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THE DOGMA OF THE 30 METER RIPARIAN BUFFER:
THE CASE OF THE BOREAL TOAD (*BUFO BOREAS BOREAS*)

by

Michael C. Goates

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Integrative Biology

Brigham Young University

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BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Michael C. Goates in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

THE DOGMA OF THE 30 METER RIPARIAN BUFFER: THE CASE OF THE BOREAL TOAD (*BUFO BOREAS BOREAS*)

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Master of Science

We tested the adequacy of standard 30 m riparian buffers for semi-aquatic vertebrate species, using the boreal toad (*Bufo boreas boreas*) as an example. We monitored toad populations in south-central Utah using radio telemetry during the summers of 2003 and 2004. We found 30 m buffers inadequate for protecting boreal toads and suggest this is likely true for other species as well. Managers must consider several factors when constructing buffers: (1) Buffer requirements may vary by time of year. While we located toads most often in wet habitats, toads commonly utilized upland habitats in late summer, occasionally at distances greater than 100 m from water. (2) A single year's observation may not be sufficient to establish adequate buffers. Toads moved into upland habitats more often and at greater distances from water (≥ 30 m) during the wetter, cooler weather conditions of 2004 than in 2003. (3) Buffer requirements may differ by sex. Male toads appeared to have stronger selection for

wetland habitats than females. Females moved greater distances from water than males, often outside of buffer areas. (4) Buffer requirements may differ by location. 30 m buffers contained 82.4% of all observations, though results varied between 50.0 and 97.2%, depending on breeding location. Finally (5) All habitat requirements should be considered when establishing buffers. Many small, unmapped streams and seeps utilized by toads for hibernation were located outside buffer zones. After ground truthing and extending 30 m buffers around these habitats, the percentage of all observations within 30 m buffers increased to 92.4%. Managers need to be aware of the accuracy of digital and other mapping sources used in creating buffers and to incorporate all critical habitats in conservation buffers. Our boreal toad example suggests that ground truthing may be the most important factor in establishing effective buffer zones.

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INTRODUCTION

Buffers

A standard 30.48 m (100 ft) buffer is commonly utilized by natural resource managers to protect aquatic and riparian resources from various disturbances (Clinnick 1985; Lynch et al. 1985; Phillips 1989; Osborne & Kovacic 1993; Davies & Nelson 1994; Bren 1995; Haberstock et al. 2000; Lee et al. 2004). However, recent research has brought the effectiveness of this standard 30 m buffer into question. For example, site specific characteristics alter a buffer's ability to control nonpoint source pollution, requiring variable buffer widths (Phillips 1989). Additionally, core habitats for semi-aquatic wildlife often extend beyond 30 m from aquatic habitats (Burke & Gibbons 1995; Semlitsch & Bodie 2003). The inadequacies of 30 m buffers for wildlife conservation are largely due to the fact that standard buffers were established for other purposes. Buffer zones are naturally vegetated terrestrial areas that are designed to protect valuable natural habitats, such as streams or wetlands, from neighboring areas where certain forms of human disturbances are allowed (Castelle et al. 1994; Haberstock et al. 2000; Cockle & Richardson 2003; Roth 2005). Riparian buffers were originally developed to protect aquatic resources and water quality (Hagar 1999; Vesely & McComb 2002). Multiple studies have shown that minimum buffer strips of 30 m will protect water resources from human activities such as timber harvests (Castelle et al. 1994; Semlitsch & Bodie 2003; Lee et al. 2004). Buffer widths between 15 to 40 m on typical, moderately well-drained soils protect streams from nonpoint source pollution (Phillips 1989). Buffer of 30.48 m maintain ambient stream temperatures following timber harvests (Lynch & Corbett 1990). Forested buffers of 30 m removed between 97 and 100% of soluble nitrogen from

runoff and subsurface waters prior to reaching streams (Doyle et al. 1975; Pinay & Decamps 1988). Following clearcut timber harvests, streams with 10 to 20 m buffer had no increase in water turbidity from overland water flow (Aubertin & Patric 1974). Buffer widths of 36 m reduce concentrations of nutrients (nitrogen and phosphorous) and microorganisms from feedlot runoff to acceptable levels (Young et al. 1980). Streams with buffers ≥ 30 m do not differ significantly from control streams without logging in their water temperatures, silt load, and algal cover (Davies & Nelson 1994). Thus the standard 30 m buffer was primarily established to protect water quality, not to protect the species in or around these bodies of water.

Currently, many agencies are mandated by law to protect biological components of riparian systems (O’Laughlin & Belt 1995; Bentrup & Kellerman 2004). Many resource management agencies have guidelines for protecting aquatic resources and the organisms associated with those resources (Lee et al. 2004). However, the guidelines for riparian buffer widths are often not based on ecological data for the system in question (Hannon et al. 2002) and managers may be required to use a “best guess” approach when determining riparian buffer zones for biological conservation. Historically, this has resulted in narrow (30 m or less) managed forest riparian buffers to maximize economic value of harvested trees (Bren 1995), though variation exists between agencies on the actual buffer zone width (Young 2000). This 30 m buffer may have little biological relevance in certain systems. Several studies involving vertebrate species (freshwater turtles, salamanders, passerine birds, small mammals, and semi-aquatic snakes) indicated that a 30 m buffer is not large enough to encompass the majority of animal observations, maintain species diversity, and may increase disease occurrence (Burke & Gibbons 1995;

Semlitsch 1998; Hagar 1999; Pearson & Manuwal 2001; Vesely & McComb 2002; Cockle & Richardson 2003; Roth 2005). A 30.5 m buffer zone encompassed only 44% of nests and hibernation burrows of three freshwater turtle species (*Kinosternon subrubrum*, *Pseudemys floridana*, and *Trachemys scripta*) in a wetland in South Carolina (Burke & Gibbons 1995). In this same study, a 73 m buffer was required to protect 90% of hibernation and nesting locations whereas a 275 m buffer was required to protect all upland hibernation and nesting locations. In western Oregon, 40 to 70 m buffers did not support all the species of forest dwelling passerine birds found in unlogged sites, though species composition and relative abundance was positively correlated with buffer width (Hagar 1999). Again in western Oregon, buffer strips of 43 m and 47 m supported total salamander abundance and species richness similar to those of unlogged forests, respectively (Vesely & McComb 2002). In western Washington, 30 m buffers did not maintain all bird species in logged areas, whereas a minimum 45 m buffer was required to maintain bird community (Pearson & Manuwal 2001). In British Columbia, species richness for small mammals did not differ significantly between 30 m buffers and control locations (Cockle & Richardson 2003). However, in this same study there was a significant difference in the percent of deer mice (*Peromyscus maniculatus*) infested with bot flies (*Cuterebra* spp.) between buffered (5%), clearcut (24%), and uncut (0%) areas. In Texas, 82.8% of all radio tracked cottonmouth (*Agkistrodon piscivorus*) observations were within 10 m of a stream (Roth 2005). However, gravid females in this study were often located further from water (up to 94 m) than males or non-gravid females, indicating that habitat important to reproduction would not fall within a 30 m buffer.

Of course, there are also examples of organisms for which a 30 m buffer is adequate. For example, in Washington and British Columbia, Pacific giant salamanders (*Dicamptodon tenebrosus*) in 20-30 m buffer strip areas did not differ significantly from those in uncut areas in their home range sizes, distances moved from stream areas, and time spent in aquatic refuges (Johnston & Frid 2002). The question is how much area needs to be conserved in order to maintain the species or population of interest (Hagar 1999; Pearson & Manuwal 2001).

Many conservation buffers do not encompass all resources necessary to maintain population stability (Dodd & Cade 1998). Areas most readily protected are those where animals congregate, such as breeding locations (Semlitsch 1998). While these habitats clearly are important during certain life history phases, they often do not represent all habitats that the species requires (Bulger et al. 2003; Bartelt et al 2004). Other habitats, particularly those where animals do not congregate, may be of equal importance to species survival, but often go unnoticed (Semlitsch & Bodie 2003). Such habitats may be useful for hibernation, foraging, or predator avoidance. The creation of successful buffers relies heavily on understanding the life history of the species for which the buffer is being created, and incorporating habitats required by all the components of an animal's life history (Richter et al. 2001). Buffers that do not protect all of these habitats are more likely to fail to meet all the desired conservation objectives (Dodd & Cade 1998).

Boreal Toad

Our study of boreal toad populations in Southern Utah offered an ideal opportunity to understand the process of establishing and determining the effectiveness of 30 m buffer zones. In the Dixie National Forest of southern Utah, managers implemented

30.48 m (100 ft.) riparian buffers to protect amphibians and other semi-aquatic species. The size of the buffer zone was based solely on studies concerning water quality (R. Rodriguez, Wildlife Program Manager, Dixie and Fishlake National Forests, pers. comm.). We used radio telemetry to determine how well this buffer zone protected habitat used by boreal toads.

Several aspects of amphibian biology make the creation of riparian buffers particularly difficult. Amphibians are often characterized as habitat specialists, requiring certain habitats to complete important life histories, such as breeding and hibernation (Bosman et al. 1996; Pilliod et al. 2002; Trenham & Shaffer 2005). As these critical habitats are often patchy in nature, amphibians need to move between patches, often at great distances over upland habitats (Pilliod et al. 2002; Bulger et al. 2003). Many amphibians will utilize terrestrial habitats adjacent to wetland areas, often at varying distances (Dodd, & Cade 1998; Semlitsch 1998; Griffin & Case 2001; Richter et al. 2001; Johnston & Frid 2002; Pilliod et al. 2002; Bulger et al. 2003; Muths 2003; Semlitsch & Bodie 2003; Bartelt et al. 2004). During these terrestrial forays, amphibians are often more difficult to locate, making the placement of conservation buffers more complicated. If the amphibians in question move into terrestrial habitats at distances perpendicular to the body of water that are greater than 30 m, the standard riparian buffer utilized by many agencies will not protect the species from human activities, such as timber harvests.

The boreal toad (*Bufo boreas boreas*) is a good example of an amphibian species that requires varied habitats and may regularly move beyond the standard 30 m buffer zone. The boreal toad inhabits high elevation montane and boreal streams and ponds of western North America (Livo & Yeakley 1997; Fridell et al. 2000). Often, toads are

located at varying distances between critical habitats, and frequently move 1 to 5 km between these areas (Muths 2003; Bartelt et al. 2004; Thompson 2004; Adams et al. 2005). Much of the natural history of the boreal toad is unknown, such as habitat requirements and movement patterns (Smits 1984; Muths 2003). Because the boreal toad is naturally found in patchy wetland environments and its critical habitats are not well understood, it is a good study species to address habitat use relative to buffer type and size.

Examining the adequacy of a 30 m buffer for boreal toads takes on added importance because its populations have declined dramatically in recent decades (Robinson et al. 1998; Muths 2003). These declines have been attributed to habitat degradation and fungal pathogens (Robinson et al. 1998; Muths 2003). Areas of greatest decline have occurred among the Southern Rocky Mountain population (SRMP) in Wyoming, Colorado, and New Mexico (Carey 1993; Livo & Yeakley 1997). Wildlife managers have observed similar negative population trends of boreal toads in other areas of western North America (Blaustein & Olson 1991; Drost & Fellers 1996; Davis & Gregory 2003). A better understanding of the natural history of this amphibian will assist conservation efforts currently underway by a variety of state, federal, and non-government agencies in the western United States by identifying critical boreal toad habitat and movement corridors. As these key natural history components are better understood, appropriate conservation buffers can be determined to mitigate negative impacts on toad survival, such as the location and timing of upland vegetation treatments, timber harvests, recreation usage, and livestock grazing.

Objectives

The goal of our study was to test the adequacy of the 30 m buffer for boreal toads. We considered a buffer to be adequate if all important habitats utilized were incorporated into the buffering system, such as habitats used for breeding, hibernating, and foraging. Additionally, adequate buffers would protect movement corridors utilized by toads connecting critical habitats.

To accomplish this we determined the appropriate size and shape of management buffer zones around toad breeding sites, analyzed habitat use, examined movement patterns, and observed if these factors varied by time of year, from year to year, by sex, or by breeding location. Buffer requirements may vary by time of year or between years due to changes in weather patterns. Differences between males and females in habitat use and movement patterns can have implications for buffer requirements. Unique site characteristics may also influence the appropriate placement of buffers. We also took these factors into consideration. Buffers that do not incorporate all the factors listed above will likely fail to meet their designed objectives.

Additionally, we tested to see if simply increasing buffer size would increase protection of critical habitat. Currently, a minimum 30.48 m (100 ft) buffer is implemented around all perennial water bodies in our study area. Wildlife managers have implemented larger buffer zones of 274.32 m (900 ft) around three of the breeding sites included in our study as well as a 91.44 m (300 ft) buffer along a stream connecting two of these breeding sites. This was done in response to a proposed timber harvest, though the actual effectiveness of these buffers was unknown.

We also compared selected habitat use to available habitat within individual toad home ranges to determine if habitats are being selected by toads based solely on habitat abundance or if specific habitats appear to be critical to boreal toad survival. This also will have implications on areas where conservation buffers should be placed in order to protect toads from human activities. If toads are selecting specific habitats regardless of habitat abundance, the shape of conservation buffers would be of greater significance than overall size alone. In this example, appropriate buffers would need to include all critical habitats for boreal toads.

MATERIALS & METHODS

Study Sites

We conducted our study at Baker Spring/Pine Creek on the western slope of Boulder Mountain (12 S 0451600 4227400) on the Dixie National Forest (DNF) and at six breeding sites on Monroe Mountain on the Fishlake National Forest (FNF) of south-central Utah (Fig.1). The FNF breeding sites are located at Barney Reservoir (12 S 0405370 4259920), Confluence of Manning and Barney Creeks (Confluence) (12 S 0406740 4258700), Dry Creek (12 S 0408500 4253630), Manning Meadows (12 S 0407160 4261100), North Fork of Box Creek (12 S 0411410 4260810), and South Fork of Box Creek (12 S 0408720 4257170). Elevations at all study sites range between 2700 and 3150 m in aspen/mixed conifer communities. These communities primarily consisted of aspen (*Populus tremuloides*), sub-alpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), and Douglas fir (*Pseudotsuga menziesii*). Many of these sites are surrounded by vast areas of mountain big sagebrush (*Artemisia tridentata vaseyana*) and silver sagebrush (*Artemisia cana*) communities,

particularly on south facing exposures. Most study sites are associated with beaver pond complexes along small streams in narrow valleys. Two sites (Manning Meadows and Barney Reservoir) are located along edges of larger impounded reservoirs in open wet grassy areas.

Radio Telemetry

We fitted external radio transmitters (Holohill BD-2.1 g) on a total of 41 adult toads in the summer of 2003 (DNF: ♂ = 7, ♀ = 6; FNF: ♂ = 14, ♀ = 14) and 43 adult toads in the summer of 2004 (DNF: ♂ = 8, ♀ = 6; FNF: ♂ = 15, ♀ = 14). We attached transmitters around the abdomen of adult toads with a harness made of plastic tubing, wire, and connector sleeves (Bartelt and Peterson 2000). We tracked all toads using a Yagi antenna and a hand held receiver. Toads were located on a weekly basis from late May or early June until late August or early September. At each observation, we recorded the UTM location (NAD 27), habitat (and microhabitat), distance to water, animal activity, and weather conditions.

Buffer Zones

We analyzed the effectiveness of the current buffers zones using ArcGIS 9 software (ESRI 2004). We superimposed 30.48 m buffer zones on the locations of all toad observations made during the study. Additionally, we superimposed the larger 274.32 m buffers on the three FNF breeding sites (Barney Reservoir, Confluence, and Manning Meadows) as well as the 91.44 m buffer along the stream connecting two of these sites (Confluence and Manning), as designated by wildlife managers. We then calculated the percentage of all toad observations that fell within the buffer at each

location. Results from Barney Reservoir and the Confluence were combined into one location (Barney/Confluence) as toads from both breeding sites moved into overlapping areas. Additionally, we used home range estimates to analyze the effectiveness of conservation buffers. We estimated the home range for each toad with ten or more observations by using the 95% adaptive kernel method (The Home Ranger 1.5; Hovey, Ursus Software 1999). Next we superimposed each home range on a GIS vegetation layer and computed the percentage of toad home ranges that were completely contained within the current buffer zones. We also calculated the median percentage of all home ranges that were within the buffering systems.

Ground Truthing

We determined if toads were utilizing streams, seeps and other bodies of water that were not included on current GIS layers used by managers. These unmapped aquatic resources would not receive buffer protection. Unmapped bodies of water utilized by toads were then included in our GIS layer, using digitized aerial photos and known toad observations as reference in determining location of unmapped bodies of water. We next placed 30 m buffers around all digitized bodies of water and calculated the percentage of toad observations within 30 m buffers for each breeding site to determine if buffer protection increased.

Statistical Analyses

We conducted rank sum and linear regression statistical analyses using S-Plus 6.2 software (Insightful Corp. 2003). We utilized Wilcoxon Rank Sum test with a continuity correction to determine differences between male and female toads in habitat use and

movement patterns. We used this nonparametric test as males and females appear to not be normally distributed in habitat use and movement patterns. Male and female toads do not appear to violate the assumption of independence in the Wilcoxon Rank Sum test. We performed linear regressions to determine if relationships existed between size of toad and percentage of time spent in upland habitats and maximum distance from water.

Habitat Use

At each observation, we recorded the habitat location of each toad. Next we superimposed the 95% adaptive kernel home range estimates (determined using Home Ranger) for each toad with ten or more observations on a GIS vegetation layer and calculated the areas of available habitat within each home range. For each toad we compared observed habitat selection to available habitat within the home range estimate. We computed a simple Chi Square test to determine if toads were using available upland and wetland habitats non-randomly. We calculated expected values of upland and wetland observations for each individual by multiplying the total number of observations by the percentage of upland and wetland habitat within each home range. We determined the observed values by recording the actual habitat selected during each observation. The Chi Square test utilized one degree of freedom from the two habitat values (upland and wetland). The second degree of freedom was calculated from the total number of observations for each toad.

Additionally, we determined if males and females differed in their upland and wetland habitat usage by computing a Wilcoxon Rank Sum test of all toad observations in upland and wetland habitats. We compared males to females for both 2003 and 2004. We also compared habitat used between 2003 and 2004 for males, females, and all toads.

We completed linear regressions to determine if there are relationships between percentage of time spent in upland habitats and size of toad using snout vent length (SVL) as a size indicator. We conducted simple linear regressions within sexes to determine if upland habitat use differs between size and years of the study.

Movement Patterns

We analyzed movement patterns of toads with a Wilcoxon Rank Sum test. We looked for significant differences in cumulative seasonal distances and median weekly distances between male and female toads. We determined the maximum observed distance from water by sex, and conducted a linear regression to determine if larger toads had greater maximum distances from water than smaller toads (using a log transformation of FNF observations).

RESULTS

Buffer Zones

Of all toad observations in 2003 and 2004, 82.4% were located within the minimum 30 m forest buffers around perennial water sources. The number of observations within minimum 30 m buffer areas varied between 50.0 and 97.2% from one breeding location to another (97.2 % Baker Spring, 72.2% Barney/Confluence, 83.5% Dry Creek, 50.0% Manning Meadows, 81.6% North Fork Box Creek, 83.5% South Fork Box Creek). For those sites with larger buffers, the percentage of observations inside buffers increased slightly from the standard 30 m buffer (83.3% Barney/Confluence, 55.0% Manning Meadows). Current buffers encompassed either all or portions of the breeding sites found along perennial streams and water bodies.

However, of the seven breeding locations in our study, six included small streams and seeps that were utilized by toads, but which were not protected by current buffer zones. Thus these portions of the breeding sites were also not protected. In addition, small unmapped streams and seeps, upland habitats, and overland dispersal routes used by toads frequently were not covered by the currently designated buffer zones.

We found that the percentage of home range protected by the established buffers varied by site. Of the 46 calculated home range estimates, only 6 (13.04%) were completely contained within the currently enacted buffer system (including the larger 91.44 m and 274.32 m buffer areas). This includes the expanded buffers of Barney/Confluence and Manning Meadows. When only considering the minimum 30.48 m buffer, 5 of 46 home range estimates were completely contained within the buffer (10.87%). Of all DNF home range estimates ($n = 16$), a median of 80.44% ($\text{♀} = 80.00\%$; $\text{♂} = 83.46\%$) of each home range was within the current buffer system. Of all FNF home range estimates ($n = 30$), a median of 67.16% ($\text{♀} = 68.79\%$; $\text{♂} = 63.47\%$) of each home range was within the current buffer system. Again, this includes the expanded buffers of Barney/Confluence and Manning Meadows. When limited to the 30.48 m buffer, a median of 80.44% ($\text{♀} = 80.00\%$; $\text{♂} = 83.46\%$) and 59.44% ($\text{♀} = 63.13\%$; $\text{♂} = 55.59\%$) of each home range was included for DNF and FNF toads, respectively.

We found no evidence that home ranges varied by sex, site, or year. The median home range for toads was 17,435 m². Female home range sizes varied between 1,180 m² and 350,510 m². Male home range sizes varied between 380 m² and 172,120 m². Using a Wilcoxon Rank Sum Test, there were no significant differences in home range size

between males and females ($Z = -0.9228$, $P = 0.3561$), between forests ($Z = 1.1417$, $P = 0.2536$), or between 2003 and 2004 ($Z = -0.3939$, $P = 0.6936$).

Ground Truthing

All but one of the breeding sites (Baker Spring) in our study had small unmapped seeps and streams that were utilized by boreal toads. Of those breeding sites with unmapped streams and seeps, all would have increased percentages of observations within the minimum 30 m buffer if this buffer were extended around the unmapped perennial bodies of water (92.9% Barney/Confluence, 89.7% Dry Creek, 90.0% Manning Meadows, 87.5% North Fork Box Creek, 90.8% South Fork Box Creek, 92.4% of all toad observations). After extending the 30 m buffer around the unmapped streams, the two sites with larger 91.44 and 274.32 m buffers had only slight increases in the percentage of observations inside buffers (95.2% Barney/Confluence, 92.5% Manning Meadows, 93.0% of all toad observations).

Habitat Use

We located toads most often in wet areas near water sources (73.9% of all observations). However, toads frequently utilized upland habitat. Upland habitats utilized by toads were typically sagebrush or aspen dominated communities, though sometimes toads utilized more barren habitats such as sparsely vegetated, rocky slopes (Fig. 2). Toads moved into upland habitats more commonly in late July and August (71.65% of all upland observations occurred after 14 July). In 2003, the percentage of upland habitat use for individual females was significantly greater than for males ($Z = 3.3561$, $P = 0.0008$; median percentages: females = 40.00%, males = 11.69%). In 2004, both sexes utilized

upland habitats, with no significant difference between percentage of upland habitat use for individual females and males ($Z = 1.1262$, $P = 0.2601$; median percentage: females = 36.36%, males = 23.21%). Between 2003 and 2004, the percent of upland habitat use was significantly different for males ($Z = -2.1378$, $P = 0.0325$; median percentage: 2003 = 11.69%, 2004 = 23.21%), but not for females ($Z = 1.499$, $P = 0.1339$; median percentage: 2003 = 40.00%; 2004 = 36.36%). Despite significant differences between upland habitat use for males between 2003 and 2004, overall differences between percentage of upland habitat use between 2003 and 2004 were not significant ($Z = 0.1892$, $P = 0.85$; 2003 = 21.43%, 2004 = 26.67%). In 2003, there was not a significant linear relationship between size of toad (using SVL as an indicator) and the percent of upland habitat use for females or males (♀ : $F_{1,10} = 1.114$, $P = 0.3161$, $R^2 = 0.1002$; ♂ : $F_{1,10} = 0.1191$, $P = 0.7371$, $R^2 = 0.01177$). In 2004, a significant relationship existed between percent upland habitat use and size for males ($F_{1,20} = 6.27$, $P = 0.02105$, $R^2 = 0.2387$), but not for females ($F_{1,16} = 1.648$, $P = 0.2175$, $R^2 = 0.09338$).

Chi Square analyses indicated that most toads observed ten or more times were using available upland and wetland habitats within home ranges non-randomly. When comparing habitat selection of DNF toads, 37.5% appeared to utilize available upland and wetland habitats randomly ($\alpha > 0.05$), while 62.5% utilized available upland and wetland habitats disproportionate to their abundance, selecting wetland habitats more frequently than availability would predict ($\alpha < 0.01$). Of FNF toads, 33.3% utilized available upland and wetland habitats proportional to habitat abundance ($\alpha > 0.05$), while 66.7% utilized available upland and wetland habitats disproportionate to habitat abundance, selecting wetland habitats more frequently than expected by availability ($\alpha < 0.05$). Additionally,

male and female toads appeared to differ in upland and wetland habitat selection within their home ranges. Males generally selected habitats disproportionate to their abundance, utilizing wetland areas more often. To a greater degree, females selected wetland and upland habitats proportional to their abundances (Table 1).

Movement Patterns

We observed toads moving farther than expected from water into upland habitats. Some toads moved greater than 100 m from stream and wetland locations into mountain big sagebrush (*Artemisia tridentata vaseyana*) habitat. In 2003, we mostly observed females moving at distances greater than 30.48 m into the upland habitats (17 of 158 female observations; 1 of 168 male observations). In 2003, two female toads were located over 100 m from the nearest water source. However, in 2004, both male and female toads moved into upland areas over 30.48 m from water (13 of 204 female observations; 13 of 285 male observations). Additionally, in 2004 six males and three females were located at distances over 100 m from water. Both sexes experienced more active dispersal in mid to late summer.

We found evidence that the maximum distance moved from water was significantly greater for DNF female toads than for male toads ($Z = 2.1394$, $P = 0.0324$). FNF movement observations show weak evidence that the maximum distance moved from water was significantly greater for female toads than for male toads ($Z = 1.9442$, $P = 0.0519$) (Fig. 3). The maximum distance moved from water by males was significantly greater in 2004 than in 2003 ($Z = -2.5758$, $P = 0.01$). Females did not differ significantly in maximum distance moved from water between 2003 and 2004 ($Z = -1.3416$, $P = 0.1797$). Male and female toads do not appear to have significant differences in median

weekly distance traveled (DNF $Z = -0.4243$, $P = 0.6713$; FNF $Z = -0.952$, $P = 0.3411$) (Fig.4).

Using snout-vent length (SVL) as an indicator, we also found evidence that larger toads moved farther from water than smaller toads. Linear regression indicated that the maximum distance moved from water was significantly greater for larger DNF toads than smaller DNF toads ($F_{1,18} = 6.714$, $P = 0.01844$, $R^2 = 0.2717$). We found evidence that the maximum distance moved from water was significantly greater for larger FNF toads than smaller FNF toads ($F_{1,39} = 6.708$, $P = 0.01343$, $R^2 = 0.1468$). Toad size does not appear to have a significant effect on median weekly distance traveled (DNF $F_{1,18} = 1.039$, $P = 0.3215$, $R^2 = 0.05458$; FNF $F_{1,39} = 0.4315$, $P = 0.5151$, $R^2 = 0.01094$).

DISCUSSION

Buffers

Our boreal toad example shows that the standard 30 m buffer is clearly inadequate. First, buffer zone requirements may vary according to time of year. In our study, toads moved into the upland more commonly in late July and August, occasionally at distances greater than 100 m from the nearest water source. Secondly, appropriate buffer zones may vary from year to year. Consequently, a single year's observation appears to be insufficient to establish adequate buffer zones. Toads moved into upland habitats more often in 2004 than 2003. Additionally, toads moved farther from water in 2004 than 2003, often at distances greater than the standard 30 m buffer zone. Third, the sexes may differ in buffer zone requirements. Male boreal toads appeared to have stronger selection for wetland habitats than females, when compared to all available

habitats within individual home ranges. Female toads moved greater distances from water than males, often outside of riparian buffer areas. Fourth, buffer zone requirements may differ according to location. We observed marked differences in the percentage of toad observations within 30 m buffers between breeding locations. Finally, all habitat requirements should be considered when establishing buffer zones. Many small streams and seeps utilized by toads were located outside buffer zones, primarily for hibernation.

This supports the findings of other authors (Burke & Gibbons 1995; Semlitsch 1998; Vesely & McComb 2002; Roth 2005) who also showed that the standard 30 m riparian buffer does not encompass all habitats and areas utilized by semi-aquatic and terrestrial vertebrates. More specifically, the 30 m buffer does not encompass critical habitats that are important to certain life history requirements, such as for hibernation (Burke & Gibbons 1995). Even though the majority of toad observations in our study were within the 30 m buffer zone, some toads, particularly females, moved outside of the buffer zone. Roth (2005) noted that even though 83% of all cottonmouth observations in his study were within 10 m of a stream, those snakes that were moving greater distances (up to 94 m) were most often gravid females, representing a critical reproductive component of the population. Similarly, female toads moving outside of the 30 m buffer in our study may be more important to population stability than their numbers alone would indicate. However, our results differ from previous studies specifically by addressing variability in habitat use by season, year, sex and age class, and location. Finally, our study emphasizes the importance of ground proofing areas where wildlife conservation buffers are implemented.

Variation by Season

Seasonal variation in selected habitats will influence placement of appropriate conservation buffers. Toads in our study differed in selected habitats during different seasons. During the breeding season (late May to early July) toads were most often located in wetland areas near breeding sites and along stream corridors, particularly males. When upland habitats were used during the breeding season, toads generally remained within 10 m of water. However, starting in mid-July, many toads moved away from breeding locations and into upland areas. All long distance movements (≥ 100 m) into upland habitats occurred after mid-July. This underscores the importance of considering multiple seasons when creating conservation buffers. If buffers had been created based solely on observations during the breeding season, upland habitats would not receive proper protection, as toads did not utilize these habitats heavily during this time period. To the best of our knowledge, the importance of seasonal variation in habitat use has not been addressed when determining wildlife conservation buffers. Managers should consider seasonal variability when determining appropriate wildlife conservation buffers and future research in this area will improve our ability to protect critical habitats.

Year-to-Year Variability

Patterns of habitat use vary from year to year as changes in the weather alter the local habitat and environment. During our study, we saw marked differences in rainfall, temperature, and humidity between 2003 and 2004. By 2003, most of south-central Utah was in the fifth year of a drought. The flow levels of most streams in the area were below average and many wetland areas and ponds were dry. During the summer of 2003, dry conditions continued for most of the summer, resulting in below average precipitation

and relative humidity. These drier conditions appeared to constrain toad mobility, limiting movement away from permanent wetland areas. As toads move away from wetland areas into drier upland areas, their risk of desiccation increases significantly (Carey 1978). Wetter conditions appear to a change habitat use and the effectiveness of conservation buffers. Unlike 2003, the summer of 2004 was cooler and wetter, with near normal precipitation. With increased precipitation and relative humidity, the risk of desiccation for toads was likely lower, particularly for smaller males. This would afford more opportunities for toads to utilized upland habitats. Consequently, we observed more upland activity in 2004 by both males and females. Some males even utilized dry upland sagebrush slopes at distances over 100 m.

These differences illustrate the importance of evaluating buffers over multiple years and during different weather conditions. During varying weather patterns, toads may utilize different habitats. Consequently, the area utilized during drier weather patterns is likely to be different from what it would be during wetter patterns, as was the case with boreal toads in our study. Thus year-to-year weather related differences must be considered when establishing buffer zones.

Variation by Sex and Size

The effect of weather and the use of upland habitats appeared to be sensitive to sex and to life history stage. This is primarily because, under similar conditions, smaller amphibians loose proportionally more water to evaporation than larger amphibians due to the higher body surface area to volume ratios of smaller individuals (Shoemaker et al. 1992). Carey (1978) observed a negative relationship with size and heating rates of boreal toads and that evaporative water loss increased with body temperature. As female toads

were generally larger than male toads (average weight: ♂ = 46.8 g, ♀ = 71.4 g; average SVL: ♂ = 82.9 mm, ♀ = 94.4 mm), this constraint would be greater for males than for females. This may explain why female toads moved into upland sagebrush dominated habitats more frequently than male toads in the summer of 2003. However, size does not appear to be a factor in utilization of upland habitats within each sex. Only for males in the wetter summer of 2004 did larger males utilize upland habitats significantly more often than smaller males. However, as radio transmitters utilized in the study were only placed on larger adults (SVL \geq 68 mm), these results may not be representative of all size and age classes.

Site Specific Variation

Buffer effectiveness is influenced by site specific variation. While differences at the landscape level, such as erosion potential (Wissmar et al. 2004), saturated hydraulic conductivity, soil moisture storage capacity, and slope (Phillips 1989; Dosskey et al. 2005) have been addressed, these recommendations were given specifically for controlling erosion and nonpoint source pollution. The principle of considering site specific differences in physical characteristics should be applied to conservation buffers critical to wildlife as well. In addition to the physical characteristics listed above, special attention should be paid to site specific variations in habitats and microclimates as well. In our search of the literature, we were unable to find studies that considered site-specific variation in habitats and microclimates when determining appropriate riparian buffers for wildlife. This is an area in need of attention.

Our study demonstrates how site specific differences in habitats influence the effectiveness of conservation buffers. The habitats surrounding the breeding site on the

DNF are more homogenous than those on the FNF, which have greater expanses of upland sagebrush habitats, intermixed with conifer and aspen stands. In addition, FNF breeding sites have greater variation in nearby topography. These sites generally were located in narrow valleys with moderately steep slopes. This variable topography supports unique plant communities due to variation in microclimate. For example, drier south facing slopes in the narrow valleys supported areas of upland sagebrush and dry meadows, whereas adjacent north facing slopes supported spruce and fir forest with cooler temperatures and higher humidities. This creates greater habitat variation within a smaller area. This greater vegetative variation at FNF sites resulted in more diversified habitat use, apparently because FNF toads had more habitat types available for use. For example, because sagebrush habitats were much reduced at the DNF site, toads did not use these areas as heavily as those at FNF sites. The differences between the DNF and FNF sites suggest that site specific characteristics can alter habitat use. Consequently, managers should consider these site specific characteristics when implementing conservation buffers.

Ground Truthing and Protecting Critical Habitats

Ground truthing may be the most important step towards establishing effective buffer zones. Buffers can only be as effective as the accuracy of the maps used to create the buffers. We found that some of the perennial streams utilized by toads were not included in the buffer system due to low resolution of GIS maps. While most named streams were identified, many of the smaller unnamed tributaries and seeps were not recognized on the GIS vegetation layers used by forest service managers. In fact, six of the seven breeding sites monitored in the study had some perennial streams utilized by

toads that were not recognized on these GIS vegetation layers. Even breeding sites that had high percentages of observations inside the buffered area had toads utilizing small, unmapped seeps and streams. It is apparent that GIS vegetation layers may not be accurate enough to identify all important habitats. They certainly were not in the case of boreal toads.

Most sites observed in our study would have higher buffer protection if a few unmapped perennial streams were digitized to the GIS layer and the minimum buffer protection of 30.48 m extended around them. The site with the lowest amount of buffer protection, Manning Meadows, would increase from 50.0% of all observations inside current buffered areas to 90.0% if two small, unmapped streams were added to the buffer system. Ground truthing to locate and digitized small streams and seeps adjacent to documented breeding locations is invaluable to insuring proper protection to hibernacula locations of boreal toads.

Thus, results from our study differ from previous studies primarily by emphasizing the importance of ground truthing. Few studies of appropriate riparian buffer widths addressed this problem. Bren (1995) remarked that digital 1:25 000 topographic coverage maps were not adequately reliable for mapping riparian buffers, particularly complex stream heads. Other authors commented on the fact that smaller streams are less likely to receive protection than larger streams (Corn & Bury 1988; Haberstock et al. 2000). Similarly, we found that small streams and seeps were often not included in management vegetation layers and may not be afforded buffer protection from various management activities, particularly timber harvests.

Small, unmapped streams could be of greater concern than indicated by observed usage alone as they may be commonly used as hibernacula. As our study focus was to observe the movement of toads during the active season, we did not follow all the monitored toads into hibernation. It is possible that many toads utilize these smaller streams and seeps for hibernation during winter months (Campbell 1970). We monitored several toads until they entered hibernation. Most of the hibernacula locations we observed were along small streams in undercut banks or root chambers. These small streams and seeps often flowed underground for short sections, particularly at or near the spring source. Small headwater streams are often not protected under currently regulations (Hagar 1999). Some of the areas with unmapped streams and seeps may have potentially high timber value due to abundance of larger spruce (*Picea* spp.) along seep channels. If left unmapped and without buffering protection, many of these critical areas could be degraded by timber harvest and a loss of insulating organic layer over underground seeps and chambers. These layers of duff and other organic add an insulating layer for hibernating toads during winter months, and hibernacula are often found in such locations (Campbell 1970). Thus, underground moist chambers along small streams appear to provide critical habitat for toads, particularly for hibernation (Campbell 1970).

Additionally, buffer shape appears to be more critical than buffer size alone. Merely increasing buffer size was not as effective at covering critical habitats as ensuring that the shape of the buffer conformed to that of the mapped plus unmapped seeps and streams. From the two sites with buffers greater than 30.48 m, most toads did not move farther away from the water than 30.48 m. In fact, the 274.32 m buffer located at

Manning Meadows did not encompass toad locations that were not already encompassed by the 30.48 m buffer. At this particular location, a 30.48 m buffer around all perennial stream and seeps would encompass far more toad observations than the larger circular buffer. As indicated above, many critical habitats for toads were not included in the buffer area due to low resolution of GIS mapping resources. Appropriately locating and digitizing these areas and adding them to the buffering system would greatly increase protection of critical habitats.

However, ground truthing and implementation of a 30 m buffer will not necessarily include all habitats used. Sometimes bigger buffers are better. Though most toad observations in upland areas were within 30.48 m of a permanent water source (165 of 206 observations), some toads, particularly females, moved to areas outside of the standard buffer. Again, as females represent critical reproductive components of the population, protection of these upland habitats at greater distances could be critical to population stability.

The reasons for upland habitat use also can influence conservation activities and the effectiveness of 30 m buffer zones. With toads, structural elements of the landscape may be important to provide thermal refuges or predator avoidance. Alternately, toads may be utilizing upland habitats for a specific prey base. These factors can vary due to the size of the buffer. Even if current buffers encompass all areas where the species of concern is located, changes in microclimate due to management activities beyond the buffer can be significant. Clearcuts adjacent to forested areas alter wind velocity, cause variation in temperature, and relative humidity greater than 240 m into the forest interior (Chen et al. 1995). For organisms that are highly sensitive to environmental fluctuations,

such as amphibians (Johnston & Frid 2002), management activities that alter the microclimate in this manner would be detrimental. In another study, Whitaker et al. (2000) reported capturing 1.2 to 2 times as many flying insects along 25 to 40 m wide riparian buffers than along undisturbed control riparian areas. Such increases have implications on insectivores, such as birds (Whitaker et al. 2000) and amphibians (Barrentine 1991). Consequently, managers determining appropriate buffer widths will need to take into consideration the changes in microclimate and species composition resulting from proposed activities neighboring buffer zones.

CONCLUSIONS

The findings from our study suggest that the standard 30 m riparian buffer is not sufficient for all conservation efforts. Managers should consider several factors when creating riparian buffers for wildlife conservation:

- Mapping resources may be too coarse to detect smaller stream and seep habitats.
- Unmapped streams and seeps may not be protected by standard 30 m buffers.
- Buffer zones need to incorporate all critical habitats for both sexes and different age classes.
- Site specific habitat and topographic characteristics should be considered in determining appropriate buffer zones.
- Seasonal changes in microclimate and habitat use should be considered when establishing buffer zones.
- Year-to-year variations in microclimate and habitat use should be considered when establishing buffer zones.

- The effects of management activities neighboring buffer zones should be considered when establishing buffer zone size.
- Sex, size and age related life history requirements should be considered when establishing buffers.

LITERATURE CITED

- Adams, S.B., D.A. Schmetterling, and M.K. Young. 2005. Instream movements by boreal toads (*Bufo boreas boreas*). *Herpetological Review* 36:27-33.
- Aubertin, G.M., and J.H. Patric. 1974. Water quality after clearcutting a small watershed in West Virginia. *Journal of Environmental Quality* 3:243-249.
- Barrentine, C.D. 1991. Food habits of western toads (*Bufo boreas halophilus*) foraging from a residential lawn. *Herpetological Review* 22:84-87.
- Bartelt, P.E., and C.R. Peterson. 2000. A description and evaluation of a plastic belt for attaching radio transmitters to western toads (*Bufo boreas*). *Northwestern Naturalist* 81:122-128.
- Bartelt, P.E., C.R. Peterson, and R.W. Klaver. 2004. Sexual differences in the post-breeding movements and habitats selected by western toads (*Bufo boreas*) in southeastern Idaho. *Herpetologica* 60:455-467.
- Bentrup, G. and T. Kellerman. 2004. Where should buffers go? Modeling riparian habitat connectivity in northeast Kansas. *Journal of Soil and Water Conservation* 59:209-215.
- Blaustein, A.R., and D.H. Olson. 1991. Declining amphibians. *Science* 253:1467.

- Bosman, W., J.J. Van Gelder, and H. Strijbosch. 1996. Hibernation sites of the toads *Bufo bufo* and *Bufo calamita* in a river floodplain. *Herpetological Journal* 6:83-86.
- Bren, L.J. 1995. Aspects of the geometry of riparian buffer strips and its significance to forestry operations. *Forest Ecology and Management* 75:1-10.
- Bulger, J.B., N.J. Scott, Jr., and R.B. Seymour. Terrestrial activity and conservation of adult California red-legged frogs *Rana aurora draytonii* in coastal forests and grasslands. *Biological Conservation* 110:85-95.
- Burke, V.J., and J.W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9:1365-1369.
- Campbell, J.B. 1970. Hibernacula of a population of *Bufo boreas boreas* in the Colorado Front Range. *Herpetologica* 26:278-282.
- Carey, C. 1993. Hypothesis concerning the causes of the disappearance of boreal toads from the mountains of Colorado. *Conservation Biology* 7:355-362.
- Carey, C. 1978. Factors affecting body temperatures of toads. *Oecologia* 35:197-219.
- Castelle, A.J., A.W. Johnson, and C. Conolly. 1994. Wetland and stream buffer size requirements- a review. *Journal of Environmental Quality* 23:878-882.
- Chen, J., J.F. Franklin, and T.A. Spies. 1995. Growing-season microclimate gradients from clearcut edges into old-growth Douglas-fir forests. *Ecological Applications* 5:74-86.
- Clinnick, P.F. 1985. Buffer strip management in forest operations: a review. *Australian Forestry* 48:34-45.

- Cockle, K.L. and J.S. Richardson. 2003. Do riparian buffer strips mitigate the impacts of clearcutting on small mammals? *Biological Conservation* 113:133-140.
- Corn, P.C., and R.B. Bury. 1988. Logging in western Oregon: responses of headwater habitats and stream amphibians. *Forest Ecology and Management* 29:39-57.
- Davies, P.E., and M. Nelson. 1994. Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. *Australian Journal of Marine and Freshwater Research* 45:1289-1305.
- Davis, T.M., and P.T. Gregory. 2003. Decline and local extinction of the western toad, *Bufo boreas*, on southern Vancouver Island, British Columbia, Canada. *Herpetological Review* 34:350-352.
- Dodd, K.C., Jr. and B.S. Cade. 1998. Movement patterns and the conservation of amphibians breeding in small, temporary wetlands. *Conservation Biology* 12:331-339.
- Dosskey, M.G., D.E. Eisenhauer, and M.J. Helmers. 2005. Establishing conservation buffers using precision information. *Journal of Soil and Water Conservation* 60:349-354.
- Doyle, R.C., D.C. Wolf, and D.R. Bezdicsek. 1975. Effectiveness of forest buffer strips in improving the water quality of manure polluted runoff. In: *Proceedings of the 3rd International Symposium on Livestock Wastes*. American Society of Agricultural Engineers. St. Joseph, MI. 299-302.
- Drost, C.A., and G.M. Fellers. 1996. Collapse of a regional frog fauna in the Yosemite area of the California Sierra Nevada, USA. *Conservation Biology* 10:414-425.

- Environmental Systems Research Institute, Inc. (ESRI) 2004. ArcGIS 9. Redlands, California, U.S.A.
- Fridell, R.A., K.M. Comella, G.N. Garnett, B.A. Zettle, T.K. Smith, and D.L. Harstad. 2000. Boreal toad (*Bufo boreas boreas*) distribution surveys in southwestern Utah 1994-1998. Publication number 00-10. Utah Division of Wildlife Resources, Salt Lake City, Utah.
- Griffin, P.C., and T.J. Case. 2001. Terrestrial habitat preferences of adult arroyo southwestern toads. *Journal of Wildlife Management* 65:633-644.
- Haberstock, A.E., H.G. Nichols, M.P. DesMeules, J. Wright, J.M. Christensen, and D.H. Hudnut. 2000. Method to identify effective riparian buffer widths for Atlantic salmon habitat protection. *Journal of the American Water Resources Association* 36:1271-1286.
- Hannon, S.J., C.A. Paszkowski, S. Boutin, J. DeGroot, S.E. Macdonald, M. Wheatley, and B.R. Eaton. 2002. Abundance and species composition of amphibians, small mammals, and songbirds in riparian forest buffer strips of varying widths in the boreal mixedwood of Alberta. *Canadian Journal of Forest Research* 32:1784-1800.
- Hovey, F.W. 1999. The Home Ranger 1.5. Ursus Software. Revelstoke, B.C., Canada.
- Insightful Corp. 2003. S-Plus 6.2.
- Johnston, B., and L. Frid. 2002. Clearcut logging restricts the movements of terrestrial Pacific giant salamanders (*Dicamptodon tenebrosus* Good). *Canadian Journal of Zoology* 80:2170-2177.

- Lee, P., C. Smyth, and S. Boutin. 2004. Quantitative review of riparian buffer width guidelines from Canada and the United States. *Journal of Environmental Management* 70: 165-180.
- Livo, L.J., and D. Yeakley. 1997. Comparison of current with historical elevational ranges in the boreal toad, *Bufo boreas*. *Herpetological Review* 28:143-144.
- Lynch, J.A., and E.S. Corbett. 1990. Evaluation of best management practices for controlling nonpoint pollution from silvicultural operations. *Water Resources Bulletin* 26:41-52.
- Lynch, J.A., E.S. Corbett, and K. Mussallem. 1985. Best management practices for controlling nonpoint-source pollution on forested watersheds. *Journal of Soil and Water Conservation* 40:164-167.
- Muths, E. 2003. Home range and movements of boreal toads in undisturbed habitat. *Copeia* 2003:160-165.
- O’Laughlin, J., and G.H. Belt. 1995. Functional approaches to riparian buffer strip design. *Journal of Forestry* 93:29-32.
- Osborne, L.L., and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology* 29:243-258.
- Pearson, S.F. and D.A. Manuwal. 2001. Breeding bird response to riparian buffer width in managed Pacific Northwest Douglas-fir forest. *Ecological Applications* 11: 840-853.
- Phillips, J.D. 1989. Nonpoint source pollution control effectiveness of riparian forests along a coastal plain river. *Journal of Hydrology* 110:221-237.

- Pilliod, D.S., C.R. Peterson, and P.I. Ritson. 2002. Seasonal migration of Columbia spotted frogs (*Rana luteiventris*) among complementary resources in a high mountain basin. *Canadian Journal of Zoology* 80:1849-1862.
- Pinay, G., and H. DeCamps. 1988. The role of riparian woods in regulating nitrogen fluxes between the alluvial aquifer and surface water: a conceptual model. *Regulated Rivers: Research and Management* 2:506-516.
- Richter, S.C., J.E. Young, R.A Seigel, and G.N. Johnson. 2001. Postbreeding movements of the dark gopher frog, *Rana sevosa* Goin and Netting: Implications for conservation and management. *Journal of Herpetology* 35:316-321.
- Robinson, M., M.P. Donovan, and T.D. Schwaner. 1998. Western toad, *Bufo boreas*, in southern Utah: notes on a single population along the East Fork of the Sevier River. *Great Basin Naturalist* 58:87-89.
- Roth, E.D. 2005. Buffer zone applications in snake ecology: a case study using cottonmouths (*Agkistrodon piscivorus*). *Copeia* 2005:399-402.
- Shoemaker, V.H., S.S. Hillman, S.D. Hillyard, D.C. Jackson, L.L. McClanahan, P.C. Withers, and M.L. Wygoda. 1992. Exchange of water, ions, and respiratory gases in terrestrial amphibians. Pages 125-150 in M.E. Feder and W.W. Bruggren, editors. *Environmental physiology of the amphibians*. University of Chicago Press.
- Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113-1119.

- Semlitsch, R.D. and J.R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* 17:1219-1228.
- Smits, A.W. 1984. Activity patterns and thermal biology of the toad *Bufo boreas halophilus*. *Copeia* 1984:689-696.
- Thompson, P.D. 2004. Observations of boreal toads (*Bufo boreas*) breeding populations in northwestern Utah. *Herpetological Review* 35:342-344.
- Trenham, P.C. and H.B. Shaffer. 2005. Amphibian upland habitat use and its consequences for population viability. *Ecological Applications* 15:1158-1168.
- U.S. Fish and Wildlife Service. 2005. Endangered and threatened wildlife and plants; revised 12-month finding for the southern Rocky Mountain distinct population segment of the boreal toad (*Bufo boreas boreas*). 50 CFR Part 17. *Federal Register* 70(188):56880-56884.
- Vesely, D.G. and W.C. McComb. 2002. Salamander abundance and amphibian species richness in riparian buffer strips in the Oregon coast range. *Forest Science* 48: 291-297.
- Whitaker, D.M., A.L. Carroll, and W.A. Montevecchi. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. *Canadian Journal of Zoology* 78:740-747.
- Wissmar, R.C., W.N. Beer, and R.K. Timm. 2004. Spatially explicit estimates of erosion-risk indices and variable riparian buffer widths in watersheds. *Aquatic Sciences* 66:446-455.

Young, K.A. 2000. Riparian zone management in the Pacific Northwest: Who's cutting what? *Environmental Management* 26:131-144.

Young, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of vegetated buffer strips in controlling pollution from feedlot runoff. *Journal of Environmental Quality* 9:483-487.

TABLES & FIGURES

TABLE 1. Percentage of toads utilizing habitats as expected, significantly different than expected, and very significantly different than expected for all toads, males, and females on the Dixie (DNF) and Fishlake (FNF) National Forests. All toads not utilizing habitats as expected were selecting wetland habitats more often than expected by habitat abundance alone.

	Not significantly different than expected ($\alpha > 0.05$)	Significantly different than expected ($0.01 < \alpha < 0.05$)	Highly significantly different than expected ($\alpha < 0.01$)
DNF			
Total	37.50%	0%	62.50%
Females	75.0%	0.0%	25.0%
Males	25.0%	0.0%	75.0%
FNF			
Total	33.3%	13.4%	53.3%
Females	50.0%	14.3%	35.7%
Males	18.75%	12.5%	68.75%

FIGURE LEGEND

FIGURE 1. Map of study area in south-central Utah on the Dixie and Fishlake National Forests. Black triangles indicate each breeding site used in the study.

FIGURE 2. Habitat Use by toads on the A) Dixie and B) Fishlake National Forests in 2003 and 2004. The X- axis lists different habitat classes. The Y-axis denotes the total number of observations at each habitat class. Black bars represent wet habitats and gray bars represent dry habitats.

FIGURE 3. Maximum Distance toads were located from water on the A) Dixie and B) Fishlake National Forests in 2003 and 2004. The X- axis lists different distance class from water. The Y-axis denotes the total number of observations at each distance class for both female (gray bars) and male (black bars) toads.

FIGURE 4. Median Weekly Distance traveled by toads on the A) Dixie and B) Fishlake National Forests in 2003 and 2004. The X- axis lists different median distance classes. The Y-axis denotes the total number of observations at each distance class for both female (gray bars) and male (black bars) toads.

FIGURE 1

Study Area

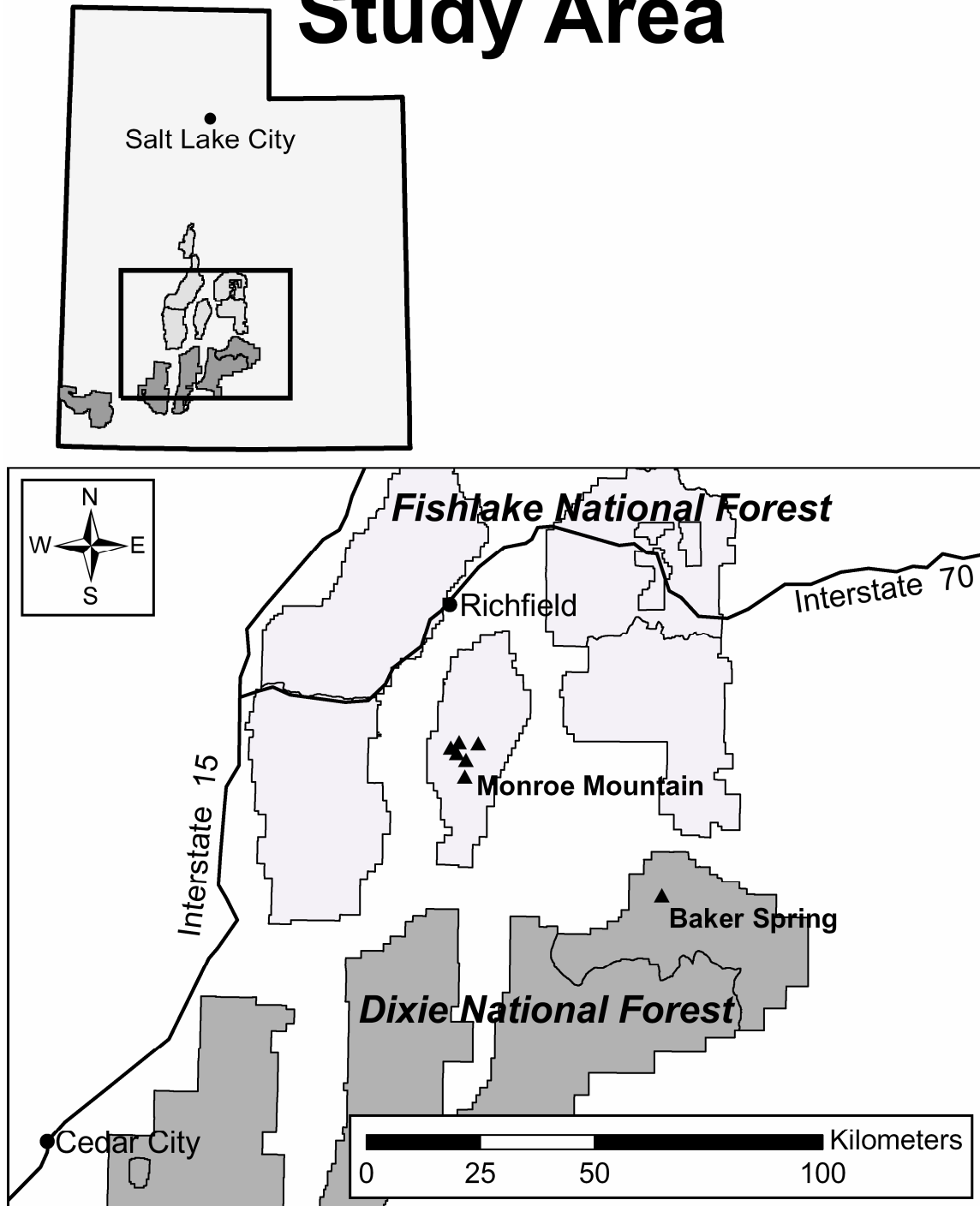


FIGURE 2

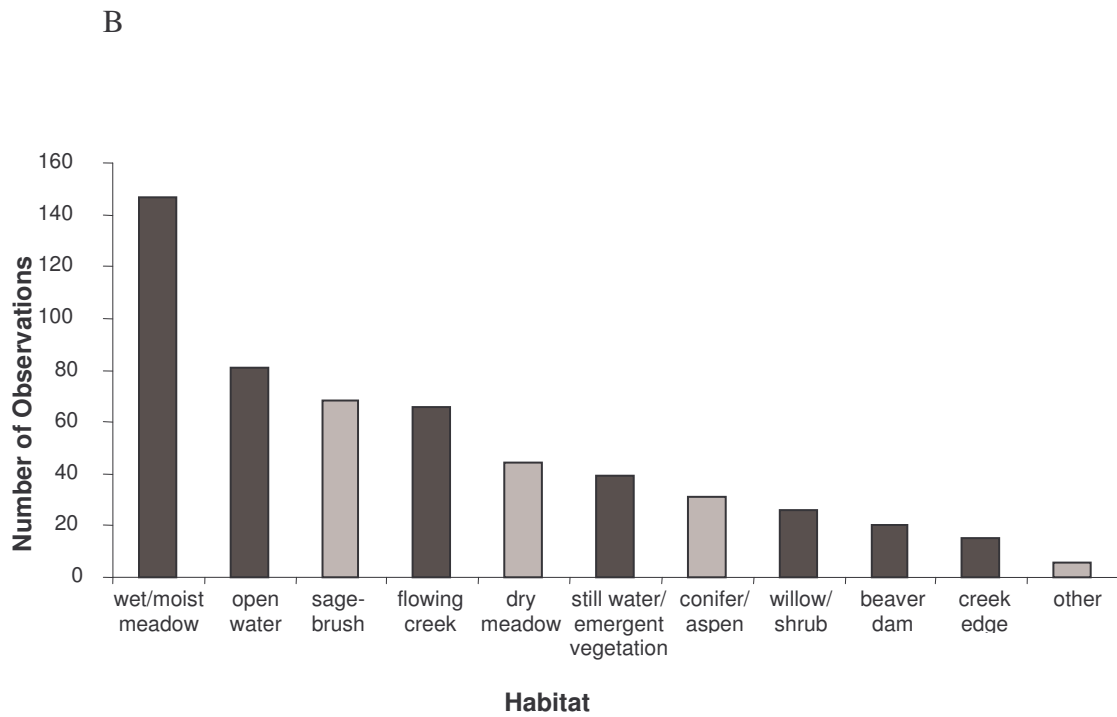
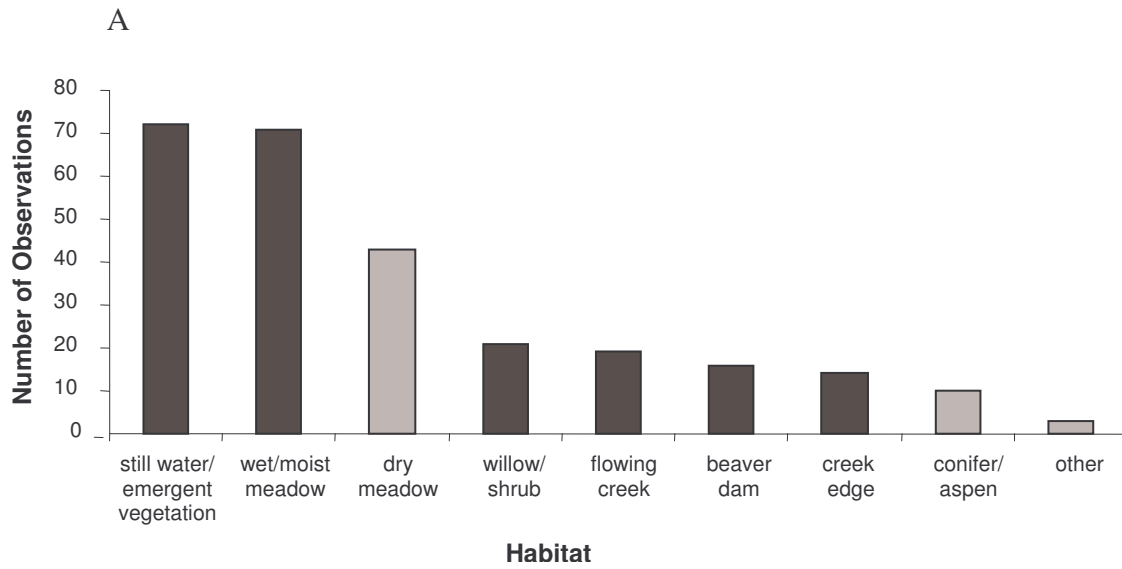
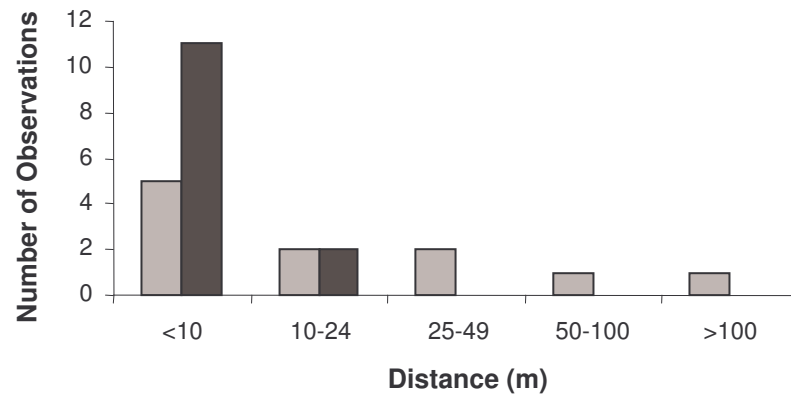


FIGURE 3

A



B

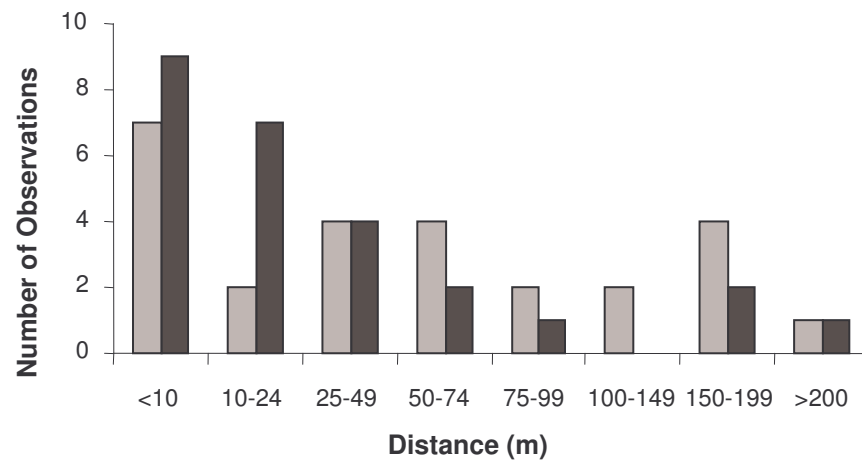
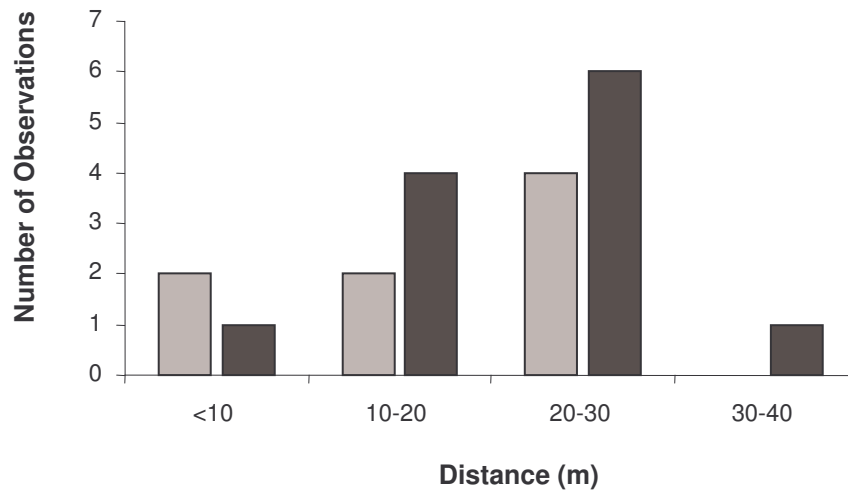
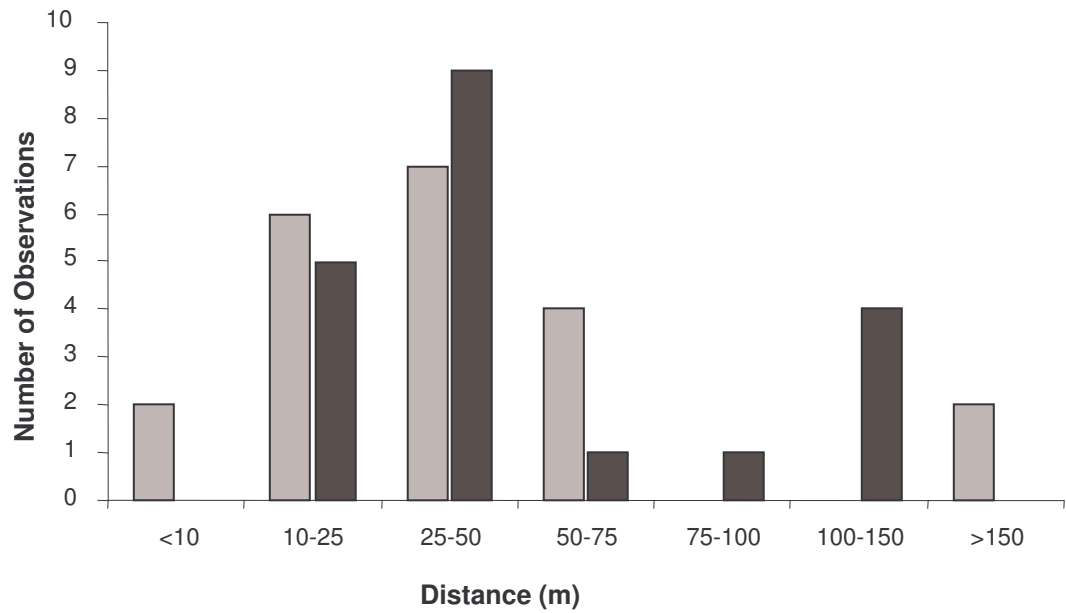


FIGURE 4

A



B



APPENDIX: BUFFER MAPS

MAP LEGEND

MAP 1. Map of current buffer system at Manning Meadows. Buffers at this site encompassed 44 out of 80 toad observations (55%) from 2003 and 2004. Habitat components: perennial grasses (*Agropyron spp.*, *Poa spp.*, *Stipa spp.*, *Bromus spp.*, etc.); silver sagebrush (*Artemisia cana*); mountain big sagebrush (*Artemisia tridentata vaseyana*); mixed conifer- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); aspen (*Populus tremuloides*); riparian- willow (*Salix spp.*), emergent aquatic vegetation.

MAP 2. Map of current buffer system at Barney/Confluence. Buffers at this site encompassed 105 out of 126 toad observations (83.3%) from 2003 and 2004. Habitat components: perennial grasses (*Agropyron spp.*, *Poa spp.*, *Stipa spp.*, *Bromus spp.*, etc.); silver sagebrush (*Artemisia cana*); mountain big sagebrush (*Artemisia tridentata vaseyana*); black sagebrush (*Artemisia nova*); mixed conifer- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); aspen (*Populus tremuloides*); riparian- willow (*Salix spp.*), emergent aquatic vegetation.

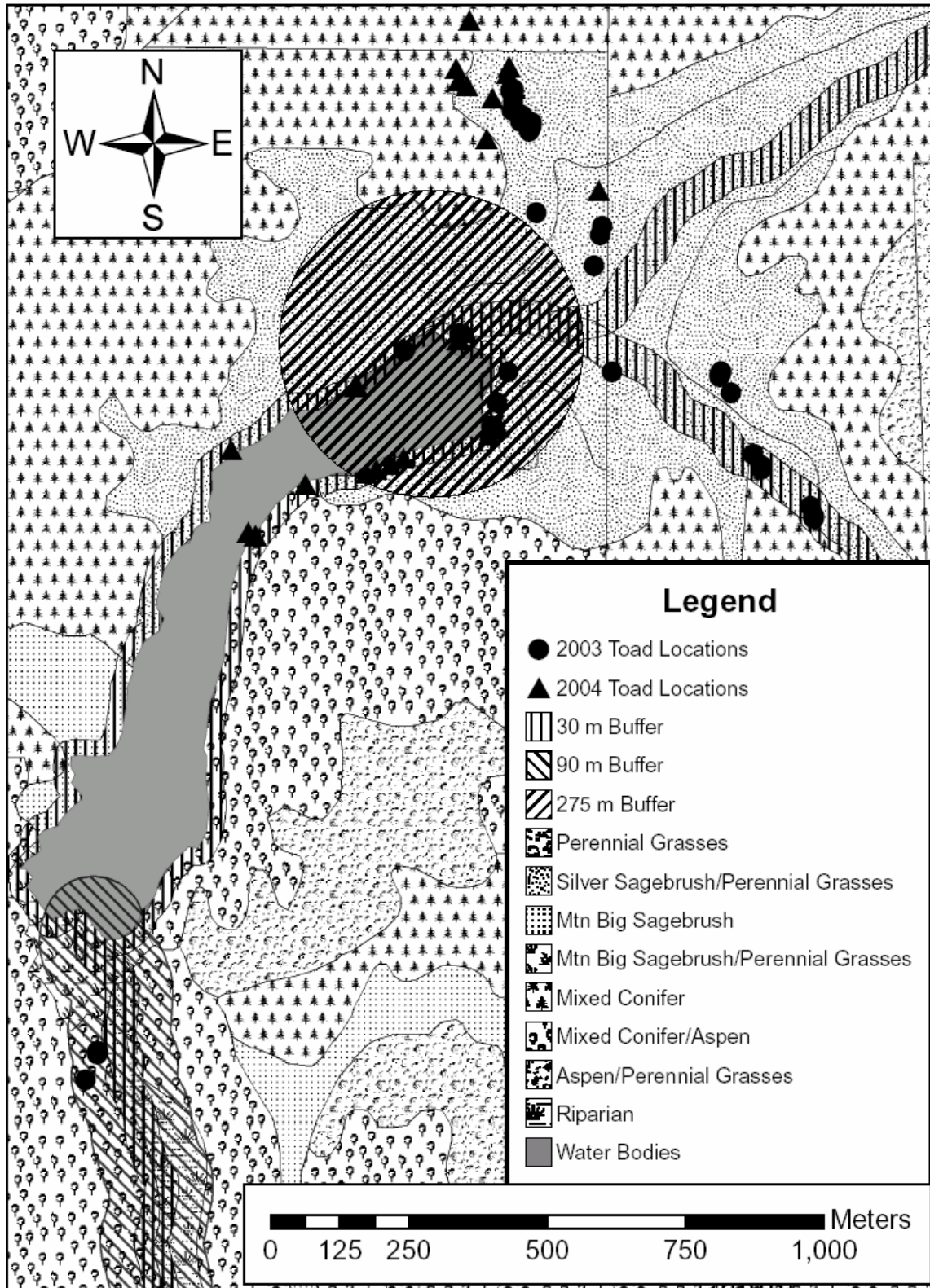
MAP 3. Map of current buffer system at North Fork Box Creek. Buffers at this site encompassed 111 out of 136 toad observations (81.6%) from 2003 and 2004. Habitat components: perennial grasses (*Agropyron spp.*, *Poa spp.*, *Stipa spp.*, *Bromus spp.*, etc.); silver sagebrush (*Artemisia cana*); mountain big sagebrush (*Artemisia tridentata vaseyana*); black sagebrush (*Artemisia nova*); mixed conifer- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); mountain mahogany (*Cercocarpus ledifolius*); aspen (*Populus tremuloides*); riparian- willow (*Salix spp.*), emergent aquatic vegetation.

MAP 4. Map of current buffer system at South Fork Box Creek. Buffers at this site encompassed 91 out of 109 toad observations (83.5%) from 2003 and 2004. Habitat components: perennial grasses (*Agropyron spp.*, *Poa spp.*, *Stipa spp.*, *Bromus spp.*, etc.); silver sagebrush (*Artemisia cana*); mountain big sagebrush (*Artemisia tridentata vaseyana*); black sagebrush (*Artemisia nova*); mixed conifer- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); mountain mahogany (*Cercocarpus ledifolius*); aspen (*Populus tremuloides*); riparian- willow (*Salix spp.*), emergent aquatic vegetation.

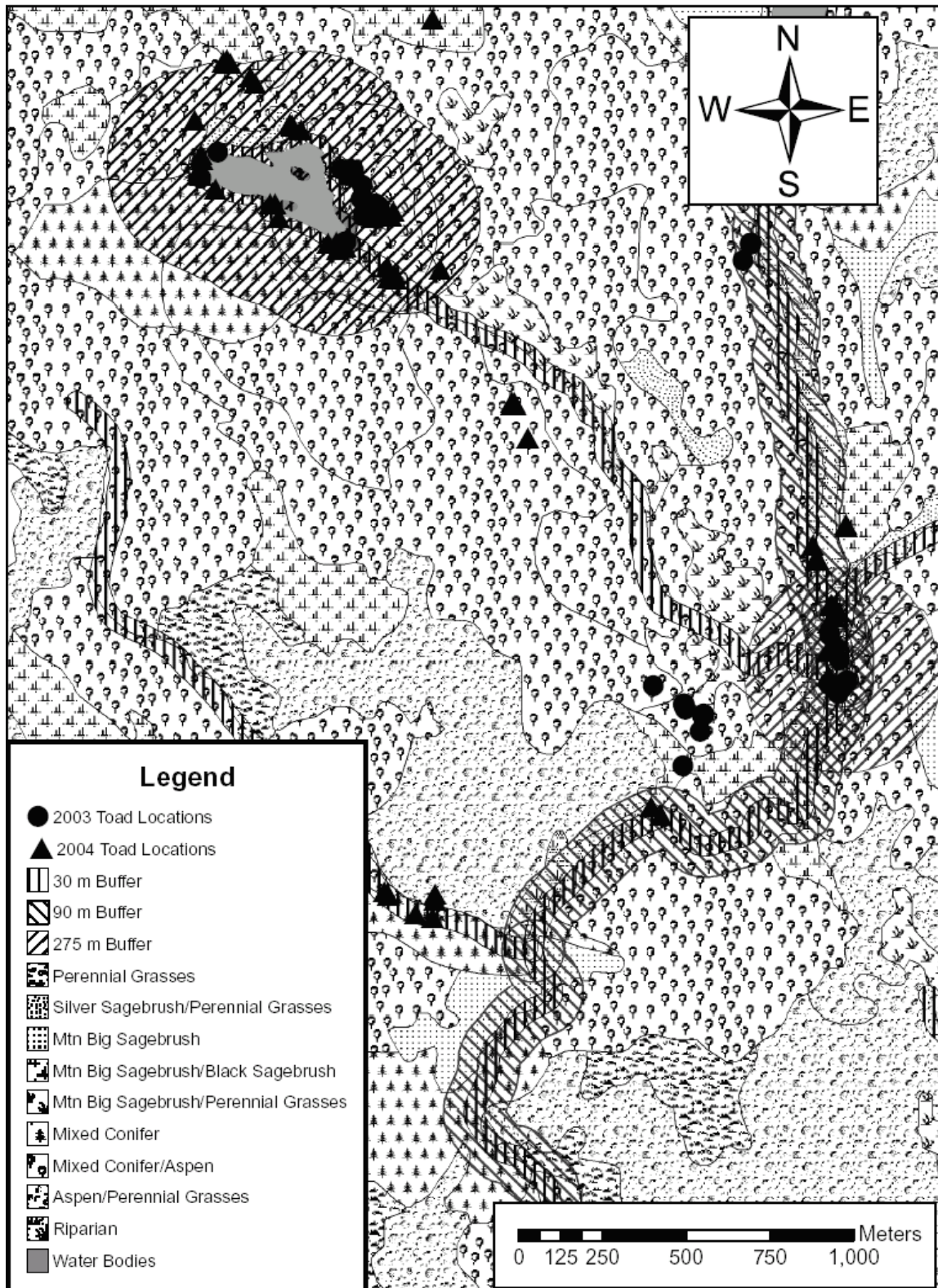
MAP 5. Map of current buffer system at Dry Creek. Buffers at this site encompassed 77 out of 96 toad observations (80.2%) from 2003 and 2004. Habitat components: perennial grasses (*Agropyron spp.*, *Poa spp.*, *Stipa spp.*, *Bromus spp.*, etc.); silver sagebrush (*Artemisia cana*); mountain big sagebrush (*Artemisia tridentata vaseyana*); black sagebrush (*Artemisia nova*); mountain mahogany (*Cercocarpus ledifolius*); mixed conifer- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); aspen (*Populus tremuloides*).

MAP 6. Map of current buffer system at Baker Spring/Pine Creek. Buffers at this site encompassed 246 out of 253 toad observations (97.2%) from 2003 and 2004. Habitat components: silver sagebrush (*Artemisia cana*); spruce-fir- Engelmann spruce (*Picea engelmannii*), blue spruce (*Picea pungens*), sub-alpine fir (*Abies lasiocarpa*), Douglas fir (*Pseudotsuga menziesii*); aspen (*Populus tremuloides*).

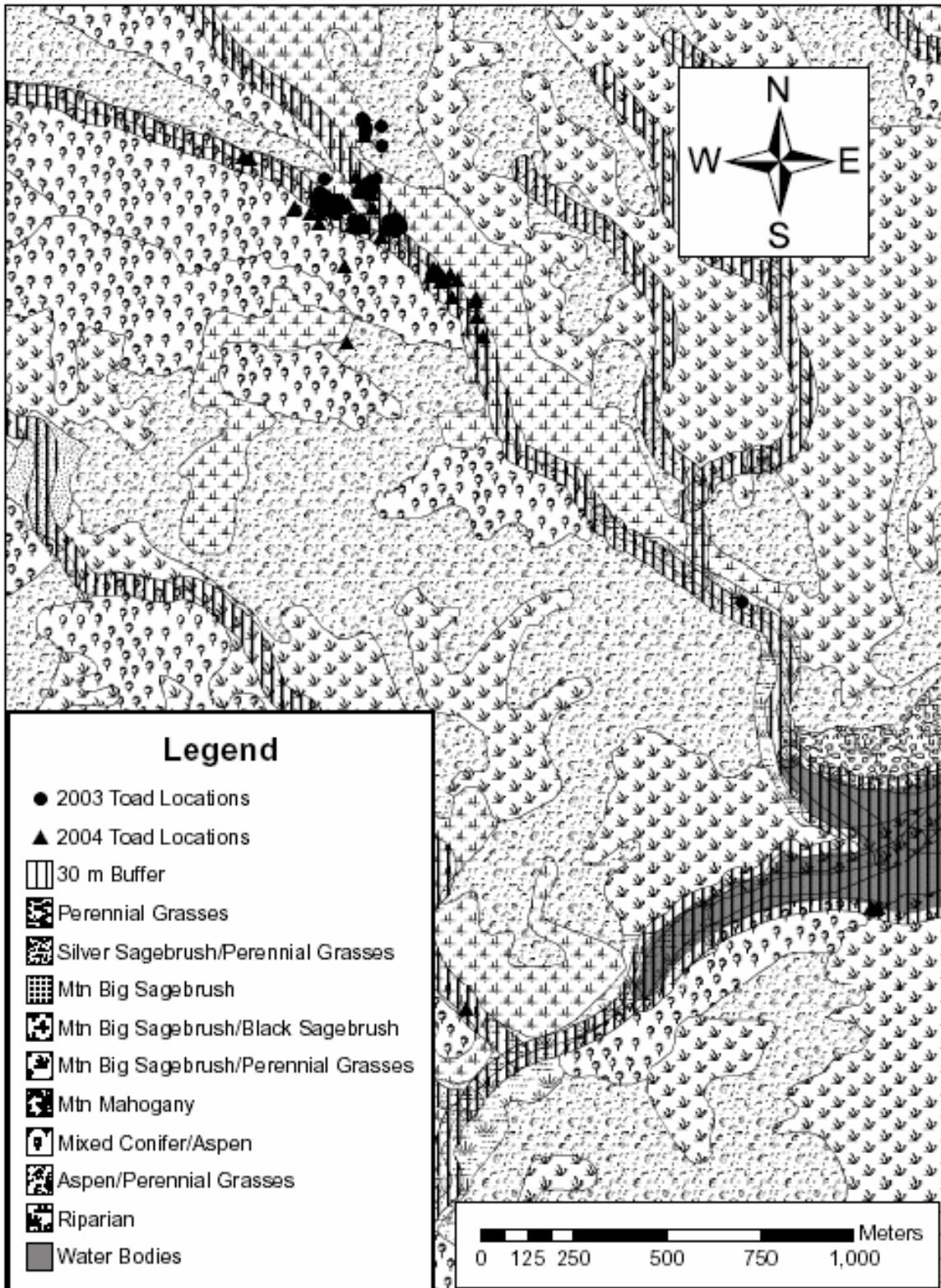
MAP 1



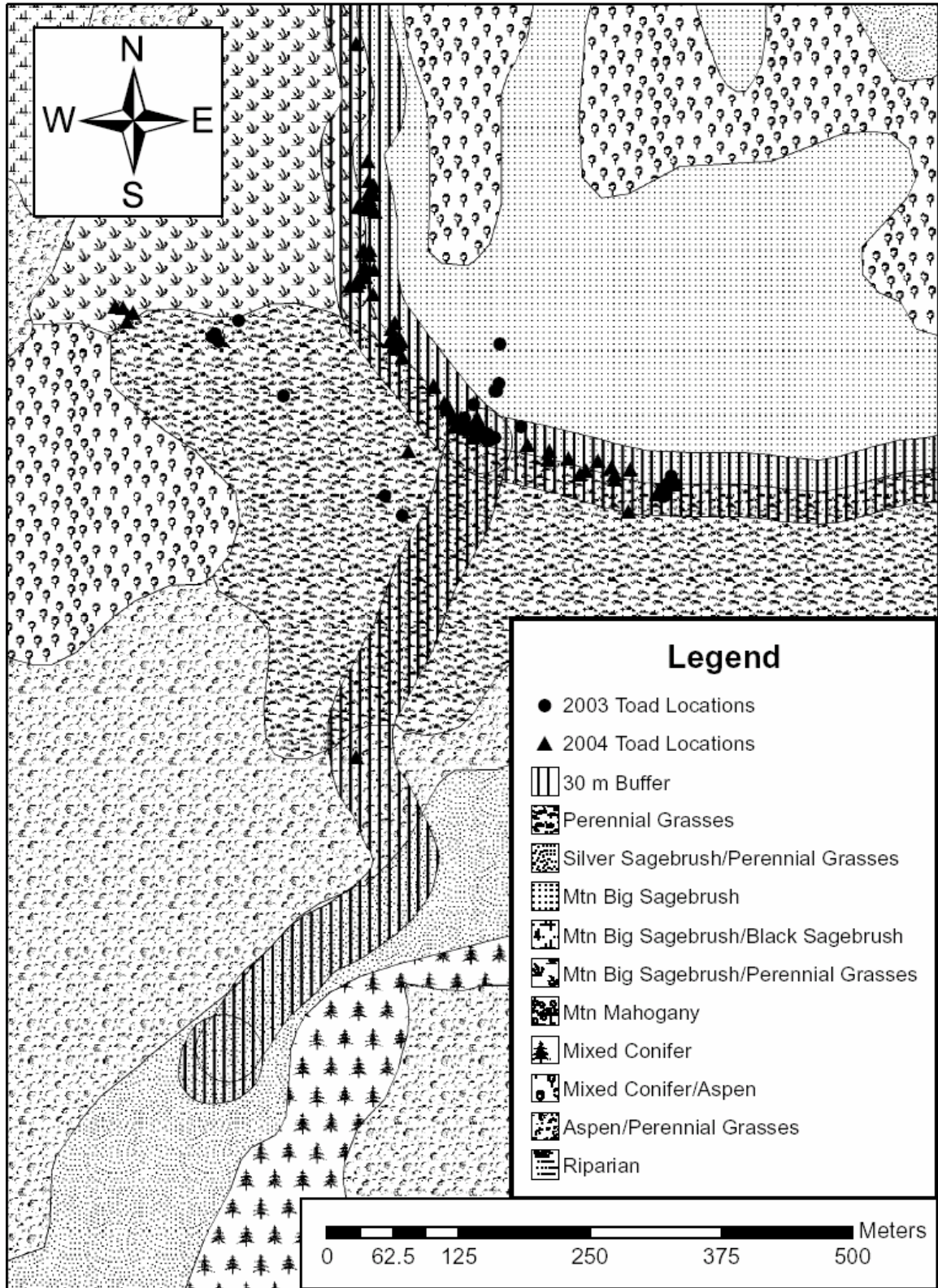
MAP 2



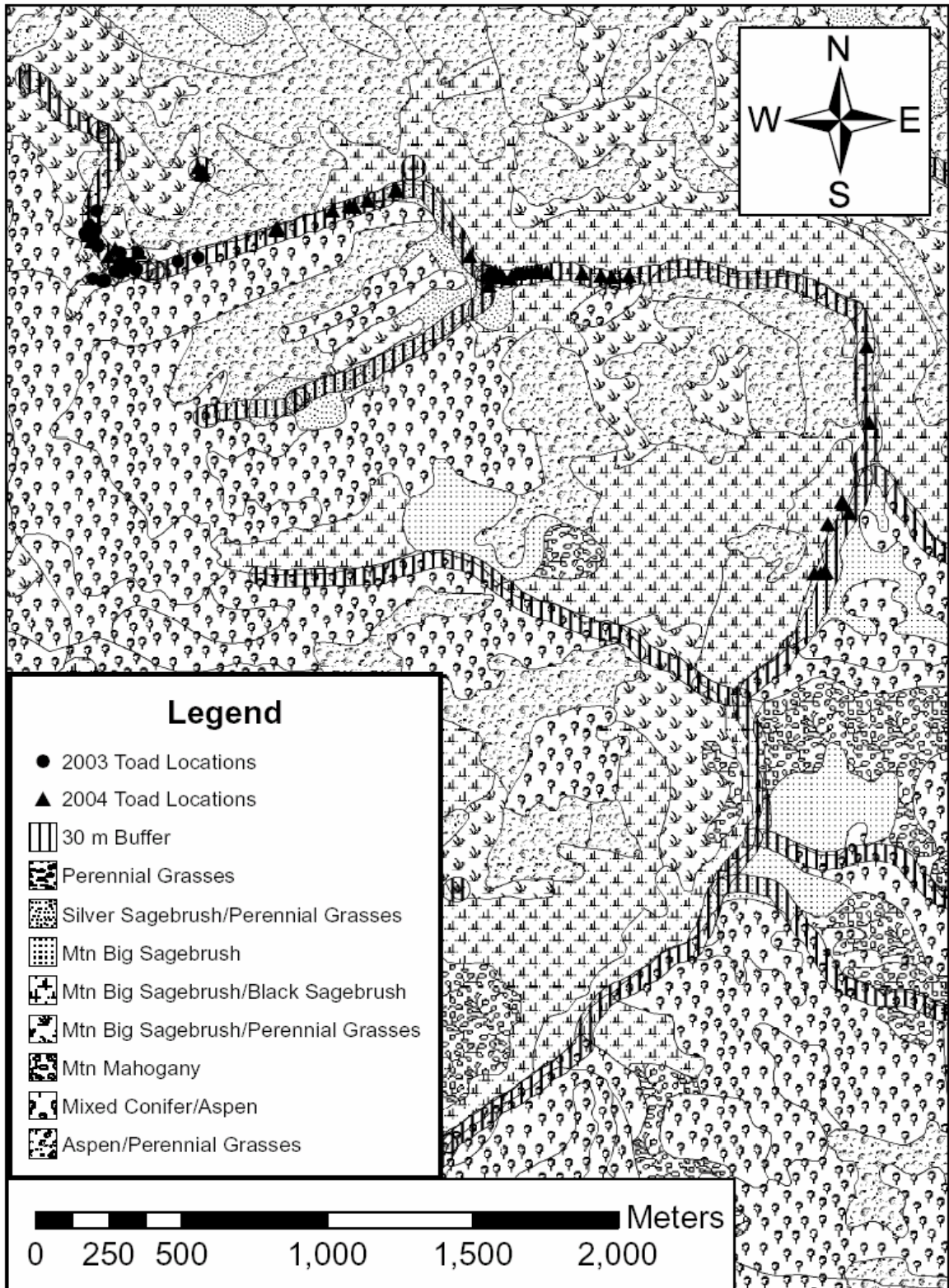
MAP 3



MAP 4



MAP 5



MAP 6

