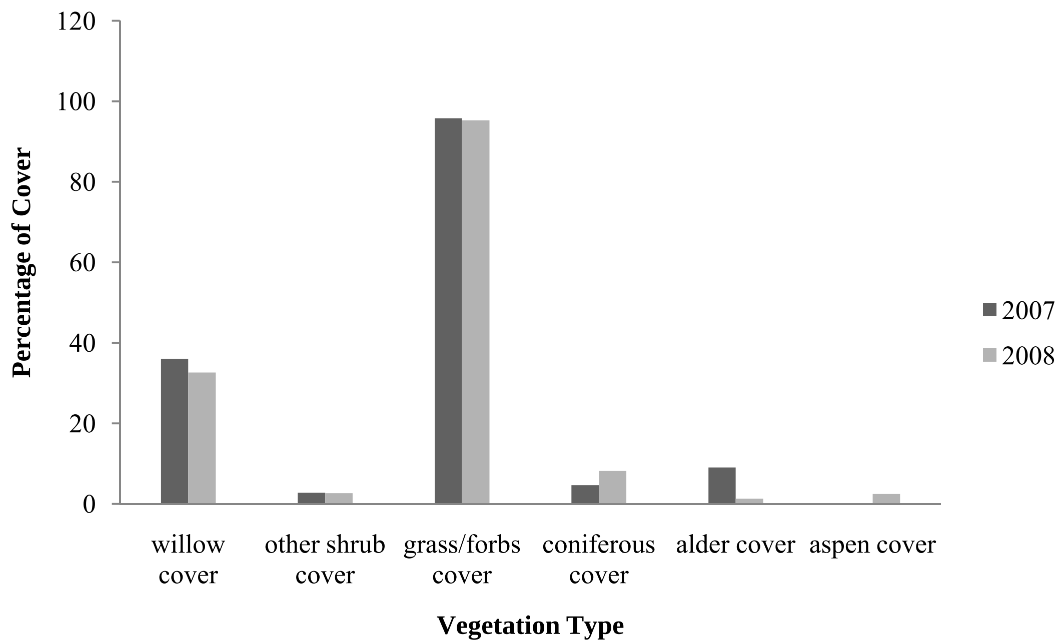

Figure 13. Comparison of the percentage of cover of each of the vegetation types between years (2007-2008), in dry areas.

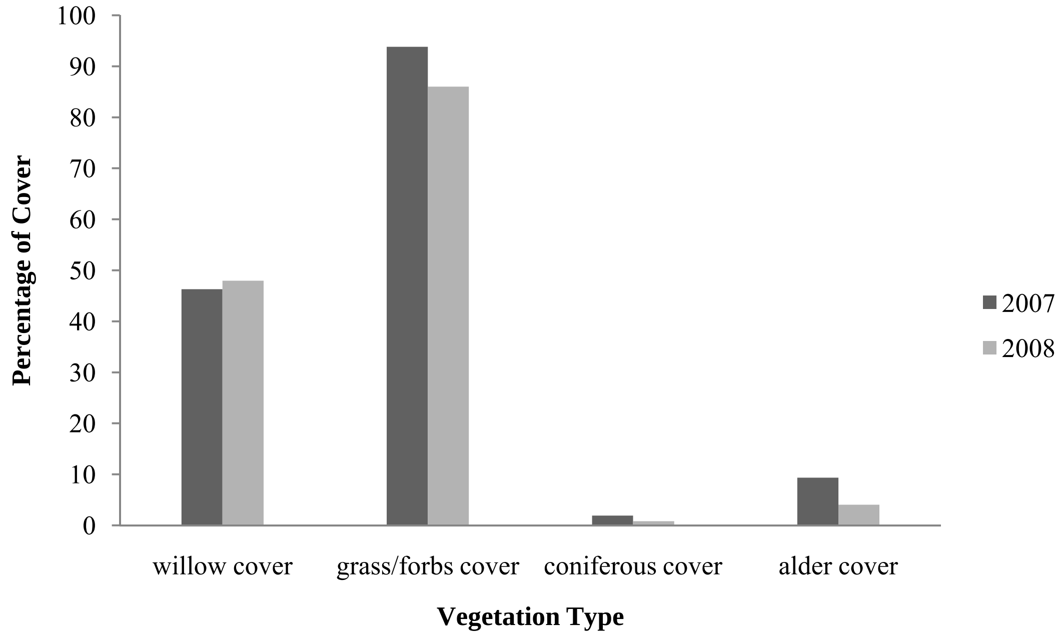

Figure 14. Comparison of the percentage of cover of each of the vegetation types between years (2007-2008), in wet areas.

A comparison of the vegetation between wet and dry areas for each year showed that they were not different (*P* > 0.05) in 2007 (see Table E-4 for each *P*-value). The percentage of difference between wet and dry areas in 2007 was <50% for grass/forbs, alder, and willow cover, and >50% for coniferous and other shrub species (Figure 15). In 2008, the percentage of willow and coniferous cover were significantly different between wet and dry areas (Table E-4). Willow cover was 32% higher (*P* = 0.035) in wet areas and coniferous cover was 90% higher (*P* = 0.017) in dry areas. Other shrub species were only present in dry areas in 2008 (Figure 16).

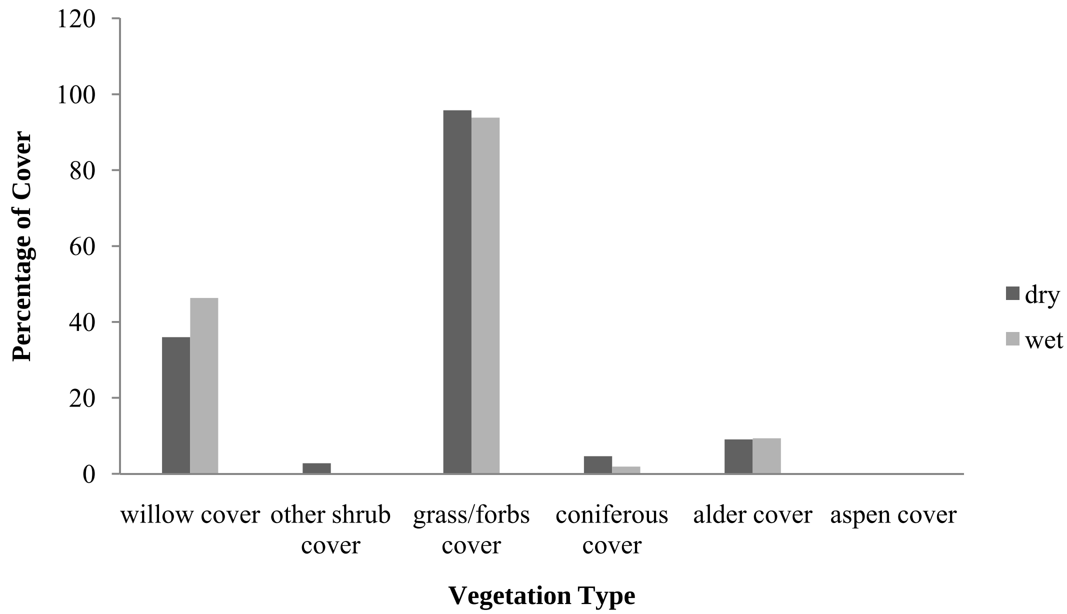

Figure 15. Comparison of the percentage of cover of each of the vegetation types between dry and wet areas for 2007.

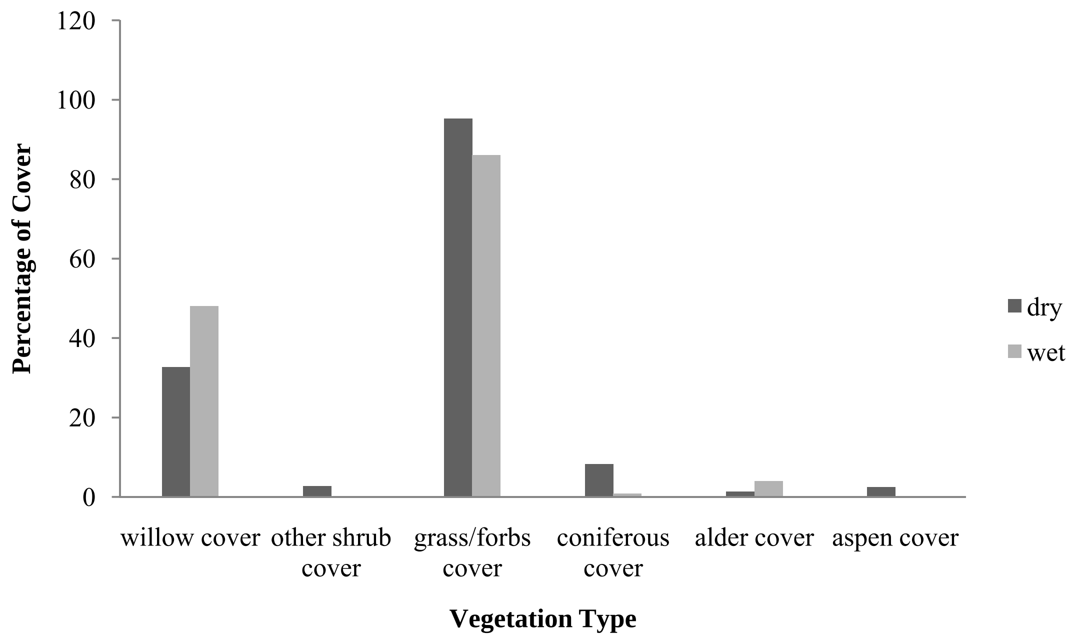

Figure 16. Comparison of the percentages of the vegetation types between dry and wet areas for 2008.

Relation between Small Mammals' Activity and Habitat Characteristics

I compared the index of activity of each species of small mammal with the habitat characteristics. I only included in the analyses those species that were present in both years of my study and in at least 3 of my study sites either year. I present the results from Spearman correlations along with scatter plots for each species of small mammals in which the relation was significant. In those cases were correlations were not statistically significant I present scatter plots for those relations that presented a trend in the data.

MILO.— The activity of MILO was not correlated with any of the hydrological variables ($P > 0.05$, Table F-1). However, scatter plots showed that MILO activity seems to follow an inverse quadratic relationship with percentage of inundated soils (Figures 17 and 18). With high activity in the extremes of wetness conditions (below 10% inundated and above 40-60% inundated), and decreased or null activity towards the middle (20-30% inundated). It is important to note that the wet site at just above 20% inundated in 2007 is almost dry or intermediate. A similar pattern is observed in both years, although higher percentage of inundated soils were needed in 2008 for the relationship to be noticeable (i.e. in 2007, the site at just above 40% inundated had high activity; whereas in 2008, activity was higher in areas above 60% inundated). The activity of MILO was not correlated with any of the vegetative variables ($P > 0.05$, Table F-1).

MIMO.— The activity of MIMO was not correlated with any of the habitat characteristics (hydrology and vegetation) ($P > 0.05$, Table F-2).

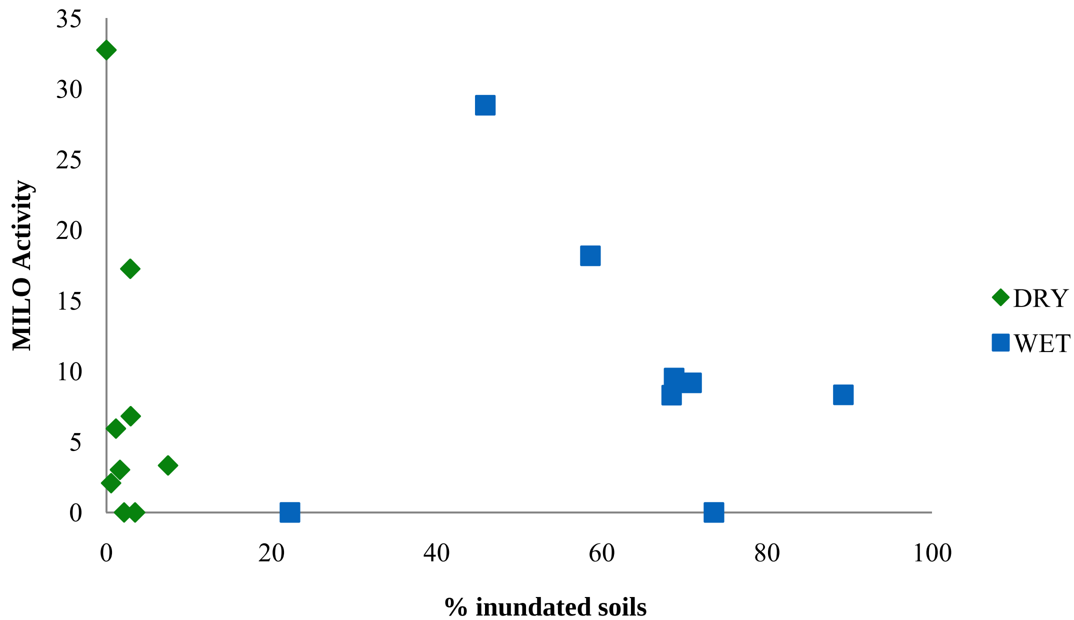

Figure 17. Relation between index of activity of MILO and percentage of inundated soils in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

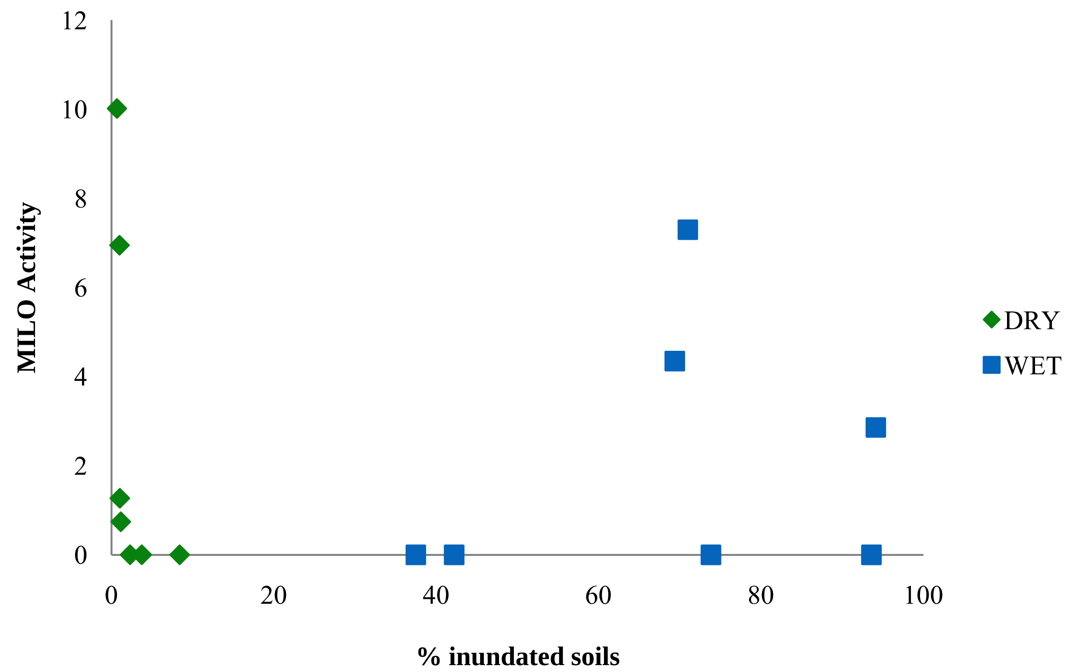

Figure 18. Relation between index of activity of MILO and percentage of inundated soils in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

PEMA.— Spearman correlations were not signinficant between activity of PEMA and any of the hydrological variables ($P > 0.05$, Table F-3). However, when observing the scatter plot between activity of PEMA and percentage of inundated soils, the relationship seems to follow a quadratic function (as with MILO), and PEMA shows a wide range of activity in dry areas, its activity decreases towards the middle conditions of inundated soils (between 20-40% inundated soils) and increases again above 60% of inundated soils (Figure 19). It is important to note that the wet site at just above 20% inundated is almost dry or intermediate between wet and dry. I only present results for

2007, because I captured the species in only 1 site in 2008. The activity of PEMA was not correlated with any of the vegetative variables ($P > 0.05$, Table F-3).

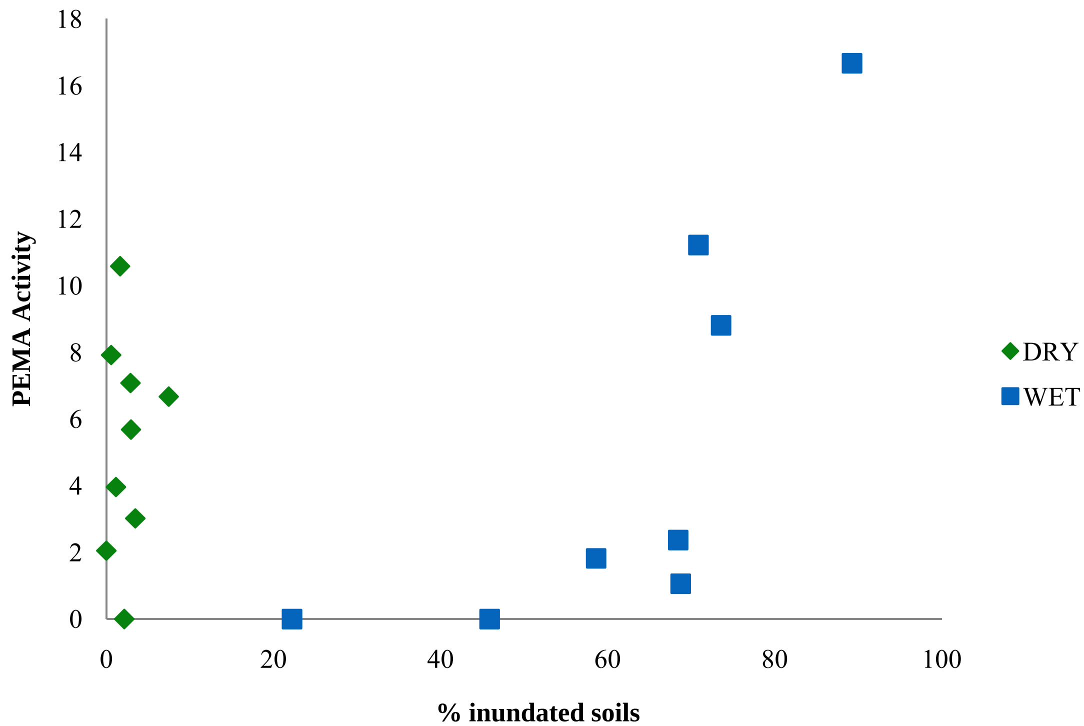

Figure 19. Relation between index of activity of PEMA and percentage of inundated soils in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

SPBE.— The activity of SPBE was not correlated with any of the hydrological variables. However, when looking at the scatter plot between SPBE activity and percentage of inundated soils, the activity of SPBE decreases as the proportion of wet areas increases, and the relationship seems to follow a negative exponential curve, with higher activity below 10% of inundated soils, and null activity above this percentage

(Figure 20). I only present results for 2007, because I captured the species in only 1 site in 2008. Results from Spearman correlations showed SPBE activity was positively correlated with percentage of other shrub cover (P = 0.028, r_s = 0.533) in 2007 only, although the scatter plot does not seem to show a strong relationship (Figure 21). Although the relationship between SPBE activity was not correlated with percentage of alder cover (P > 0.05, Table F-4), the scatter plot shows activity of SPBE in areas with no alder cover, and null activity in areas with alder cover, following an exponential curve (Figure 22).

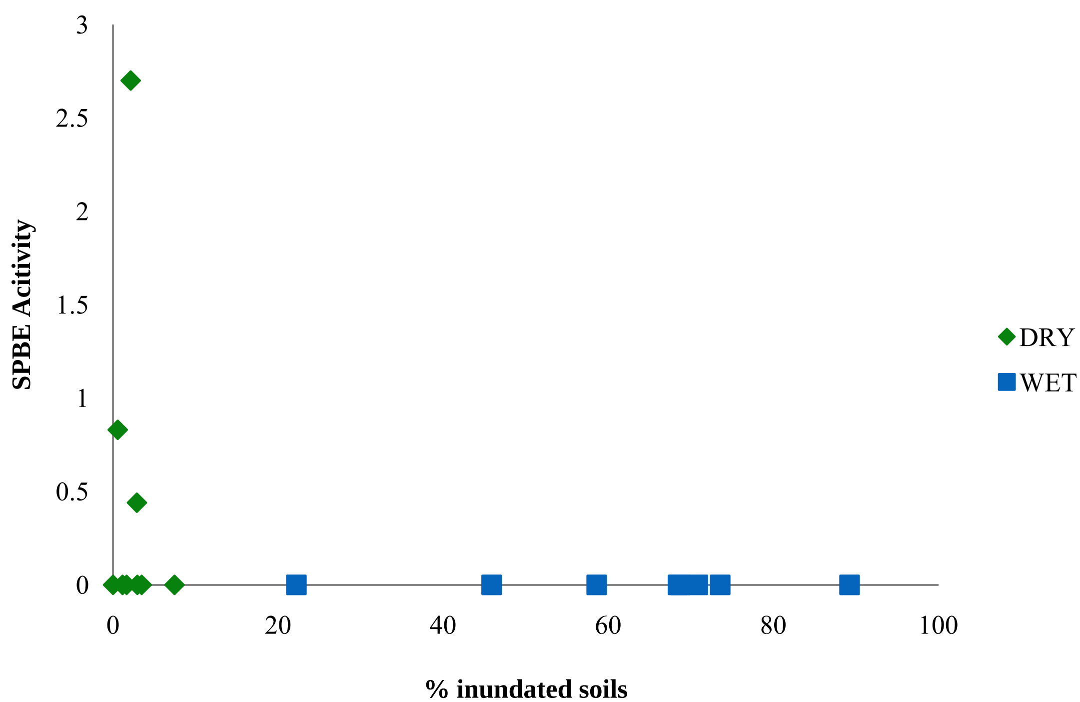

Figure 20. Relation between index of activity of SPBE and percentage of inundated soils in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

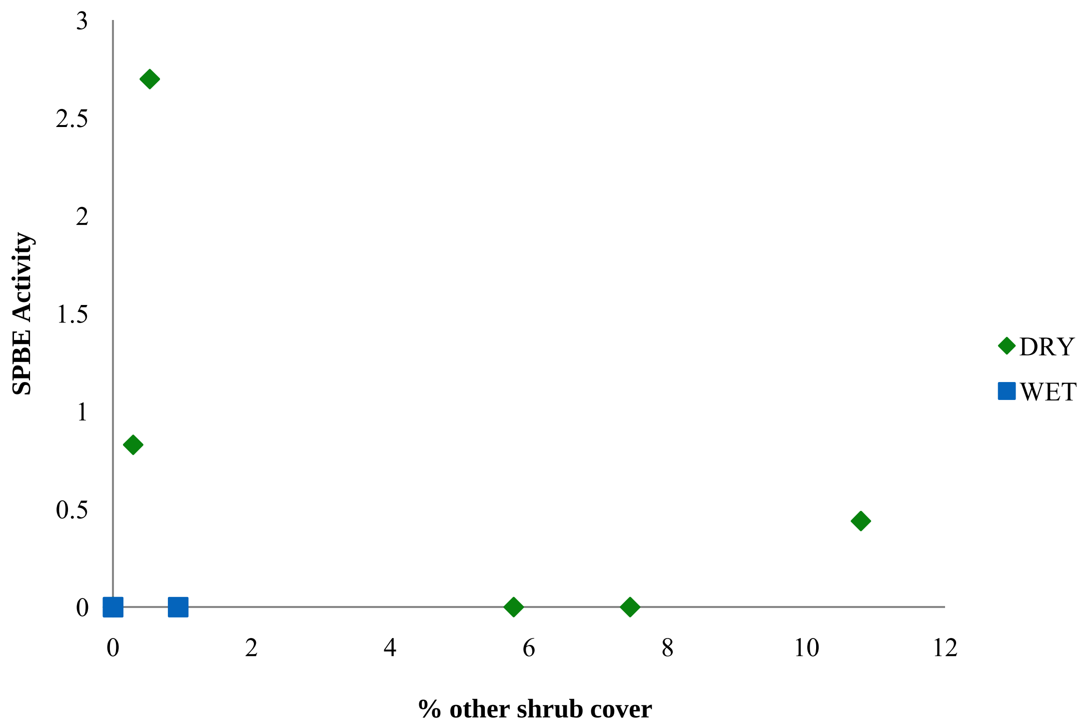

Figure 21. Relation between index of activity of SPBE and percentage of other shrub cover in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

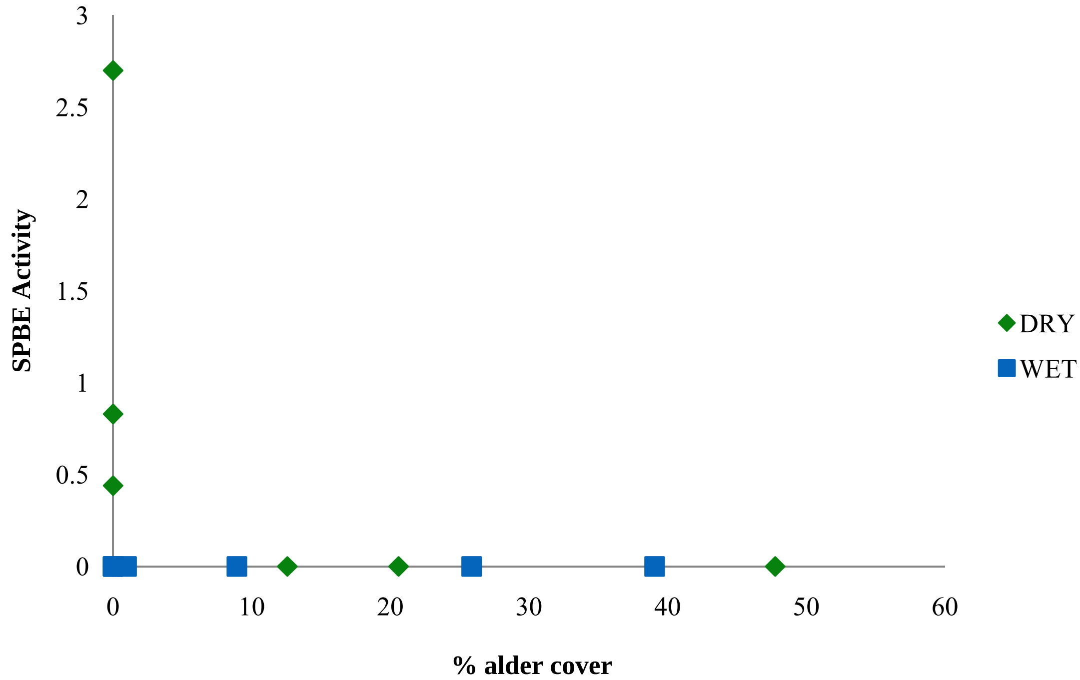

Figure 22. Relation between index of activity of SPBE and percentage of alder cover in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

SOREX.— Spearman correlation results showed a positive relation between activity of SOREX and percentage of inundated soils for both years ($P = 0.022$, $r_s = 0.549$, in 2007; and $P = 0.042$, $r_s = 0.550$, in 2008). The relationship in 2007 seems to follow a quadratic function, with the highest level of activity towards the middle wetness conditions of inundated soils (~40% inundated) (Figure 23). In 2008, the same pattern is observed, althouhg the highest level of activity occurred above 70% of inundated soils (Figure 24). The activity of SOREX was not correlated with any of the vegetative variables ($P > 0.05$, Table F-5).

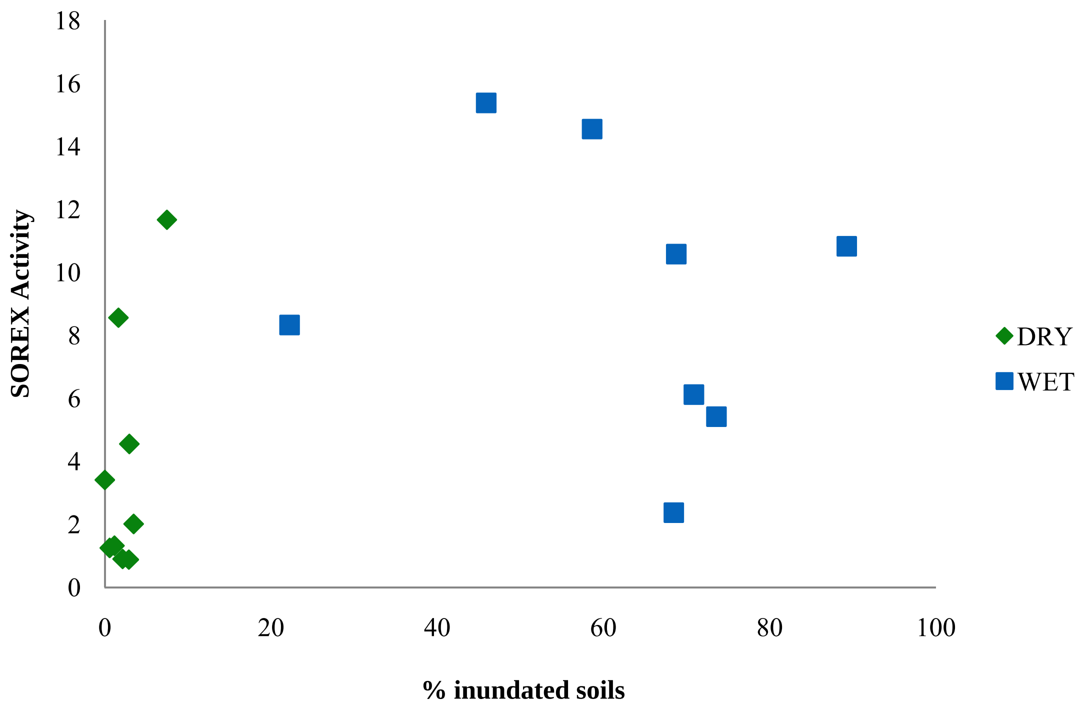

Figure 23. Relation between index of activity of SOREX and percentage of inundated soils in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

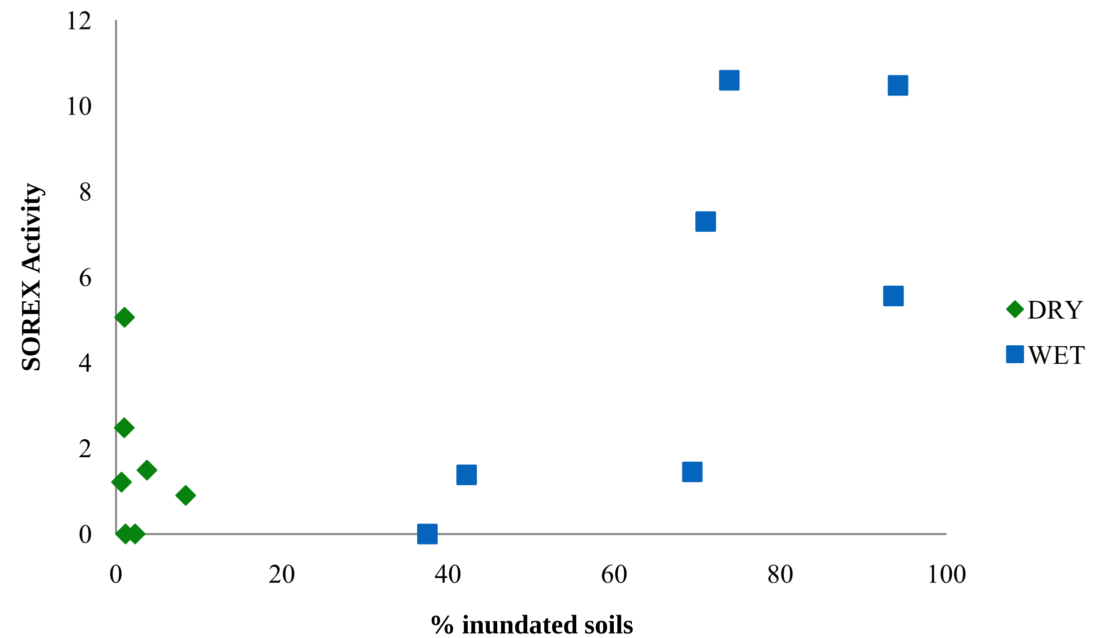

Figure 24. Relation between index of activity of SOREX and percentage of inundated soils in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

TAAM.— The Spearman correlation showed a negative relationship between TAAM activity and percentage of inundated soils for both years (P = 0.002, r_s = -0.687 in 2007 and P = 0.006, r_s = -0.692 in 2008). The relationship is not linear, but it seems to follow a negative exponential function, with most of the activity of TAAM concentrated in dry areas, and when wetness increases (above 5-10% inundated) activity of TAAM is null or low (only 2 captures in wet areas out of ~180 captures total in 2 years) (Figures 25 and 26). The activity of TAAM was negatively correlated with percentage of alder cover (P = 0.009, r_s = -0.611) in 2007. The activity of TAAM plotted against percentage of alder cover in 2007 shows an exponential relationship, with activity of TAAM concentrated in areas without alder cover (Figure 27). Although the relationship between TAAM activity and percentage of alder cover in 2008 was not significant ($P > 0.05$, Table F-6), the scatter plot shows the same pattern as in 2007, with an exponential relationship with activity of TAAM concentrated in areas with no alder cover (Figure 28). The activity of TAAM was positively correlated with other shrub cover ($P = 0.017$, $r_s = 0.624$) in 2008. However, the scatterplot does not seem to show a very strong relationship (Figure 29).

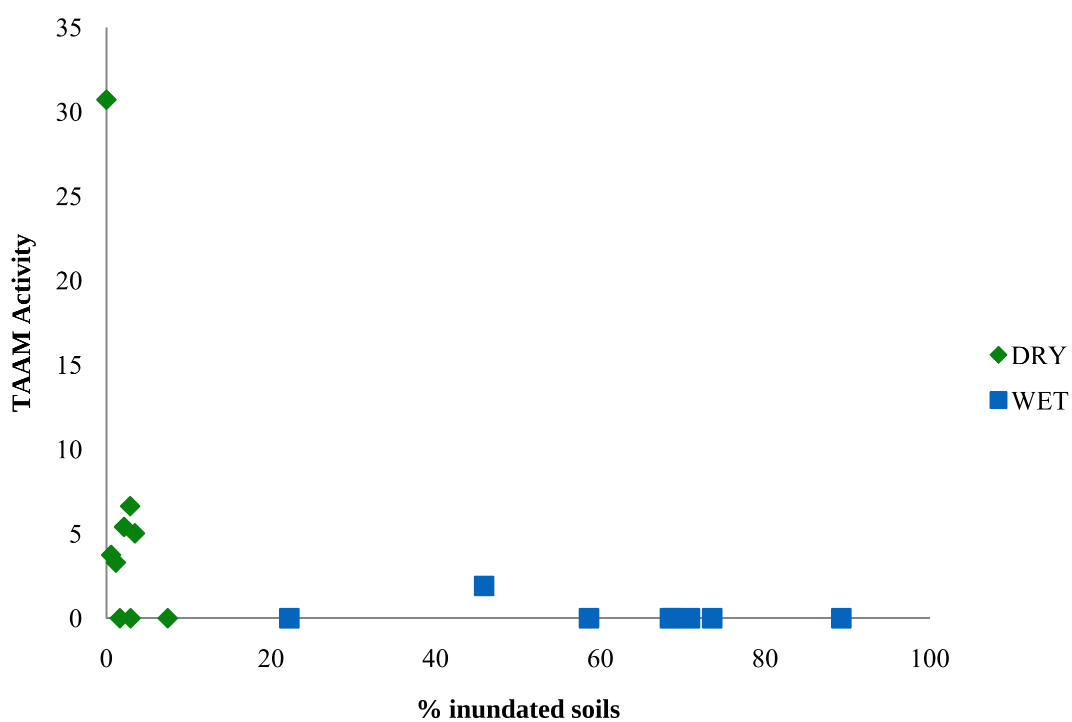

Figure 25. Relation between index of activity of TAAM and percentage of inundated soils in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

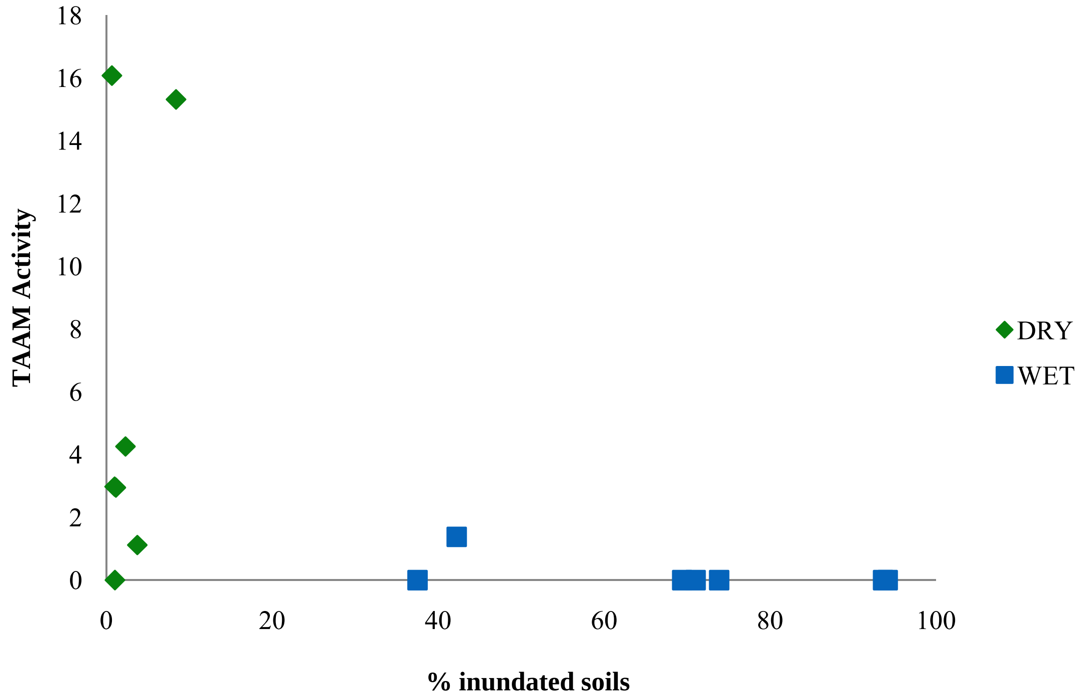

Figure 26. Relation between index of activity of TAAM and percentage of inundated soils in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

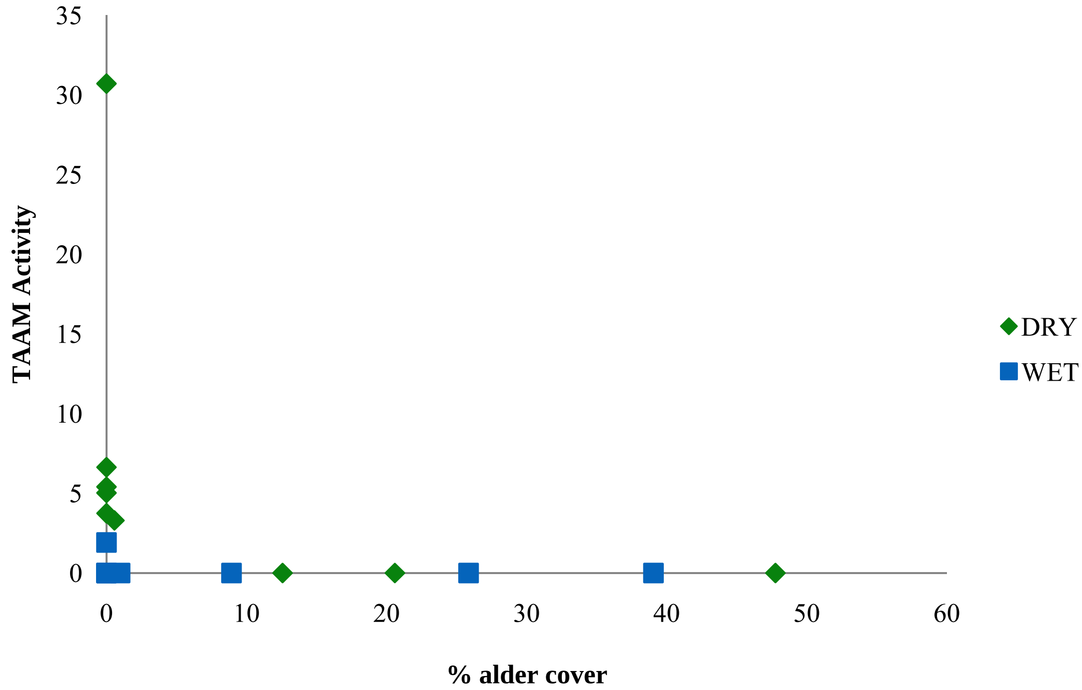

Figure 27. Relation between index of activity of TAAM and percentage of alder cover in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

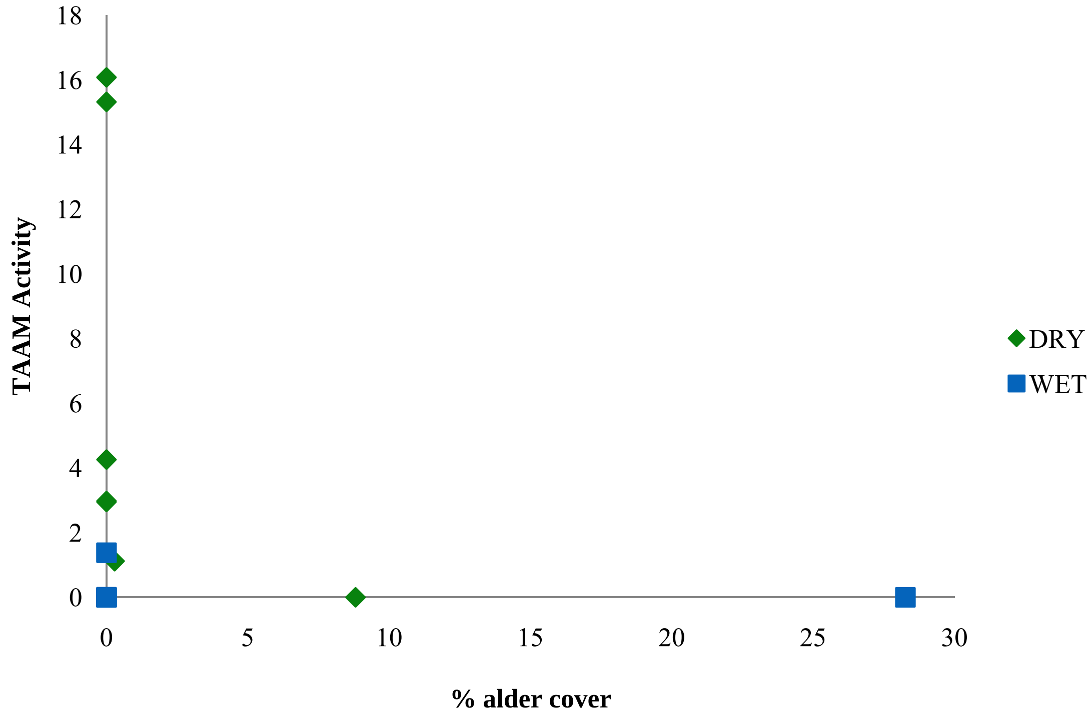

Figure 28. Relation between index of activity of TAAM and percentage of alder cover in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

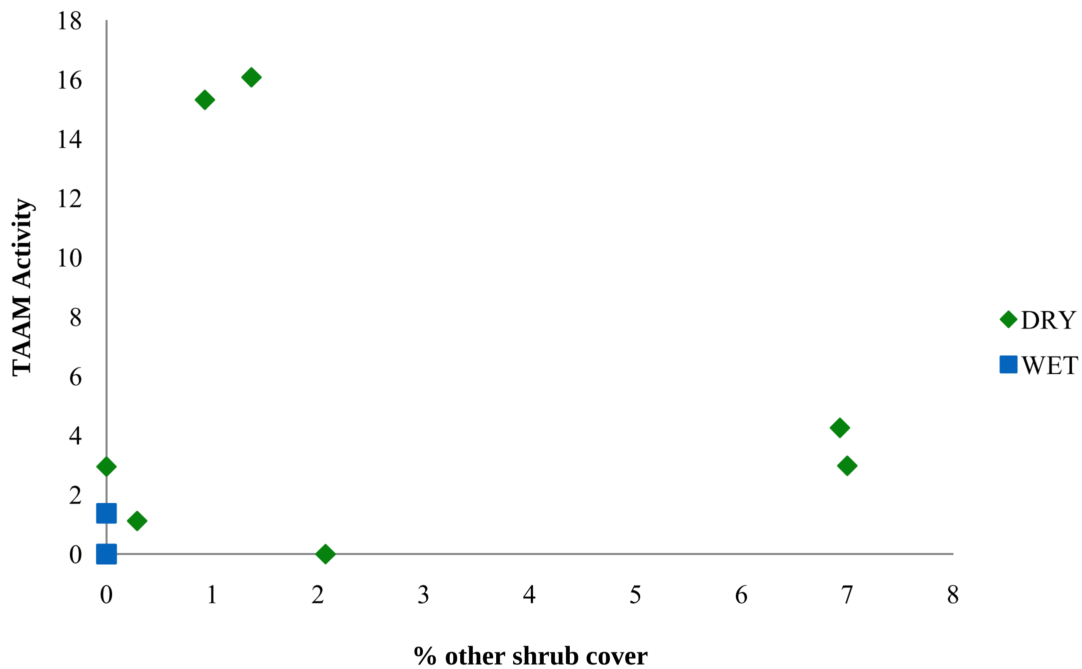

Figure 29. Relation between index of activity of TAAM and percentage of other shrub cover in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

ZAPR.— The activity of ZAPR was not correlated with any of the hydrological variables (*P* > 0.05, Table F-7). Although the scatter plot of ZAPR and percentage of inundated soils seems to follow an inverse quadratic relationship in 2007, with high activity in dry areas (below 10% inundated), null activity between 20-60% inundated, and then activity increases again above 60% inundated (Figure 30). However, there is one record of null activity at 90% inudated. In 2008, the relation is not very clear, as ZAPR was active along the range of inundated soils conditions (Figure 31). The activity of ZAPR was not correlated with any of the vegetative variables (*P* > 0.05, Table F-7), either year. However, the scatter plots show a negative exponential relation between

ZAPR activity and percentage of alder cover in both years, with activity of ZAPR concentrated in sites with no alder cover (and below 10% alder cover in 2007) (Figures 32 and 33).

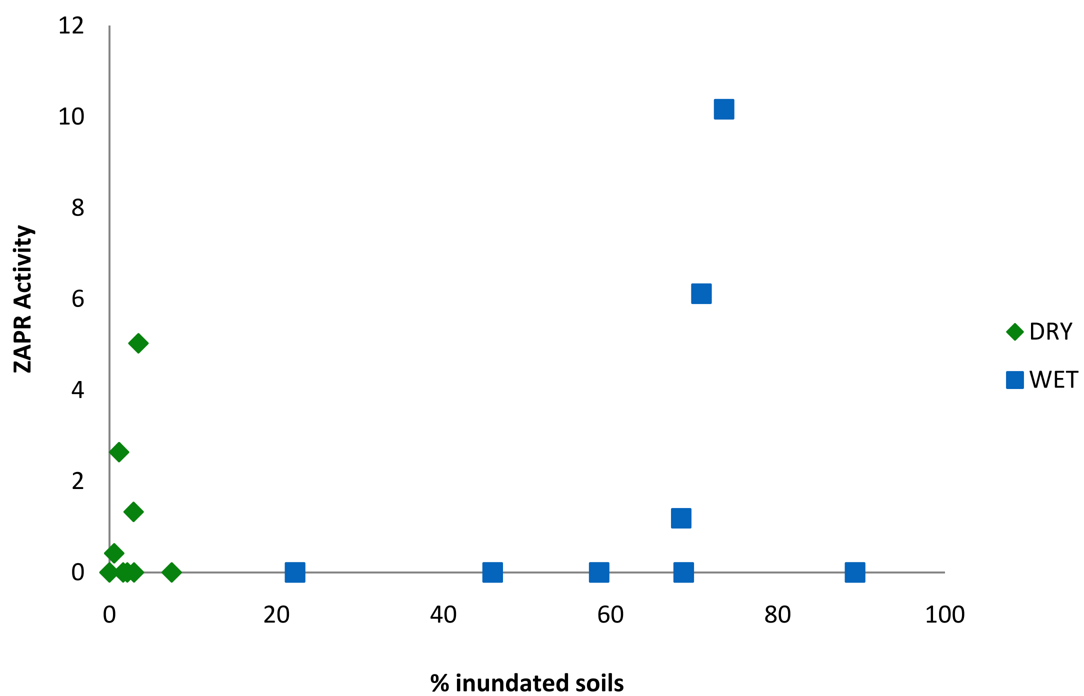

Figure 30. Relation between index of activity of ZAPR and percentage of inundated soil in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

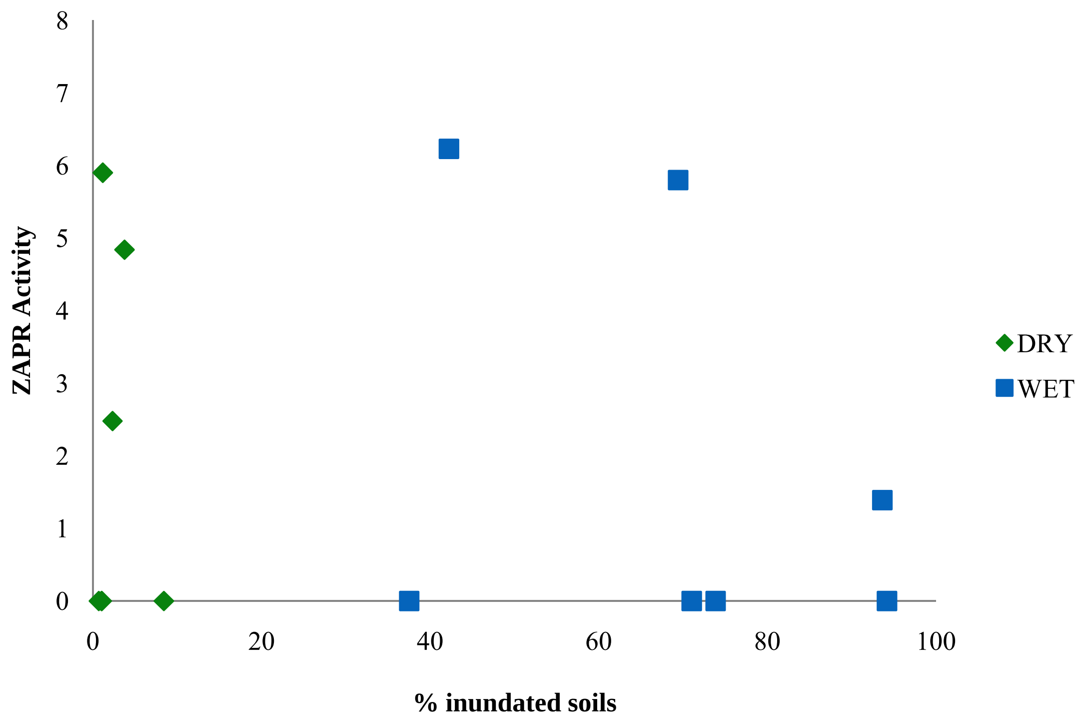

Figure 31. Relation between index of activity of ZAPR and percentage of inundated soil in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

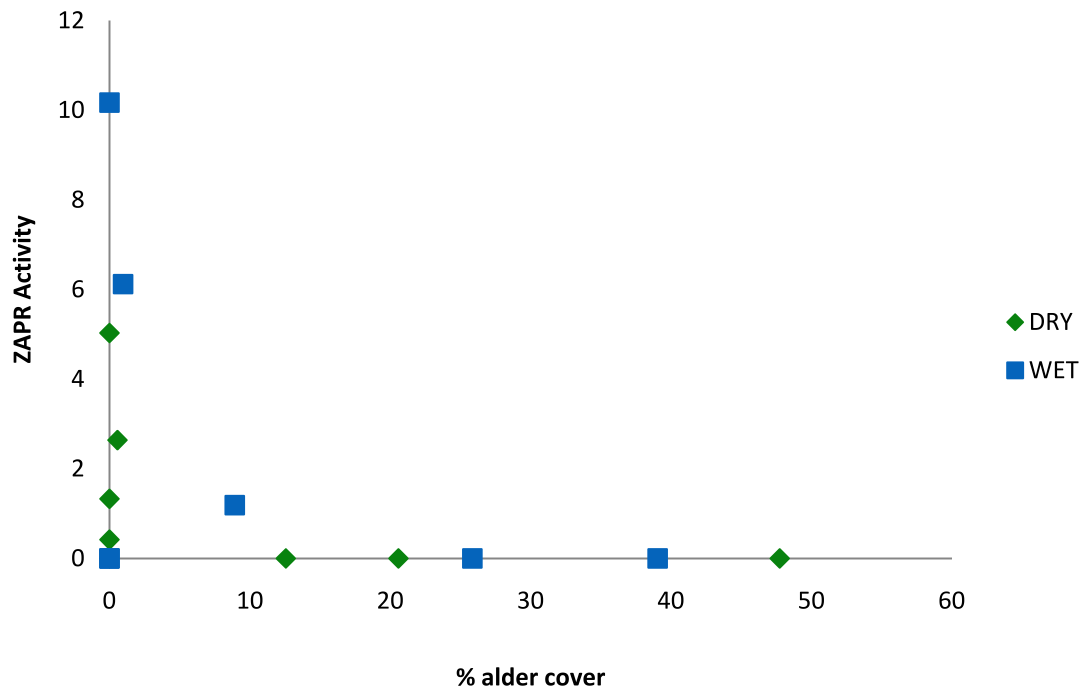

Figure 32. Relation between index of activity of ZAPR and percentage of alder cover in wet and dry areas in 2007. Index of activity is number of captures per 100 trap-nights.

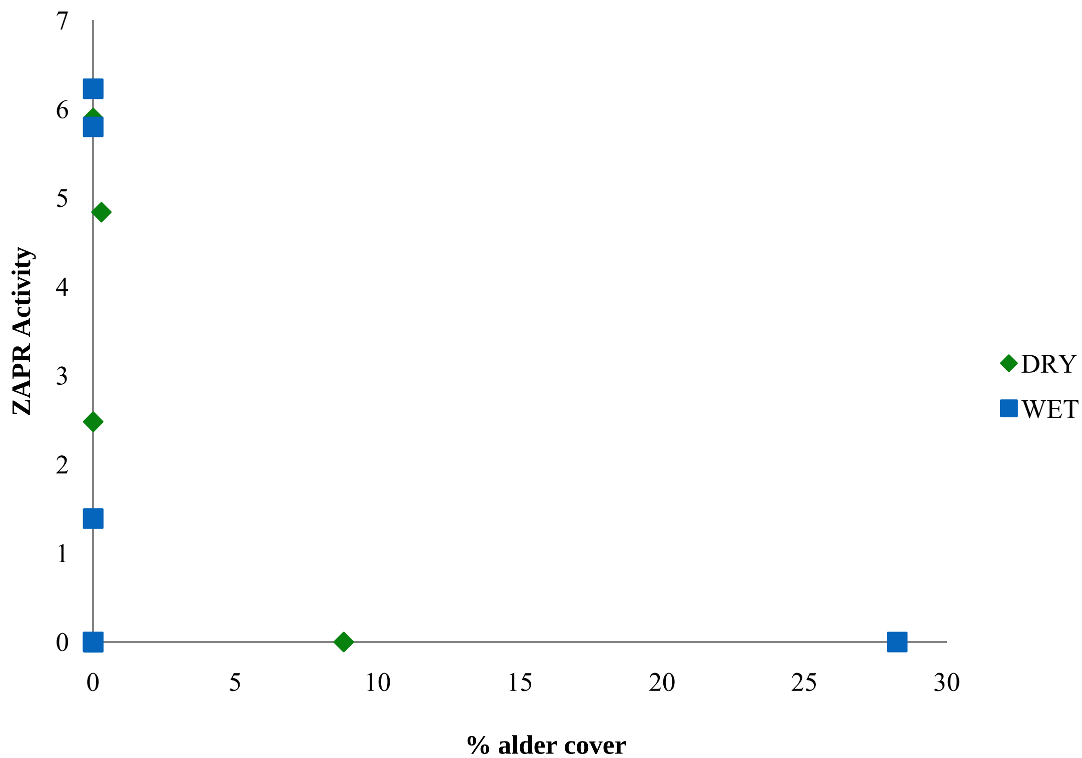

Figure 33. Relation between index of activity of ZAPR and percentage of alder cover in wet and dry areas in 2008. Index of activity is number of captures per 100 trap-nights.

After comparing the overall IA for wet and dry areas in 2007 and 2008, the results of Spearman correlation showed a significant correlation between the overall index of activity of small mammals with only the percentage of willow cover in 2008 ($P = 0.037$, $r_s = 0.560$).

Movement Patterns of Small Mammals

I attached transmitters to 2 PEMA and 7 TAAM. I obtained 66 relocations for PEMA and 195 relocations for TAAM. Fifty eight percent ($n = 38$) of the relocations I obtained for PEMA were in the meadow and 42% ($n = 28$) were in the forest areas

(Figure 34). I did not find a significant difference in proportion of relocations between the 2 habitat types (χ^2 = 1.515, df = 1, P = 0.218). Of the 38 relocations in the meadow, 87% (n = 33) were in dry areas and 13% (n = 5) were in wet areas. The difference in proportion of relocations between wet and dry areas was statistically significant (χ^2 = 47.515, df = 1, $P \leq 0.001$). All the relocations in forest occurred in dry areas.

The proportion of relocations for TAAM differed between habitat types (χ^2 = 75.082, df = 1, $P \leq 0.001$). Nineteen percent (n = 37) of the relocations were in the meadow and 81% (n = 158) were in the forest. All of the relocations for TAAM occurred in dry areas (Figure 35).

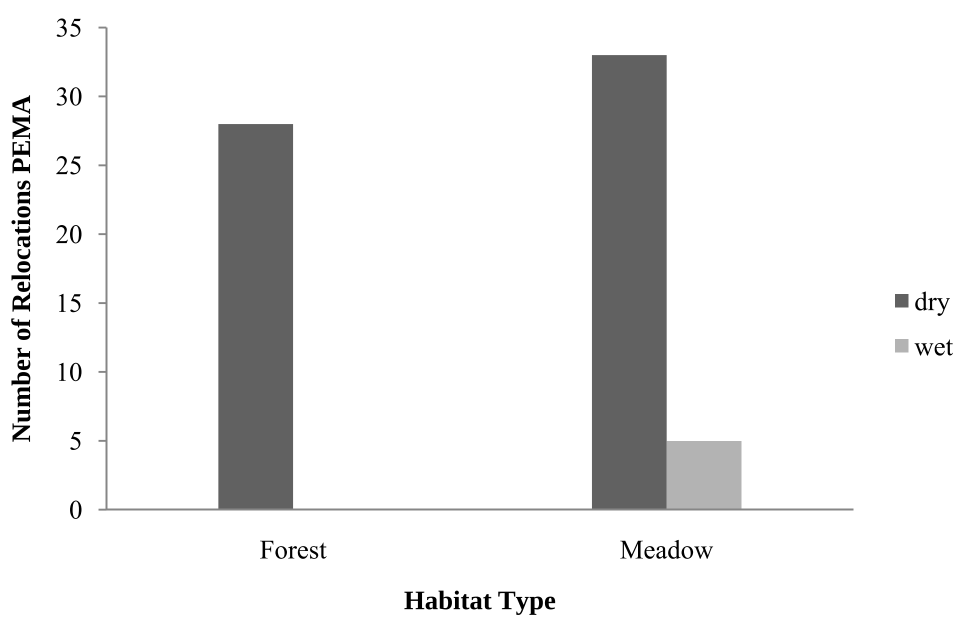

Figure 34. Comparison of the number of relocations at each habitat type for PEMA.

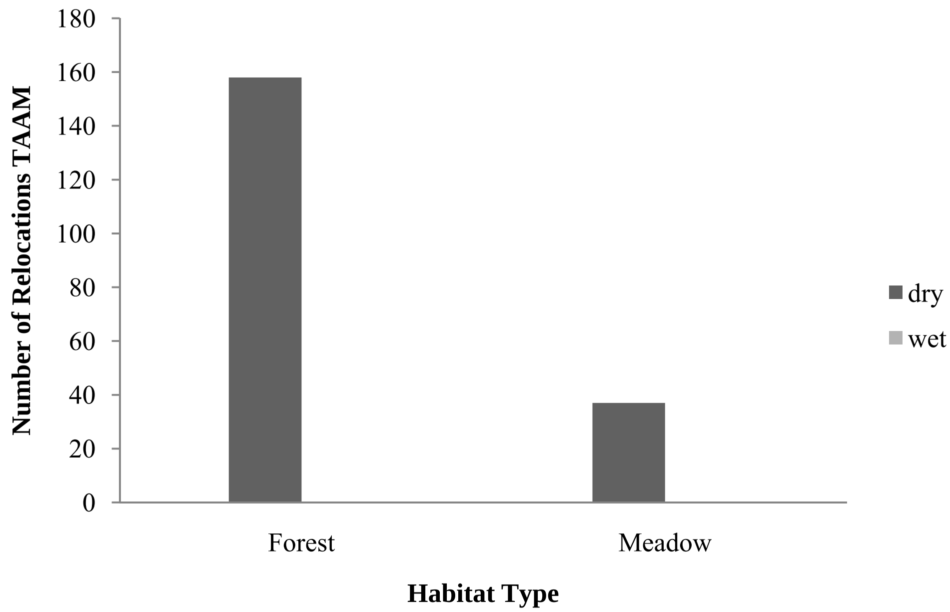

Figure 35. Comparison of the number of relocations at each habitat type for TAAM.

DISCUSSION

I predicted that abundance and activity of chipmunks and squirrels would be lower in areas with wetter conditions. Overall, small mammal species were abundant, very active and widely distributed across meadows. When I analyzed each independent species, I found some significant relationships with habitat characteristics, but I did not find differences in their activity between wet and dry areas when I considered the overall assemblage.

Of all the species that were present in both years, chipmunks and squirrels activity was almost restricted to dry areas, with only 2 captures (1 in 2007 and 1 in 2008) of TAAM in wet areas; whereas voles, mice and shrews were active in both site types. My results in conjunction with previous research support the idea that passerines nests located in drier areas of the meadows are more likely to be predated, as they are exposed to a larger assemblage (all of the species present only in dry areas, plus the species that are present in both wet and dry areas) of potential predators.

Of the most active species, TAAM and PEMA are well known predators. Species of chipmunks (*Tamias* spp.) and PEMA have been photographed predating on yellow warbler nests (Cain et al. 2003). Chipmunks were one of the most important predators photographed at yellow warbler nests, and represented 43% (n = 14) of the predation events (Cain et al. 2003). My results showed that TAAM avoided wet areas and was limited mainly to dry areas of the meadows edges, whereas PEMA was widely distributed across the meadows with similar activity indexes in both wet and dry areas, and was present in both meadow edges as well as interiors. Nests located in drier areas could be affected by both TAAM and PEMA, whereas PEMA could be the most important predator in wet areas. However, I only observed fluctuations between years in PEMA populations, but not in TAAM, which was one of the most active species both years of my study.

My results show there was a change in species presence between years among my study sites. One species in particular showed a notable fluctuation between years; PEMA was one of the most widely distributed species in 2007 but I only found 2 individuals in 1 site in 2008. Several studies have discussed the fluctuations of small mammals' populations in relation with changes in cone production in mountains in California (Morrison and Hall 1998, Wilson et al. 2008). Although changes in small mammal abundance and activity between years were beyond the scope of my study, it is important to note that the hydrology in my study areas changes year to year and depends upon precipitation and snow pack at the beginning of the season. The variation of available water during growing season impacts the forest seed production, which in turn influences the small mammals' populations that feed on seeds. The 2 years when I conducted my field work were particularly dry (see below), and the dry conditions I found in 2007 may have affected the seed production for the fall 2007, which caused PEMA to almost disappear from the majority of my study sites in 2008. SOREX, TAAM, and MILO were also widely distributed among and across meadows in 2007, but the first 2 did not experience such a remarkable decrease between years. On the other hand, MILO numbers decreased in 2008 compared to 2007 but only in wet areas. The low activity of PEMA in 2008 caused a change in overall index of activity between years, although there were not differences in activity between wet and dry areas either year.

As mentioned above, wetness conditions in the meadows depend upon snow pack at the beginning of the breeding season. Snow pack values have been declining since 1999, with drought conditions that started in summer 1999 (Mathewson 2009). In 2007 the snow pack was lower than in 2006, producing a dry summer in 2007, which influenced the seed production for the fall that year and caused the decrease in activity of small mammals overall, and specially PEMA. The drought conditions continued into 2008, although the snow pack at the beginning of 2008 was higher than in 2007 (California Data Exchange Service 2009) which produced slightly wetter conditions in the summer of 2008. However, the wetter conditions in 2008 may not have been sufficient to influence higher seed production during the fall of 2008, and from the dry conditions observed during 2007 and 2008 it is probable to expect a similar activity of small mammals in 2009 to that observed in 2008.

I found the activity of chipmunks and squirrels was negatively influenced by the presence of water. These 2 species were active only in dry areas with less than 10% of inundated soils, which shows that these 2 species avoid areas with inundated soils, with a clear shift in activity (from high to null or almost null activity) when there is a change in wetness conditions (from dry to wet). This result suggests that TAAM and SPBE are not likely to be potential predators in wet areas of the meadows, but in dry areas. And between TAAM and SPBE, TAAM is likely the most important predator in dry areas, as this species ventures further into the meadows compared with SPBE, which usually stays at the forest edge.

On the other hand, I observed an inverse quadratic relationship between the activity of MILO, PEMA , SOREX and ZAPR with percentage of inundated soils, with high activity of these species in the extreme of wetness conditions (too wet or too dry), and null or low activity in intermediate conditions. This can be explained by probably differences in types of food and food availability; with higher arthropod density in the inundated areas (Erman 1984) and higher seed availability in drier areas of the meadows.

TAAM, SPBE and ZAPR were negatively influenced by alder cover, with low or no activity in sites that presented alder cover. Two species (TAAM and SPBE) were positively influenced by the percentage of other shrub cover (e.g., sagebrush, gooseberries, and currant), which in turn were associated with drier areas of the meadows. Willow cover was higher in wet areas, whereas coniferous cover was higher in dry areas. These results reinforce the idea that wetter areas would favor willow flycatcher nesting success, as wetter areas will have more willow used for nesting.

Most of the relocations for PEMA and TAAM occurred in the forest and in dry areas. My results from trapping coincide partially with the telemetry results, and even when I relocated both species in the meadow, TAAM was limited to dry locations at the meadow/forest edge, whereas I relocated PEMA in the meadow interior, 300 m from the forest edge. The telemetry results should be looked with caution due to small sample size, especially with PEMA. It is important to note that although my sample size of radio-collared individuals was small my results from radio-telemetry and trapping showed that TAAM was more active in dry areas, closer to the forest edge. More radio-tagged individuals of PEMA would be necessary to be able to compare the results from radio-telemetry with those of trapping for this species. Studies have found that those species of passerines nesting closer to the forest edge are exposed to higher predation rates (Cain et al. 2003). Thus, TAAM is likely the most important predator of willow flycatcher nests located in areas closer to the forest edge.

SUMMARY OF MANAGEMENT IMPLICATIONS

Willow flycatcher populations have been declining and the rate of annual population change is determined by adult survival, recruitment, and fecundity (Green et al. 2003). Robinson et al. (1993) proposed that 2.0 – 2.5 young/female/season is the minimum fecundity for small passerines to maintain stable populations. However, willow flycatchers in central Sierra Nevada showed values from 0.86 to 2.1 (annual mean 1.5) (Mathewson et al. 2006). We could indirectly increase recruitment by increasing nesting success. Thus, reducing nest predation will help increase the number of juveniles that can be recruited for next breeding seasons and will help increase the abundance of willow flycatchers.

My results coincide with previous research and suggest that keeping meadows wetter would help keep certain predators (e.g., yellow-pine chipmunks and California ground squirrels) that were more active in dry areas from predating on nests. Among chipmunks and squirrels, chipmunks have been photographed predating on nests in the meadows (Cain et al. 2003). In addition, we need to increase wetness in the meadows by ensuring to cover greater areas of continuous standing water. The wet areas I found were patchy, with high proportion of saturated areas. Saturated areas are those close to become dry areas by evaporation, therefore they do not represent a barrier for small mammal movement, and what it is necessary is to increment the proportion of inundated areas in the meadows. The species of small mammals I recorded are generalists and predation on nests could happen incidentally while they are foraging (Vickery et al. 1992), thus making nesting areas less accessible for them will help reduce nest predation. An increment in inundated soils will help prevent squirrels and chipmunks to invade the nesting areas, and an increase in wetness continuity could prevent or reduce mice access to nesting areas.

Restoring the hydrology of the meadows by increasing the areas covered by inundated soils will not only help deter predators such as chipmunks to reach willow flycatcher nesting areas, but will also help inhibit forest encroachment into the meadows. Consequently, reducing the availability of favorable areas for forest associated nest predators (i.e., chipmunks and squirrels). In addition, wetter areas will favor an increment in food availability for flycatchers. Different arthropod species (e.g., wasps, bees, flies, moths) are commonly preyed upon by flycatchers. These arthropod species tend to be abundant in wet environments, as some have an aquatic stage during part of their life cycles, or are dependent upon the riparian vegetation of the meadows (Erman 1984). In addition, higher percentages of inundated soils will also help restore the vegetation of the meadows, by favoring an increase in willow cover. Willow is the substrate used by willow flycatchers for nesting (Green et al. 2003). Bombay et al. (2003) found willow flycatchers select meadows with higher willow cover, and within these meadows they select territories with more willow cover. Furthermore, willow flycatcher nesting success was higher in areas with greater willow cover (Bombay et al. 2003). In turn, greater willow cover provides increased nest concealment, which can help reduce predation by avian predators (e.g., Clark's nutcrackers [*Nucifraga columbiana*], Copper's hawk [*Accipiter cooperii*] and brown-headed cowbird [*Molothrus ater*]; Cain et al. 2003).

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APPENDIX A

Table A-1. Site (meadows) location and ownership.

Site	Location (county)	Ownership
Central Perazzo	Sierra	Tahoe National Forest
East Corral	Plumas	Warner Valley State Wildlife Area
Independence	Nevada	Tahoe National Forest
Little Truckee 1	Sierra	Tahoe National Forest
Little Truckee 2	Sierra	Tahoe National Forest
Little Perazzo	Sierra	Tahoe National Forest
South Bog	Plumas	Warner Valley State Wildlife Area
South Perazzo	Sierra	Tahoe National Forest
Tallac	El Dorado	Lake Tahoe Basin Management Unit
Truckee Marsh	El Dorado	Lake Tahoe Basin Management Unit

Table A-2. Meadow area (ha), area covered by willow in each meadow (ha), number of willow flycatcher territories at each meadow, area trapped at each meadow (ha), and number of traps allocated at each meadow. Values are presented for 2007 for all meadows, except Little Perazzo that was sampled in 2008 only.

Meadow	Meadow Area	Willow Area	# willow flycatcher territories	Area trapped	# traps
Central Perazzo	70.5	7.7	7	1.5	40
East Corral	15.81	3	7	2.3	46
Independence	19.64	5.1	2	2.8	65
Little Perazzo	24.53	4.2	1	3.1	65
Little Truckee 1	39.1	5.7	4	3.5	70
Little Truckee 2	58.7	5.5	5	3.4	64
South Bog	18.39	6.3	7	1.4	29
South Perazzo	34.7	4.3	1	2.8	60
Tallac	36.48	7.5	1	4.9	93
Truckee Marsh	103.85	10	0	3.5	70
Total	421.7	59.3	35	29.2	602

APPENDIX B

Table B-1. Spearman correlations between the small mammal variables: index of activity and relative abundance for wet and dry areas, in each year. Spearman's rho>0.5 shows variables with strong positive correlation.

Year	Site Type	r_s	*P*	*N*
2007	Dry	0.933	0	9
	Wet	0.976	0	8
2008	Dry	0.857	0.014	7
	Wet	0.857	0.014	7

APPENDIX C

Table C-1. P-values from the Mann-Whitney U-test for the comparison of the activity index of each species between wet and dry areas for 2007.

	SPECIES										
	MILO	MIMO	MUER	PEMA	SOREX	SOPA	SPBE	TAAM	TASE	TASP	ZAPR
Mann-Whitney U	26.000	34.000	35.000	31.000	12.000	32.000	24.000	13.500	36.000	31.500	35.500
P	0.333	0.835	0.864	0.630	0.021	0.346	0.083	0.015	1.000	0.289	0.957

Table C-2. P-values from the Mann-Whitney U-test for the comparison of the activity index (IA) of each species between wet and dry areas for 2008.

	SPECIES							
	MILO	MIMO	PEMA	SOREX	SPBE	TAAM	TADO	ZAPR
Mann-Whitney U	22.000	21.000	24.000	12.000	21.000	5.000	21.000	24.000
P	0.733	0.317	0.917	0.109	0.317	0.008	0.317	0.944

Table C-3. Mean Index of Activity and the differences (%) between years for each species in wet and dry areas.

	Wet			Dry		
	2007	2008	difference	2007	2008	difference
MILO	10.30	2.07	79.9	7.91	2.71	65.7
MIMO	3.82	0.30	92.1	1.49	na	100.0
MUER	0.26	na	100.0	0.13	na	100.0
PEMA	5.24	0.54	89.7	5.22	0.04	99.2
SOPA	na	na	na	0.13	na	100.0
SOREX	9.20	5.25	42.9	3.84	1.59	58.6
SPBE	na	na	na	0.44	0.30	31.8
TAAM	0.24	0.20	16.7	6.09	6.10	0.2
TADO	na	na	na	na	0.13	100.0
TASE	0.07	na	100.0	0.11	na	100.0
TASP	0.40	na	100.0	na	na	na
ZAPR	2.18	1.92	11.9	1.00	1.89	47.1

Table C-4. P-values from the Mann-Whitney U-test for the comparison of the activity index (IA) of each species between 2007 and 2008 for wet areas.

	SPECIES					
	MILO	MIMO	PEMA	SOREX	TAAM	ZAPR
Mann-Whitney U	10.000	21.000	11.000	14.000	28.000	27.000
P	0.031	0.299	0.033	0.105	1.000	0.896

Table C-5. P-values from the Mann-Whitney U-test for the comparison of the activity index (IA) of each species between 2007 and 2008 for dry areas.

	SPECIES					
	MILO	PEMA	SOREX	SPBE	TAAM	ZAPR
Mann-Whitney U	21.000	4.000	19.500	26.000	31.500	29.000
P	0.259	0.002	0.203	0.444	1.000	0.771

APPENDIX D

Table D-1. Spearman Correlations among habitat characteristics in 2007-2008.

Year			% inundated soils	% saturated soils	mean water depth	% dry soils	% willow	% other shrub	% grass/forbs	% coniferous	% alder	% aspen
2007	% inundated soils	r_s	1.000	0.526	0.610	-0.936	0.248	-0.161	-0.108	-0.318	0.162	.
		P	.	0.030	0.009	0.000	0.338	0.538	0.681	0.213	0.535	.
		N	17	17	17	17	17	17	17	17	17	17
	% saturated soils	r_s	0.526	1.000	0.434	-0.740	0.263	0.052	-0.044	-0.224	-0.062	.
		P	0.030	.	0.082	0.001	0.308	0.842	0.866	0.386	0.814	.
		N	17	17	17	17	17	17	17	17	17	17
	mean water depth	r_s	0.610	0.434	1.000	-0.672	0.250	-0.488	-0.093	-0.227	0.127	.
		P	0.009	0.082	.	0.003	0.333	0.047	0.723	0.382	0.626	.
		N	17	17	17	17	17	17	17	17	17	17
	% dry soils	r_s	-0.936	-0.740	-0.672	1.000	-0.377	0.149	0.205	0.413	0.005	.
		P	0.000	0.001	0.003	.	0.135	0.568	0.429	0.099	0.984	.
		N	17	17	17	17	17	17	17	17	17	17
	% willow	r_s	0.248	0.263	0.250	-0.377	1.000	0.115	-0.476	-0.490	-0.719	.
		P	0.338	0.308	0.333	0.135	.	0.661	0.053	0.046	0.001	.
		N	17	17	17	17	17	17	17	17	17	17
	% other shrub	r_s	-0.161	0.052	-0.488	0.149	0.115	1.000	-0.021	0.242	-0.261	.
		P	0.538	0.842	0.047	0.568	0.661	.	0.938	0.350	0.312	.
		N	17	17	17	17	17	17	17	17	17	17
	% grass/forbs	r_s	-.108	-0.044	-0.093	0.205	-0.476	-0.021	1.000	0.600	0.556	.
		P	0.681	0.866	0.723	0.429	0.053	0.938	.	0.011	0.020	.
		N	17	17	17	17	17	17	17	17	17	17

Table D-1. Continued.

Year			% inundated soils	% saturated soils	mean water depth	% dry soils	% willow	% other shrub	% grass/forbs	% coniferous	% alder	% aspen
	% coniferous	r_s	-0.318	-0.224	-0.227	0.413	-0.490	0.242	0.600	1.000	0.515	.
		P	0.213	0.386	0.382	0.099	0.046	0.350	0.011	.	0.034	.
		N	17	17	17	17	17	17	17	17	17	17
	% alder	r_s	0.162	-0.062	0.127	0.005	-0.719	-0.261	0.556	0.515	1.000	.
		P	0.535	0.814	0.626	0.984	0.001	0.312	0.020	0.034	.	.
		N	17	17	17	17	17	17	17	17	17	17
	% aspen	r_s	.	.	.	.	.	.	.	.	.	.
		P	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17
2008	% inundated soils	r_s	1.000	0.516	0.134	-0.947	0.640	-0.774	-0.024	-0.638	-0.076	-0.310
		P	.	0.059	0.648	0.000	.014	0.001	0.935	0.014	0.795	0.281
		N	14	14	14	14	14	14	14	14	14	14
	% saturated soils	r_s	0.516	1.000	0.112	-0.653	0.473	-0.681	-0.405	-0.773	-0.187	-0.447
		P	0.059	.	0.703	0.011	0.088	0.007	0.151	0.001	0.523	0.109
		N	14	14	14	14	14	14	14	14	14	14
	mean water depth	r_s	0.134	0.112	1.000	-0.226	0.279	-0.214	-0.513	-0.101	0.009	-0.310
		P	0.648	0.703	.	0.436	0.334	0.462	0.061	0.732	0.975	0.281
		N	14	14	14	14	14	14	14	14	14	14
	% dry soils	r_s	-0.947	-0.653	-0.226	1.000	-0.697	0.806	0.163	0.709	0.217	0.378
		P	0.000	0.011	0.436	.	0.006	0.001	0.578	0.005	0.456	0.182
		N	14	14	14	14	14	14	14	14	14	14
	% willow	r_s	0.640	0.473	0.279	-0.697	1.000	-0.404	-0.097	-0.757	-0.443	-0.447
		P	0.014	0.088	0.334	0.006	.	0.152	0.742	0.002	0.112	0.109
		N	14	14	14	14	14	14	14	14	14	14

Table D-1. Continued.

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	% willow	% other shrub	% grass/forbs	% coniferous	% alder	% aspen
% other shrub	r_s	-0.774	-0.681	-0.214	0.806	-0.404	1.000	0.112	0.566	0.112	0.343
	P	0.001	0.007	0.462	0.001	0.152	.	0.703	0.035	0.704	0.230
	N	14	14	14	14	14	14	14	14	14	14
% grass/forbs	r_s	-0.024	-0.405	-0.513	0.163	-0.097	0.112	1.000	0.109	0.061	0.344
	P	0.935	0.151	0.061	0.578	0.742	0.703	.	0.711	0.835	0.228
	N	14	14	14	14	14	14	14	14	14	14
% coniferous	r_s	-0.638	-0.773	-0.101	0.709	-0.757	0.566	0.109	1.000	0.500	0.465
	P	0.014	0.001	0.732	0.005	0.002	0.035	0.711	.	0.069	0.093
	N	14	14	14	14	14	14	14	14	14	14
% alder	r_s	-0.076	-0.187	0.009	0.217	-0.443	0.112	0.061	0.500	1.000	0.527
	P	0.795	0.523	0.975	0.456	0.112	0.704	0.835	0.069	.	0.053
	N	14	14	14	14	14	14	14	14	14	14
% aspen	r_s	-0.310	-0.447	-0.310	0.378	-0.447	0.343	0.344	0.465	0.527	1.000
	P	0.281	0.109	0.281	0.182	0.109	0.230	0.228	0.093	0.053	.
	N	14	14	14	14	14	14	14	14	14	14

APPENDIX E

Table E-1. P-values from the Mann-Whitney U-test for the comparison of the hydrology characteristics in wet and dry areas between years (2007-2008).

Site Type		% inundated soils	% saturated soils	mean water depth
Dry	Mann-Whitney U	31.000	29.000	22.000
	P	0.958	0.788	0.315
Wet	Mann-Whitney U	20.000	26.000	20.000
	P	0.355	0.817	0.355

Table E-2. P-values from the Mann-Whitney U-test for the comparison of the hydrology characteristics between wet and dry areas each year (2007-2008).

year		% inundated soils	% saturated soils	mean water depth
2007	Mann-Whitney U	0.000	13.000	6.000
	P	0.001	0.025	0.004
2008	Mann-Whitney U	0.000	7.000	20.000
	P	0.002	0.025	0.565

Table E-3. P-values from the Mann-Whitney U-test for the comparison of the vegetation variables between years for wet and dry areas.

		% Cover of each Vegetation Type					
Site Type		willow	other shrub	grass/forbs	coniferous	alder	aspen
Dry	Mann-Whitney U	25.000	24.000	29.000	22.000	23.500	27.000
	P	0.491	0.420	0.788	0.313	0.331	0.257
Wet	Mann-Whitney U	26.000	24.500	21.000	23.000	19.000	28.000
	P	0.817	0.350	0.416	0.514	0.215	1.000

Table E-4. P-values from the Mann-Whitney U-test for the comparison of the vegetation characteristics between wet and dry areas each year (2007-2008).

		% Cover of each Vegetation Type					
Year		willow	other shrub	grass/forbs	coniferous	alder	aspen
2007	Mann-Whitney U	24.000	20.000	30.500	18.000	34.000	36.000
	P	0.248	0.072	0.589	0.077	0.835	1.000
2008	Mann-Whitney U	8.000	3.500	18.000	6.500	22.000	21.000
	P	0.035	0.003	0.406	0.017	0.657	0.317

APPENDIX F

Table F-1. Spearman correlations between index of activity of MILO and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	0.100	-0.041	0.330	-0.064	-0.232	-0.418	-0.364	-0.338	0.203	na
	P	0.703	0.875	0.195	0.807	0.371	0.095	0.151	0.184	0.435	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	-0.270	-0.378	0.345	0.340	-0.021	0.164	0.080	0.269	0.219	0.110
	P	0.351	0.183	0.227	0.234	0.943	0.576	0.786	0.353	0.452	0.708
	N	14	14	14	14	14	14	14	14	14	14

Table F-2. Spearman correlations between index of activity of MIMO and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	-0.122	0.148	-0.265	0.090	-0.048	0.351	-0.235	-0.033	-0.253	na
	P	0.641	0.571	0.303	0.731	0.856	0.167	0.365	0.901	0.327	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	0.103	0.447	-0.378	-0.172	0.241	-0.229	0.103	-0.286	-0.144	-0.077
	P	0.726	0.109	0.182	0.557	0.407	0.432	0.725	0.321	0.624	0.794
	N	14	14	14	14	14	14	14	14	14	14

Table F-3. Spearman correlations between index of activity of PEMA and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	0.145	-0.234	-0.066	-0.052	0.297	0.170	-0.348	0.014	0.037	na
	P	0.579	0.366	0.800	0.844	0.247	0.515	0.171	0.958	0.887	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	0.047	-0.393	0.004	0.115	0.274	0.002	0.282	0.043	-0.211	-0.113
	P	0.874	0.164	0.990	0.694	0.343	0.995	0.329	0.884	0.470	0.701
	N	14	14	14	14	14	14	14	14	14	14

Table F-4. Spearman correlations between index of activity of SPBE and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	-0.442	-0.183	-0.052	0.337	0.205	0.533	-0.102	0.073	-0.407	na
	P	0.076	0.482	0.844	0.186	0.431	0.028	0.698	0.782	0.105	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	-0.447	-0.378	-0.034	0.447	-0.034	0.267	-0.103	0.394	-0.144	-0.077
	P	0.109	0.182	0.907	0.109	0.907	0.357	0.725	0.163	0.624	0.794
	N	14	14	14	14	14	14	14	14	14	14

Table F-5. Spearman correlations between index of activity of SOREX and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	0.549	0.392	0.402	-0.498	-0.199	-0.427	0.297	-0.053	0.427	na
	P	0.022	0.120	0.110	0.042	0.445	0.087	0.247	0.841	0.087	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	0.550	-0.068	0.408	-0.466	0.501	-0.230	0.108	-0.140	0.347	0.173
	P	0.042	0.816	0.147	0.093	0.068	0.429	0.713	0.633	0.224	0.555
	N	14	14	14	14	14	14	14	14	14	14

Table F-6. Spearman correlations between index of activity of TAAM and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	-0.687	-0.314	-0.442	0.569	0.132	0.401	-0.380	-0.085	-0.611	na
	P	0.002	0.220	0.076	0.017	0.614	0.110	0.132	0.746	0.009	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	-.692	-0.289	-0.275	0.645	-0.190	0.624	0.132	0.296	-0.323	-0.257
	P	0.006	0.317	0.342	0.013	0.515	0.017	0.654	0.305	0.260	0.375
	N	14	14	14	14	14	14	14	14	14	14

Table F-7. Spearman correlations between index of activity of ZAPR and hydrological characteristics and vegetative characteristics (% cover), in both years (2007-2008).

Year		% inundated soils	% saturated soils	mean water depth	% dry soils	willow	other shrubs	grass/forbs	coniferous	alder	aspen
2007	r_s	0.132	0.046	-0.161	-0.155	0.445	0.368	-0.470	-0.024	-0.258	na
	P	0.614	0.861	0.538	0.552	0.074	0.147	0.057	0.928	0.316	na
	N	17	17	17	17	17	17	17	17	17	17
2008	r_s	0.022	0.343	0.034	-0.178	-0.068	-0.270	-0.146	0.015	-0.163	-0.229
	P	0.941	0.230	0.908	0.543	0.817	0.351	0.618	0.959	0.579	0.432
	N	14	14	14	14	14	14	14	14	14	14

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