Final Report

Baseline and initial monitoring assessment of *Martes americana,* the American Marten, at Heavenly Ski Resort, Lake Tahoe

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TABLE OF CONTENTS

LIST OF FIGURES **5**

LIST OF TABLES **7**

EXECUTIVE SUMMARY **8**

INTRODUCTION **10**

CURRENT HABITAT DEFINITIONS FOR *MARTES AMERICANA* 13
PROBLEM STATEMENT 13
PREVIOUS *MARTES AMERICANA* RESEARCH ON HEAVENLY SKI AREA 15

OBJECTIVES **15**

STUDY AREA **16**

METHODS **18**

REMOTE DETECTION: INFRA-RED CAMERAS AND TRACK PLATE STATIONS 18
REMOTE DETECTION: SNOWTRACKING 19
IKONOS SATELLITE IMAGERY 20
SCHEDULING 23
EQUIPMENT 23

DATA QUALITY AND AVAILABILITY **23**

DATA ACQUIRED FROM OTHER SOURCES 23
Data generated from Ikonos imagery *29*

STATISTICAL AND SPATIAL ANALYSES **31**

Kruskall-Wallis ANOVA *31*
One-way repeated measures ANOVA *32*
Paired samples t-test *32*
Area and distance calculations *32*

RESULTS **32**

CAMERA AND TRACK PLATE DETECTION STATIONS (2002) 32
CAMERA AND TRACK PLATE DETECTION STATIONS (1993) 35
COMBINATION OF 1993 AND 2002 SURVEY DATA (P/A) FROM CAMERA STATIONS 36
ANALYSIS OF TIME SERIES BASED ON CAMERA DETECTIONS 2002 42
Winter *42*
Summer *46*
SEASONAL CAMERA STATION COMPARISON 48
SNOWTRACKING 50
Other species recorded with remote detection methods *52*
MARTEN HABITAT DELINEATIONS 53

DISCUSSION **57**

ACTIVITY LEVELS OF MARTEN AT HEAVENLY 58

WHAT THE SNOWTRACK DATA INDICATES REGARDING ANIMAL MOVEMENTS 60
COMPARISON OF 1993 STATION DETECTIONS TO 2002 STATION DETECTIONS 61
WHAT CAN BE SAID ABOUT PREDICTING MARTEN OCCURRENCES? 62
EVALUATION OF REMOTE PHOTOGRAPHS – COMMENTS ON INDIVIDUAL ANIMALS 63
Home ranges 63
LANDSCAPE PERSPECTIVE BASED ON IKONOS SATELLITE IMAGERY 68
HABITAT STATUS 68
Habitat rule definitions 70
The importance of an educated staff – collaboration is imperative 74

MANAGEMENT RECOMMENDATIONS 75

SUGGESTIONS FOR FURTHER STUDY 76

ACKNOWLEDGEMENTS 77

REFERENCES CITED 78

APPENDIX 1 81

APPENDIX 2 84

LIST OF FIGURES

Figure 1. *Martes americana,* the American marten. 10
Figure 2. Heavenly ski area at Lake Tahoe in California and Nevada..... 17
Figure 3. Ikonos imagery fused XS-Pan with Brovey transform clipped to the extent of the USFS special use permit area for Heavenly Ski area..... 22
Figure 4. Example of existing spatial data and the lack of ground control when compared to truth data..... 24
Figure 5. Example of the quality of the roads data layer. Digital road layer shown in black overlaid on Ikonos imagery..... 25
Figure 6. Zoom picture of how some ski runs on file are somewhat consistent with actual conditions. Note the shape and size of the reservoir is in error as well (center)..... 26
Figure 7. Clearly the ski run layer is not an acceptable layer for use in analysis based on the representative sample shown here. There is considerable lack of truth in location, shape, and extent of indicated ski runs..... 27
Figure 8. Extent of available data from LTBMU shown using the vegetation layer as an example. Data are not available from this source for the entire study area, only for the jurisdiction within the Lake Tahoe Basin. 28
Figure 9. Example of vegetation attribute inaccuracy. Polygon B (Lodgepole pine) is labeled 50% tree canopy cover while polygon A (Jeffery pine) is attributed with 10% canopy cover..... 29
Figure 10. Permutations of detections at camera stations for the 2002 survey..... 34
Figure 11. Summer versus winter detections in the 1993 surveys..... 38
Figure 12. Comparison of detections for the 1993 and 2002 surveys, respectively. 39
Figure 13. Comparison of detections during summer surveys in 1993 and 2002..... 40
Figure 14. Winter detections in 1993 and 2002, respectively..... 41
Figure 15. Order in which camera stations had positive detections during the first round of camera stations in the winter survey. 43
Figure 16. Detection times at stations during winter surveys. 44
Figure 17. Detection time during summer surveys. 46
Figure 18. Frequency histogram of the timing of detections during winter surveys (top) and summer surveys (bottom). The bi-modal distribution during the winter is clear. Time ranges indicated above bars indicate no activity at camera stations in the winter between approximately 8am and 3pm. During the summer activity was seen throughout the day and night. Labels on figures on the right indicate count. 49
Figure 19. Snow tracks of marten collected during the winter 2002 survey and subnivean access points identified while tracking..... 51
Figure 20. Area (ha) for each stand shown by canopy cover type for Rule 1 habitat..... 55
Figure 21. Area (ha) for each stand type of rule 1 (blue) and rule 2 (purple) habitat, respectively..... 55
Figure 22. Area (ha) for each dominant cover class for Rule 3 habitat. "None" indicates open area such as ski run..... 56
Figure 23. Comparison between area (ha) by dominant cover species for rules 3 (blue) and 4 (purple), respectively..... 56
Figure 24. Camera detections that could not physically be made by the same individual marten. The animal would have had to travel over 3.5km straight line distance in 11 minutes. 65

Figure 25. This photograph clearly indicates the marten is a male. 66
Figure 26. Theoretical home ranges for two known different individual marten (red and green circles) and one hypothesized third individual (pink circle). 67
Figure 27. Mean canopy cover (%) for rules 1 and 2 for each overstory stand type. 71
Figure 28. Canopy cover (%) for rules 3 and 4 for each overstory stand type. 72
Figure 29. Comparison of mean canopy cover by stand type between habitat defined by detection station only (purple) and habitat defined by detection station and snowtrack data (blue). 73

LIST OF TABLES

Table 1. Selected runs to be sampled during winter 2002 field season. 19
Table 2. Data recorded using the GPS and TDS data logger for each snowtrack transect. 20
Table 3. Summary of basic information regarding remote detection stations and success of positive marten detection in 2002. 33
Table 4. Seasonal detections in 2002. 35
Table 5. Seasonal detections in 1993. 36
Table 6. Comparison of seasonal detections for 1993 and 2002. Those stations that had detections in winter and summer for each year or no detections at all are highlighted in yellow. Stations with the same seasonal pattern are highlighted in green. Stations that had no detections in 1993 but then had detections in 2002 are highlighted in cyan. 37
Table 7. Summary of camera detections during summer surveys. Number of discrete detections in the day and night (based on sunrise and sunset) are given by station..... 44
Table 8. Results from Kruskall-Wallis ANOVA on winter survey data. No significant difference in time of detection was found between camera stations. 45
Table 9. Results from one-way ANOVA on winter detection data. No significant difference was found between camera stations but there was a significant difference in time of day of detections. 45
Table 10. Summary of camera detections during summer surveys. Number of discrete detections in the day and night (based on sunrise and sunset) are given by station..... 46
Table 11.Results from Kruskall-Wallis ANOVA on summer survey data. No significant difference in time of detection was found between camera stations. 47
Table 12. Results on one-way ANOVA for summer camera data. There was no significant difference in the time of activity at stations during the summer. 48
Table 13. Results from the paired samples t-test on daytime activity at camera stations. 50
Table 14. Results from the paired samples t-test on nighttime activity at camera stations. ... 50
Table 15. Characteristics of the subnivean access points identified while snowtracking. 52
Table 16. Detail of subnivean access points indicating which kinds of access are used for different types of subnivean access. 52
Table 17. Species other than marten that were detected at camera and trackplate stations and during snowtracking. 53
Table 18. Area delineated as marten habitat based on four different rule-based classifications. 54
Table 19. Area (HA) by dominant canopy species for each of the 4 habitat layers. 54
Table 20. Canopy cover estimates for each stand type compared for habitat defined by camera station data alone and by both camera station data and snowtrack data. 57

EXECUTIVE SUMMARY

Vail Corporation leases land from the USFS to operate Heavenly Ski Resort and as such is required to meet and comply with environmental regulations and mandates. The American marten (*Martes americana*) is considered to be a species of concern by the USFS Lake Tahoe Basin Management Unit (LTBMU) and as such is given special consideration and monitoring in special use permitted areas such as Heavenly. Heavenly first conducted a marten survey in 1993 using remote camera detection and track plate stations. Marten were found to occur within the administrative boundary. However, Heavenly did not fulfill the obligations of its Master Plan by additional monitoring within a 5-year period, nor did the LTBMU enforce this requirement of the Master Plan until 2001. In 2001 Heavenly, the LTBMU and DRI collectively approved and funded a marten survey to gain additional knowledge about marten within Heavenly boundaries. The research presented here was conducted in partial fulfillment of the Master Plan by Heavenly as approved by the LTBMU.

Detection stations were re-established based on the best available location information from the 1993 survey in order to make temporal comparisons of marten presence/absence. More marten detections were found in 2002 than in 1993. Location of detections varied seasonally and geographically between the two survey years. From the 2002 data, marten were found to be active only at night during the winter but were found to be diurnal during the summer months. These findings are in agreement with research conducted outside the basin in non-recreation managed areas.

Preliminary snow tracking data collection was successful in terms of feasibility and data quality. Precise location of where marten occurred as well as detailed data describing subnivean access were collected and analyzed. The pilot snowtracking indicates that important information can be learned about marten activities that relate to landscape use.

Analysis of available digital spatial data layers for Heavenly was conducted and found that existing data are outdated, inaccurate, and non-comprehensive for the area. Marten habitat could neither be updated nor delineated using existing digital data layers. Therefore marten habitat was delineated with July 2002 Ikonos satellite imagery, based on canopy cover and dominant overstory species composition. Four habitat delineations are presented to educate managers about the process of defining and determining extent of wildlife habitat. Of the presented habitat delineations only one represents what is most likely the closest approximation of the areas within Heavenly managed boundaries that marten use. This habitat delineation is based on camera detections, snow track data, and wildlife habitat relationship model theory and collectively represents over 1400 ha.

Marten at Heavenly were found to use a greater range of forest conditions than have been published based on surveys outside the Lake Tahoe Basin. The individual marten at Heavenly use a variety of forest stand types and were found not only to cross open areas such as ski runs and lifts, but to use them for foraging activity during the winter. Based on survey results of this work, much of Heavenly is used by marten, including very dense stands and stands with very low canopy cover. What remains unknown and is of critical importance, however, is the relative suitability of each of these habitat types. That is, can the existing

habitat map be further refined to reflect which areas are most important, which are less important and what are the respective habitats used for?

Management recommendations were made based on results from this work, from integration of existing published literature and from information in the Heavenly Master Plan. Recommendations encompass a variety of tasks ranging from data collection to restrictions on activities within Heavenly to additional research that would refine current habitat definitions.

INTRODUCTION

The American marten is one of seven species in the genus *Martes* within the Family Mustelidae, Order Carnivora (Corbet and Hill, 1986). Along with the Eurasian pine marten (*M. martes*), the sable (*M. zibellina*), and the Japanese marten (*M. melampus*), it belongs to a group of closely related and ecologically similar species called the "boreal forest martens". (Buskirk, 1992). The only other *Martes* in North America is the much larger-bodied fisher (*M. pennanti*). The American marten (*M. americana*) is a slender-bodied endotherm with relatively short limbs and a bushy tail. Marten fur is dense and ranges in color from pale yellowish buff to tawny brown to almost black (Figure 1). The marten throat and chest bib ranges in color from pale straw to orange (Clark, 1987). Male martens range in total body length from 510-680 mm and weigh 470-1300 grams. Female martens range in total body length from 455-600 mm, and weigh 280-850 grams (Nowak 1999).

Figure 1. *Martes americana,* the American marten.

The American marten is endemic to and found throughout North America in coniferous dominated montane forests (Ruggiero et al., 1993; Spencer et al., 1983). It occurs from the southern Rockies in New Mexico northward to treeline in Canada and Alaska, and from the southern Sierra Nevada eastward to Newfoundland in Canada. In the contiguous western

United States, martens are limited to mountain ranges within a narrow band of coniferous forest habitats (Buskirk and Ruggiero, 1994). Although subspecies have been identified, there is discussion in the literature regarding whether or not the marten should be recognized as one species or as several subspecies (Clark et al, 1987; Hall 1981). For example, the Humboldt Marten, *M. a. humboldtensis* and the Sierra Nevada marten *M. a. sierrae* are considered to be subspecies that occur in northern California and the Sierra Nevada, respectively (Kucera, et al. 1995).

In California, the marten was historically distributed throughout the Sierra Nevada, California Cascades, and the Coast ranges, from the Oregon border southward to Sonoma County. Martens are currently distributed throughout the Sierra Nevada and Cascades (Buskirk and Zielinski, 1997). The species' core elevation range is from 5,500 to 10,000 feet, and they are most often found in the Sierra Nevada above 7,200 feet. In a 1994 USFS General Technical Report, Ruggerio et al. identified management considerations and research needs for marten within eight categories: distribution and taxonomy, population ecology, reproductive biology, food habits and predator-prey relationships, habitat relationships, home range, community interactions, and conservation status. While these issues were addressed in terms of marten populations throughout their greater geographic range, there is much to be learned about local populations in the Sierra Nevada of Nevada and California in each and all of these categories.

Marten are omnivores. In the Sierra Nevada red squirrels, rabbits, other small mammals, insects, birds, nuts/seeds, vegetation and berries comprise the marten's diet, as seasonally available (Hargis and McCullough, 1984). Mean home range sizes in the Sierra Nevada are reported between 3.2km^2 and 3.6km^2 for females and males, respectively (Barrett and Spencer, 1982). Reproduction requires suitable natal dens, which have different characteristics than resting dens. While some effects of forest fragmentation have been reported based on studies in the Intermountain west (Hargis and Bissonette, 1997), fragmentation from recreational or other activities has not been evaluated in the southern Lake Tahoe Basin. Reports in gray literature indicate habitat preferences differ by geographic range, such as Pacific Northwest versus Sierra Nevada.

Marten home ranges are very large relative to their body size by mammalian standards. Consistent with observations that home range size expands as habitat quality declines, home range sizes for eastside martens (Inyo and Humboldt-Toiyabe National Forests) are at least three times larger than that known for westside martens (Buskirk and Ruggiero, 1994; Buskirk and Zielinski, 1997). In eastside habitat, male home ranges average 2,749 acres in size and female home ranges average 1,155 acres in size (Kucera, 1996).

Breeding occurs from June to August. Implantation of the fertilized eggs in the uterus is delayed until February, and embryonic development then proceeds for 28 days. The average number of young per litter is 2.6 (1-5). The young weigh approximately 28 grams at birth, open their eyes after 39 days and are weaned at 6 weeks. The female is the sole caregiver. Kits typically reach adult size at 3.5 months (Nowak, 1999) and attain sexual maturity at 15-39 months (Jonkel, 1963). Dispersal distances of 24 to 60 miles have been reported (Nowak, 1999).

Marten natal dens are typically found in cavities in large trees, snags, stumps, logs, burrows, caves, rocks, or crevices in rocky areas. The dens are lined with vegetation and have been found to occur primarily in structurally complex, late successional forests (Buskirk and Ruggiero, 1994). Post-natal dens are typically found in cavities, logs, underground or in slash piles. (Bull and Heater, 2000). Canopy cover and the number of large old trees in these patches exceed levels available in the surrounding suitable habitat. The availability of habitat suitable for natal dens may limit reproductive success and population recruitment; this has direct repercussions on future population size (Buskirk and Ruggiero, 1994).

The marten diet in the Sierra Nevada, and specifically in the Lake Tahoe Basin, changes seasonally but is predominately microtine rodents, tree squirrels (*Tamiasciurus douglasii* and *Glaucomys sabrinus*), snowshoe hares (*Lepus americanus*) and, especially in the summer, ground squirrels (*Eutamias* sp. and *Spermophilus lateralis*) (Zielinski et al., 1983; Martin, 1987). Voles make up a large portion in terms of frequency of the marten diet, but snowshoe hare, and grouse (*Lagopus* sp. and *Bonasa umbellus, Falcipennis canadensis, Dendragapus obscurus*) account for 78% of caloric intake (Cumberland, Dempsey and Forbes, 2001).

Some marten research has been conducted near the Lake Tahoe Basin. Schempf and White (1977) reported highest marten abundance in fir forests just outside of northern Lake Tahoe. A pine marten habitat suitability model was evaluated and refined by Barrett and Spencer (1982) based on three areas near the Lake Tahoe Basin, California in Sagehen Creek Basin. The model quantified the relationship of marten habitat in terms of foraging, resting, and cover preferences. Spencer et al. (1983) also described resting and foraging habitats in the Sagehen Creek Basin. Their results indicated that marten use of a variety of habitats such as meadow-forest transition zones and low elevation lodgepole pine stands. Results from this work also corroborated earlier studies indicating that marten avoid open areas and stands with less than 30% canopy closure. A progress report in 1995 by Zielinski et al. documented results of efforts ongoing at the time including data on rest sites, natal dens, and preliminary mean home range size for this area.

Because so little is known about marten in the Lake Tahoe Basin, there is much to be learned. No research has focused specifically on the Lake Tahoe Basin to date. Most marten work has been conducted over larger areas, such as Sierra Nevada or Pacific Northwest wide. A 1993 meeting hosted by the California Owl EIS team in Redding on the status of marten and fisher resulted in a wealth of comments that can be summarized as the collective recognition that relatively little is known about marten in the Pacific Southwest. Kucera et al. (1995) described the current distribution of marten in California based on field surveys and called for the use of only quantitative field methods to document the species distribution. Zielinski and Stauffer (1996) published a survey design specifically for marten in California. Foresman and Pearson (1998) follow up with a comparison of two survey methods, track plates and remote cameras.

Current habitat definitions for *Martes americana*

Past work on marten habitat has indicated this species prefers coniferous forest habitat with large diameter trees and snags, large downed logs, moderate-to-high canopy closure, and an interspersion of riparian areas and meadows. Important habitat attributes include vegetative diversity with predominately mature forest in addition to snags, suitable dispersal cover, and large woody debris (Allen, 1982). Martens have traditionally been found to select stands with 40 to 60 percent canopy closure for both resting and foraging and have been cited as avoiding stands with less than 30 percent canopy closure (Spencer et al., 1983).

Important forest types in the western slopes of the Sierra Nevada and northern Sierra Nevada for marten have been found to include red fir, lodgepole pine, subalpine conifer, mixed conifer-fir, Jeffrey pine, and eastside pine. Martens are closely associated with relatively mesic, late successional coniferous forests with complex physical structures (large snags, large down woody material, and debris piles), especially near the ground. These complex ground cover characteristics appear to provide protection from predators, support prey, allow access to subnivean (below snow) spaces, and provides protective thermal microenvironments particularly important in the winter (Buskirk and Powell, 1994; Thompson and Harestad, 1994; Spencer et al. 1983). Empirical data on marten use of forested habitat on the eastside of the Sierra Nevada are sparse. Marten in these habitats appear to focus on microhabitat elements available in greater proportion than westside areas, such as rock piles and scree slopes (Kucera 1996).

The use of squirrel middens by marten has been documented throughout the western United States and specifically in the northern Sierra Nevada (Spencer, 1987; Martin and Barrett 1991). At the Sagehen study site on the Tahoe National Forest, Spencer et al. (1983) noted that marten preferred sites with Douglas squirrel feeding sign (middens) (Spencer et al., 1983). It has been suggested that marten select rest and denning sites near tree squirrel middens due to the number of prey items that are attracted to middens (chipmunks, shrews, flying squirrels, voles, mice) (Pearson and Ruggiero, 2001). Marten also directly use middens for rest sites and denning sites due to the insulative properties of woody material such as that found in middens (Buskirk, 1984; Spencer, 1987; Martin and Barrett, 1991; Bull and Heater, 2000). Martens also use middens as subnivean access points (Sherburne and Bissonette, 1993).

Problem Statement

The Heavenly Ski Resort Master Plan was accepted by the US Forest Service (USFS) and the Tahoe Regional Planning Agency (TRPA) in June 1996. This document outlines requirements for minimizing loss and degradation of significant wildlife habitat (section 7.4-10) and establishes guidelines to monitor and protect pine marten populations. The initial environmental impact statement (EIS) indicated marten do occur, based on the 1993 Harland Bartholomew and Associates Forest Carnivore Surveys. However, no monitoring efforts for marten have been conducted since the Master Plan was adopted. As a result, little is known about the status of marten populations at Heavenly including population size, habitat usage,

or impacts from anthropogenic activities and subsequent behavioral adaptations, if any. The USFS is mandated not to approve development plans submitted by the resort unless adequate research supported and data interpretation have been shown to fulfill the requirements indicating minimal or no impact on selected species and associated habitats, specifically American marten, in the Master Plan.

A list of tasks were drafted (see *Objectives*, below) to assist Heavenly Ski Resort with meeting the requirements for American marten and associated habitat as outlined in the Master Plan and to quantify the initial status of marten. The results from this research provide a scientific baseline for addressing critical management issues for conservation and protection of American marten population(s) at Heavenly.

Impacts to marten at ski resorts are unknown from both individual animal and population perspectives. Recreation at ski areas across the country is expanding in terms of number of users and number of user-days as winter resorts become summertime recreation destinations for hikers, mountain-bikers, and other outdoor enthusiasts. Heavenly Ski Resort at Lake Tahoe boasts 29 ski lifts including a high-speed gondola that shuttles eight skiers to the top of the Von Schmidt trail in under 12 minutes, or approximately 2800 people an hour. With one of the US's largest snowmaking systems, up to 69% of Heavenly's 84 runs may be covered by man-made snow. During the winter months when the landscape is under snowpack, heavily used areas are restricted to groomed and ungroomed trails, inter-trail treed islands, and the within-boundary backcountry. Snowmaking may impact marten in the late fall or early winter or during times of low precipitation in peak season months, although these impacts are undocumented.

Human presence, the compaction of snow, trail grooming, noise and photopollution (artificial light), habitat fragmentation, altered stand age and structure of critical habitat, and a negatively affected prey base are all possible factors impacting marten populations at Heavenly, or any, ski resort in the Tahoe Basin. At Heavenly in particular, the new gondola provides easy and fast hiking access to the upper mountain, but new trails have not been established to accommodate this summertime activity. The impacts of increased user days and increased seasonal use on marten are unknown. Management for quality winter habitat is in part dependent on an understanding of the structure, type, and abundance of coarse woody debris (CWD) for subnivean access (Corn and Raphael, 1992). Heavenly’s soil erosion control policy is to preserve most downed woody debris and the Master Plan guidelines require that trees larger than 24 inches diameter at breast height (DBH) be retained, intact, within boundaries. Policies such as retaining CWD may increase habitat for marten, but without rigorous scientific analyses, the effects of such policies remain unsubstantiated. A very basic survey was conducted and is discussed below. However, to quantify basic population parameters and articulate the status of marten at Heavenly, a study designed to address specific critical questions that can be used for quantitative analysis is fundamental and necessary.

Previous *Martes americana* research on Heavenly Ski Area

Forest carnivore surveys were initiated in January 2002 as part of requirements listed in the Heavenly Ski Resort Master Plan as approved by the U.S. Forest Service (USFS) and Tahoe Regional Planning Agency (TRPA) in June 1996. The master plan outlines requirements for minimizing loss and degradation of significant wildlife habitat (section 7.4-10) and establishes guidelines to monitor and protect American marten populations. The initial environmental impact statement (EIS) indicated that marten do occur based on a 1993 Harland Bartholomew and Associates Forest Carnivore Survey. Since the 1993 initial monitoring effort, however, no further surveys had been conducted for forest carnivores at Heavenly Ski Resort.

The initial forest carnivore survey effort conducted by Harland Bartholomew and Associates in 1993 involved the use of track plate stations and infra-red cameras at 27 stations which were placed within an area delineated by including habitat one-half mile beyond the perimeter of all proposed project development and activity areas at Heavenly. American marten were detected at 16 sites using a combination of baited tracking plates and infrared cameras. In 2002, station placement was designed to mimic the 1993 station placements. No metadata existed to document exact locations of these stations, and therefore repeat (2002) stations were installed as close to the 1993 locations based on rudimentary maps from the Methods and Results of the Heavenly Ski Resort Forest Carnivore Surveys (Harland Bartholomew and Associates, Inc. June 1993). Results of this work were reported based on summer and winter surveys and related to an unpublished literature review. Clearly marten are present at Heavenly, but little else is known other than the fact that they do occur and that peak activity is after sunset during peak ski area activity months (winter). Management decisions cannot be made based on this initial information alone.

OBJECTIVES

This research initiated collection of baseline data, developed a viable methodology that quantified specific aspects of marten at Heavenly Ski Resort and provided a monitoring protocol. Marten were last documented at Heavenly in 1993. The purpose of the proposed project was to document continued marten occurrence at Heavenly and to provide an initial analysis of the status of marten and quantify their use of the resort landscape. To meet these objectives the following was accomplished:

1. Evaluate existing data and collection methodologies for marten at Heavenly.
2. Establish current P/A of marten.
3. Document habitat preferences for marten activities and timing of activities.
4. Delineate existing habitat within the ski area.
5. Compare marten activities and habitat preferences at Heavenly to results from other studies within the Tahoe Basin and in the greater Sierra Nevada.
6. Provide the Forest Service and Heavenly Ski Resort suggestions for continued research and monitoring of marten based on the results of data collections and analysis from the research.

STUDY AREA

Located to the southwest of Lake Tahoe, Heavenly Ski Area is one of the largest ski resorts in the Lake Tahoe Basin (Figure 2). The USFS administrative permit area for Heavenly ski area is 4226.16 ha and includes lands within the Lake Tahoe Basin as well as outside the basin and falls both in California and Nevada. Heavenly Ski Resort at Lake Tahoe boasts 29 ski lifts including a high-speed gondola that shuttles eight skiers to the top of the Von Schmidt trail in under 12 minutes, or approximately 2800 people an hour. With one of the US's largest snowmaking systems, up to 69% of Heavenly's 84 runs may be covered by man-made snow. During the winter months when the landscape is under snowpack, heavily used areas are restricted to groomed and ungroomed trails, inter-trail treed islands, and the within-boundary backcountry.

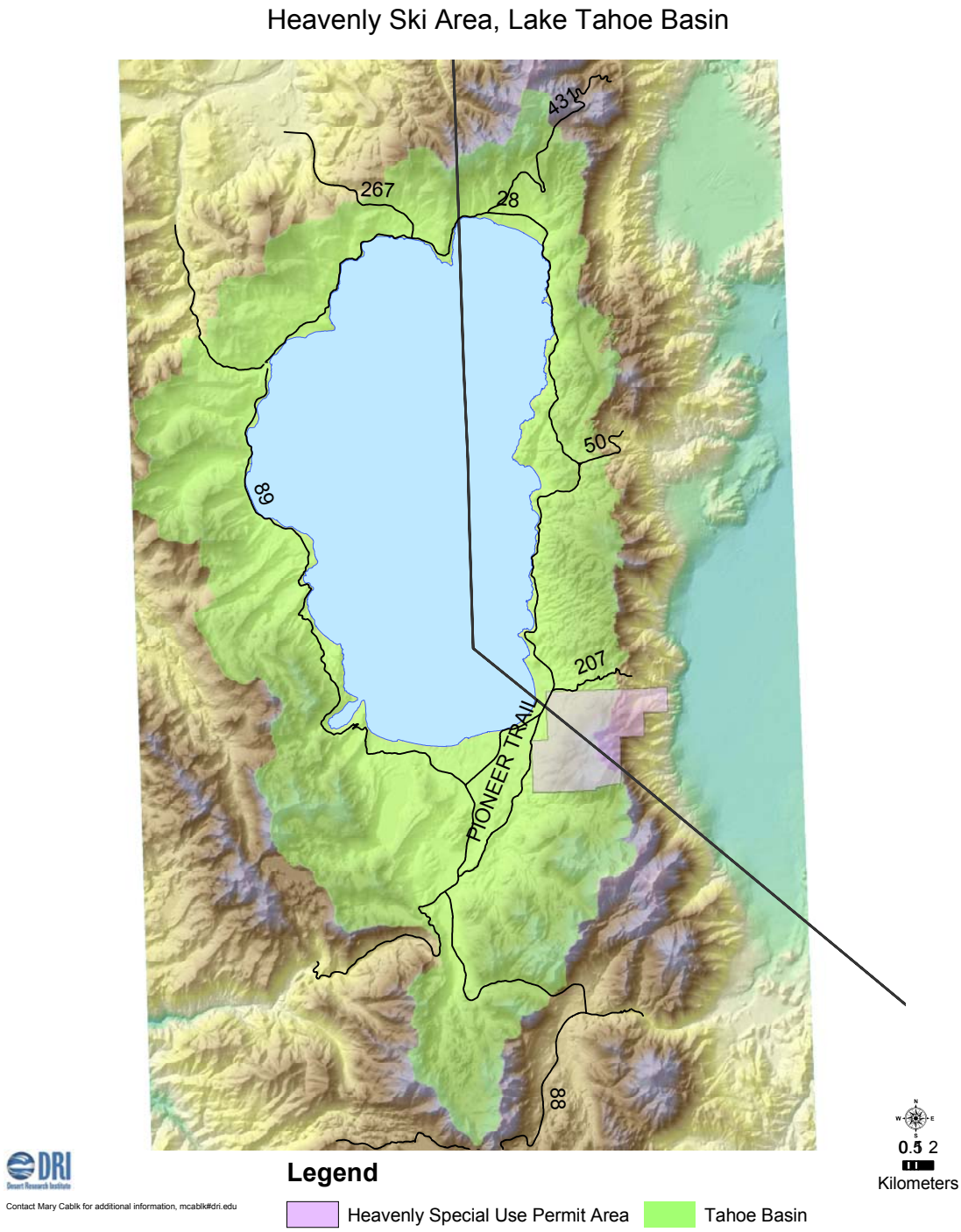

Figure 2. Heavenly ski area at Lake Tahoe in California and Nevada.

METHODS

Remote Detection: Infra-red cameras and track plate stations

The initial forest carnivore survey effort conducted in 1993, involved the use of trackplate stations and infra-red monitors and cameras at 27 stations which were placed within an area delineated by including habitat one-half mile beyond the perimeter of all proposed project development and activity areas at Heavenly. In 2002, station placement was designed to mimic the 1993 station placements. No metadata existed to document exact locations of these stations, and therefore repeat (2002) stations were installed as close to the 1993 locations based on rudimentary maps from the Methods and Results of the Heavenly Ski Resort Forest Carnivore Surveys (Harland Bartholomew and Associates, Inc., 1993).

Camera stations included Trail Master 1550 (Active Infra-red Trail Monitor) and Trail Master 550 (Passive Infrared Trail Monitor) in conjunction with the Trail Master 35-1 camera kit. Stations were baited with approximately one pound of organic chicken necks per station. Part of the chicken was placed in a 12" by 12" wire mesh bait cage, and part was attached to the outside of the bait cage. All equipment and bait was placed at a minimum of five feet above the ground. Trackplates were also initially used which consisted of a box made of four pieces of 32" X 12" plywood into which a 30" X 8" sooted aluminum plate was placed. Locations of all stations were recorded using a Garmin 12XL GPS (UTM zone 10, NAD83) connected to a Ranger Tripod Data Systems (TDS) database unit. All data not collected in this projection and datum, such as data acquired from other sources, were converted to UTM zone 10 NAD83 for use with Ikonos satellite imagery.

Cameras were set up in three rounds of nine stations each and were monitored in accordance to the accepted USFS forest carnivore monitoring protocol (Zielinski and Kucera, 1995). A total of 26 stations were maintained for 30 days or until a marten detection occurred, whichever came first. One station was removed due to vandalism and threats of violence from a transient population. This station was considered unsafe for crew to visit. Three rounds of 26 stations were conducted during the following time periods:

Round 1 - January 4, 2002 - February 6, 2002
Round 2 - February 7, 2002 - March 9, 2002
Round 3 - March 10, 2002 - April 15, 2002
Round 4 – June 10, 2002 – July 9, 2002
Round 5 – July 17, 2002 – August 19, 2002
Round 6 – August 20, 2002 – September 21, 2002

Camera stations were visited, re-baited and film was collected for development, and reset if necessary, every four to five days accessed on snowshoes or skis. All digital detections recorded by the Trail Master receivers were downloaded into a database, and concomitant photos were labeled with date, time and station information. All detection photos were copied in triplicate for USFS, Heavenly and DRI records.

Trackplates were set up at six of the 27 original stations and were placed no farther than 40 meters from the cameras. This was done to duplicate initial survey methods. Trackplates, which were also baited with chicken, were checked synonymously with the camera stations. All tracks were collected and identified.

Date and time records of photographs of marten were converted to absolute time against a starting time, where this starting time (0) was 1640 h of the first day the stations were installed. Absolute time for each camera detection as related to this zero-point were calculated in days to detection.

Remote Detection: Snowtracking

Snowtracking was conducted after any amount of snowfall occurred during the previous 14 hours. USFS personnel were allowed early access to the mountain on suitable days so that tracking could be conducted for up to an hour before public access disturbed fresh tracks. Depending on topography, snowtracking was conducted on either skis or snowshoes.

Transects to be snowtracked were identified to sample runs and lifts equally, as well as being located on the periphery of the resort or within (termed outside or inside). Runs on the periphery of the resort are termed "outside" and runs within the resort are termed "inside". This differentiation was made based on the ready access to large tracts of forested habitat without anthropogenic interference. Runs were selected to compare data on where marten are known and are not known to occur. "Known" indicates that marten had been known to occur near a given run or lift while "Unknown" indicates that marten were not known to occur near a given run or lift based on USFS wildlife biologist expertise. All categories were attempted to have equal representation in terms of survey numbers where possible, i.e., same number of runs/lifts.

Table 1. Selected runs to be sampled during winter 2002 field season.

Name	Run/Lift	Known	Unknown	Inside/Outside
Face – eastside	Run	√		Outside
Ridge – Canyon	Run	√		Outside
Top of Gondola	Lift	√		Outside
Powderbowl	Lift	√		Inside
Stagecoach	Lift	√		Inside
Galaxy – wetland	Run		√	Outside
North Bowl	Run		√	Outside
Galaxy – Perimeter	Run		√	Inside
Little Dipper/Comet Ex.	Lift		√	Inside

Table 2. Data recorded using the GPS and TDS data logger for each snowtrack transect.

Factor	*Type*	*Categories*
Canopy cover (Cc)	Category	0% = 1 1-20% = 2 21-40% = 3 41-60% = 4 61-80% = 5 81-100% = 6
Species (Sp) dominant overstory tree	Category	Jefferey Pine = 1 Western White Pine = 2 White Bark Pine = 3 Mountain Hemlock = 4 Willow/Riparian = 5 Aspen = 6 Red fir = 7 White Fir = 8
Grooming (Gr) on adjacent run the night before tracking	binary	No = 0 Yes = 1
Snow-making (Sn)	binary	0 = no, 1 = yes
Inside/outside runs (Io)	binary	Outside = 1, inside = 2

If a marten track was detected along a transect, the transect was suspended and the track was followed. Information collected during forest carnivore tracking included: other animal tracks observed, subnivean access (one-way or two way), subnivean access type (branch, rock, downed log etc.), canopy cover, dominant tree species, and slope. One-way subnivean access was defined as a location where an individual marten both enters and exits. A two-way access is a location where an individual marten may enter and another access point exists within 50m. In this instance an individual may or may not enter and exit from the same location. These definitions follow previous work of Corn and Raphael (1992). Marten tracks were followed for as long as the tracks remained visible, and then the original transect was completed.

Ikonos satellite imagery

A multi-agency purchase of basin-wide satellite imagery purchased wall-to-wall multispectral and panchromatic bands of Space Imaging Ikonos imagery. The imagery was acquired on July 19, 2002 and is therefore very timely. Fortunately the imagery was acquired after the Gondola Fire occurred so smoke does not interfere with the quality of the scenes that comprise the Heavenly Ski area. This imagery was made available by DRI for the purposes of this project. Without the Ikonos imagery the habitat delineations would have been impossible.

The imagery was purchased with the highest level of processing including atmospheric and terrain corrections. It was orthorectified with cubic convolution and produced as a GeoTiff file which was converted to appropriate native ENVI and Band-interleaved by line (BIL) formats for further processing and interpretation. This is 11-bit imagery and all processing was conducted to maintain the integrity of 11-bit data.

The imagery was masked to the extent of the Heavenly special use permit boundary and fused using a Brovey transform (Figure 3). The purpose of this transform is to combine the spectral information of the multispectral bands (4m) with the spatial resolution of the panchromatic band (1m). This transformation was conducted in ERMapper to maintain 11-bit data.

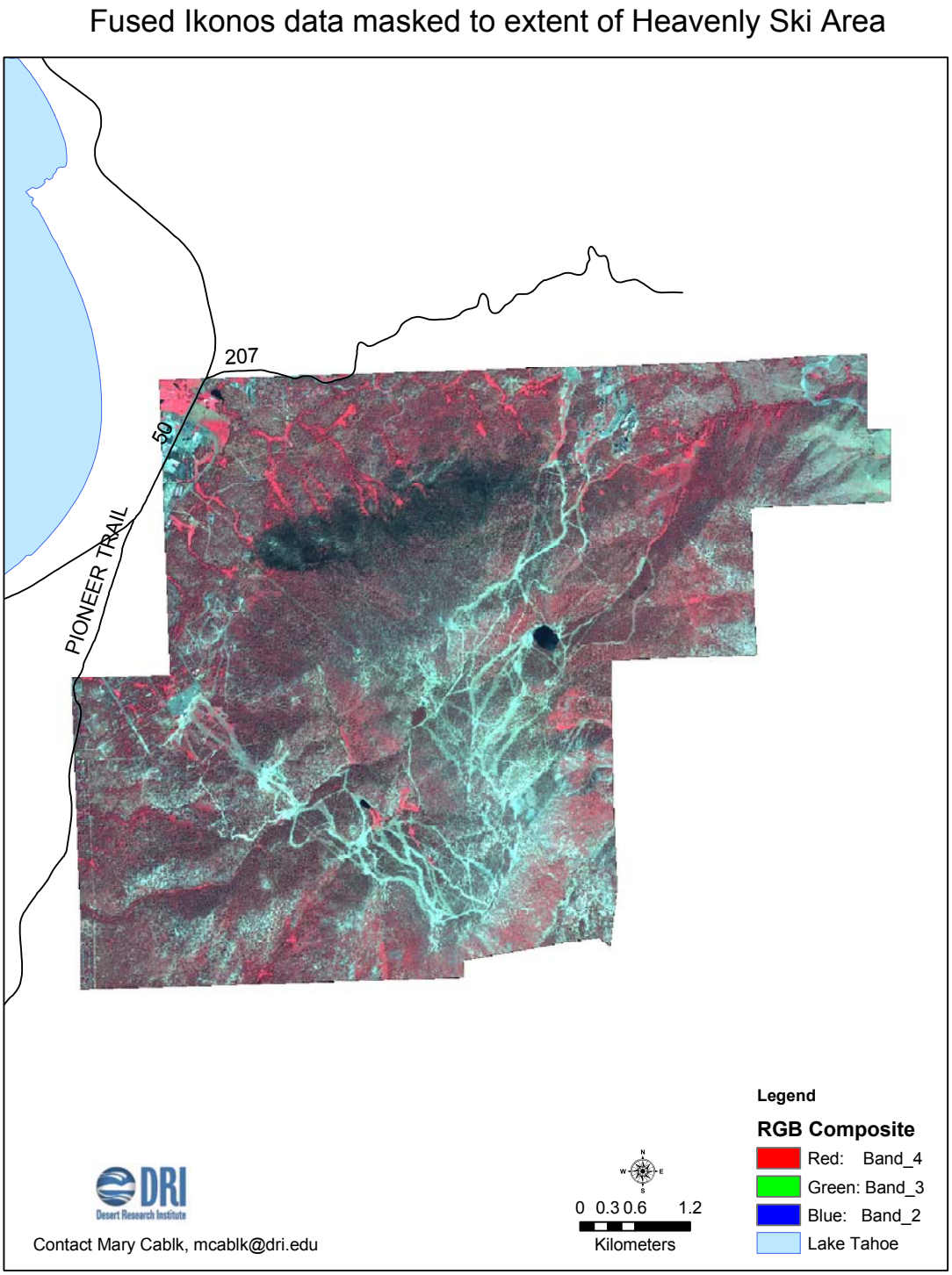

Figure 3. Ikonos imagery fused XS-Pan with Brovey transform clipped to the extent of the USFS special use permit area for Heavenly Ski area.

Scheduling

The work was scheduled by submitting requests for access to the mountain through Heavenly Ski Patrol. Scheduling with Heavenly Ski Patrol is critical for a number of reasons. First, safety was the highest priority. Some areas were unavailable for surveying due to dangerous snow conditions and avalanche control measures. Other areas were off limits entirely and were not sampled, specifically locations where avalanche control measures involving explosives were used.

Equipment

A Garmin 12XL GPS receiver was used for data collection in conjunction with TDS Ranger Data Logger and Solo Software. All of the data was collected digitally, directly with the Ranger Data Logger, and then transferred into a laptop. GIS data management, creation of graphics, and analyses were conducted using ArcView version 3.3, ArcGIS version 8.1, and Arc/Info. All image processing was conducted with ENVI version 3.5 and ERMapper.

DATA QUALITY AND AVAILABILITY

Data acquired from other sources

Spatial data were available and readily provided from the USFS LTBMU and included a vegetation layer and the spatial extent (boundary) of the special use permit area for Heavenly**.** These data were created before metadata documentation was a standard feature accompanying digital data layers and therefore best estimates about data quality are guesswork. However, it is known that digital data layers in USFS GIS are created almost entirely from aerial photography. The use of photointerpretation for creating digital data layers results in tremendous error, spatially, and these errors are exemplified throughout the data layers provided by the USFS. It should be noted that these statements do not reflect criticism on the USFS or any department or employee, rather, these are qualification statements relating to the reliability and accuracy of data that might have been used in analyses. For example, ski runs and major roads overlaid on the Ikonos 4m imagery are shown in Figure 4.

It is clear that some of the data “match”, such as roads (Figure 5). This means that the digital lines representing roads are true to their location on the ground. Some of the ski runs appear to have some good co-location to the imagery (Figure 6) but in the immediate vicinity, other runs are not in their “correct” locations, are depicted as either wider or narrower than reality, and in one instance in this figure, are shown to exist where clearly there is no ski run at all. In some instances ski runs occur in the Heavenly CAD layer because they represent future expansion projects, that is they are runs which may occur in the future but do not exist at present. Perhaps the best example to illustrate the degree of spatial inaccuracy is Figure 7, which does not geo-register with the imagery, both omits runs indicated in the imagery and

includes runs which do not exist, and in some instances generates different shapes created by the runs.

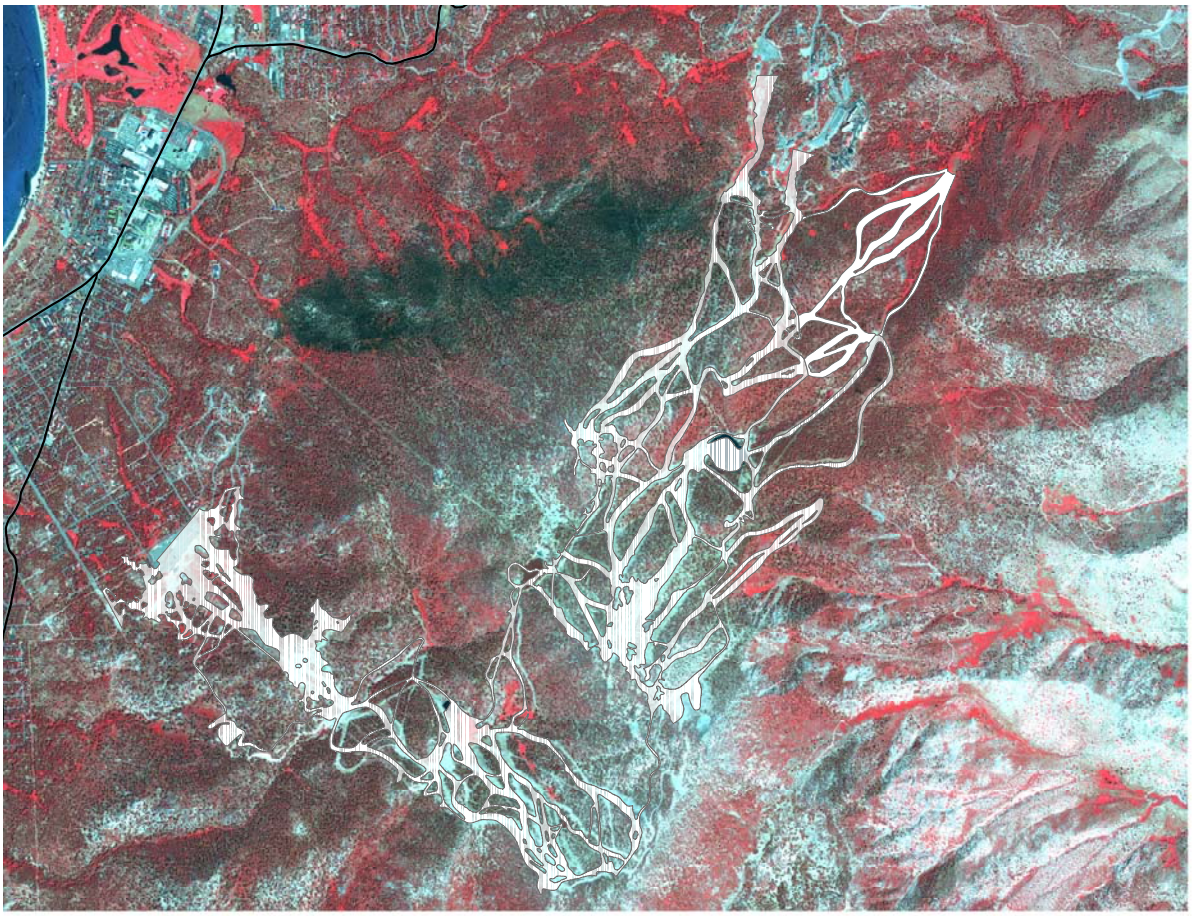

Figure 4. Example of existing spatial data and the lack of ground control when compared to truth data.

The reason that spatial digital data created from aerial photography results in such spatial inaccuracy is beyond the scope of this document. However, a short summary may assist the reader with understanding why this occurs. Aerial photographs are taken from unstable platforms, namely, aircraft that are at the mercy of winds and other disruptive factors. Steep terrain cannot be corrected for unless photographs are orthorectified, an expensive and time-consuming process. The Ikonos imagery is terrain corrected, georectified, and processed to the highest extent, creating a data set that is highly accurate spatially. The effect of terrain is shown demonstrated in Figure 5, where the land is flat and therefore a road could effectively be digitized off of an aerial photograph with good ground-to-photo match. The result of examining existing data is critical for conducting accurate, reliable scientific analyses. To use the existing ski run data layer in any analysis would result in inaccurate, incomplete, imprecise, and unusable results. We can have no confidence in results generated from a study that incorporates such unreliable and inaccurate data.

Figure 5. Example of the quality of the roads data layer. Digital road layer shown in black overlaid on Ikonos imagery.

Another difficulty was that the vegetation layer did not extend beyond the Lake Tahoe Basin (Figure 8). Comparing the vegetation layer with the Ikonos imagery, again there are fewer questions about spatial accuracy because the data layer was not created to "match" set anthropogenic features, such as roads. In fact, examination of the vegetation layer revealed its boundaries coincided fairly well with ski runs, where runs were wide enough to be delimited at such. However, some islands within ski runs were not digitized and were therefore grouped into the same description as the surrounding run.

Figure 9 illustrates attribute error in the vegetation data layer. The identified polygons appear in the imagery to be very similar in canopy cover. Yet, the two polygons identified in Figure 9 are said to have very different canopy cover and species composition. There is little room for argument that these two polygons do not have 50% and 10% tree canopy cover, respectively. This misrepresentation is pervasive throughout the data set. There are other factors to note that can be seen in this figure, such as inconsistencies where some polygons include parts of ski runs but others do not. Polygons also appear arbitrary in line work, meaning there does not appear to be a physical differentiation used to divide a stand into two or more separate polygons.

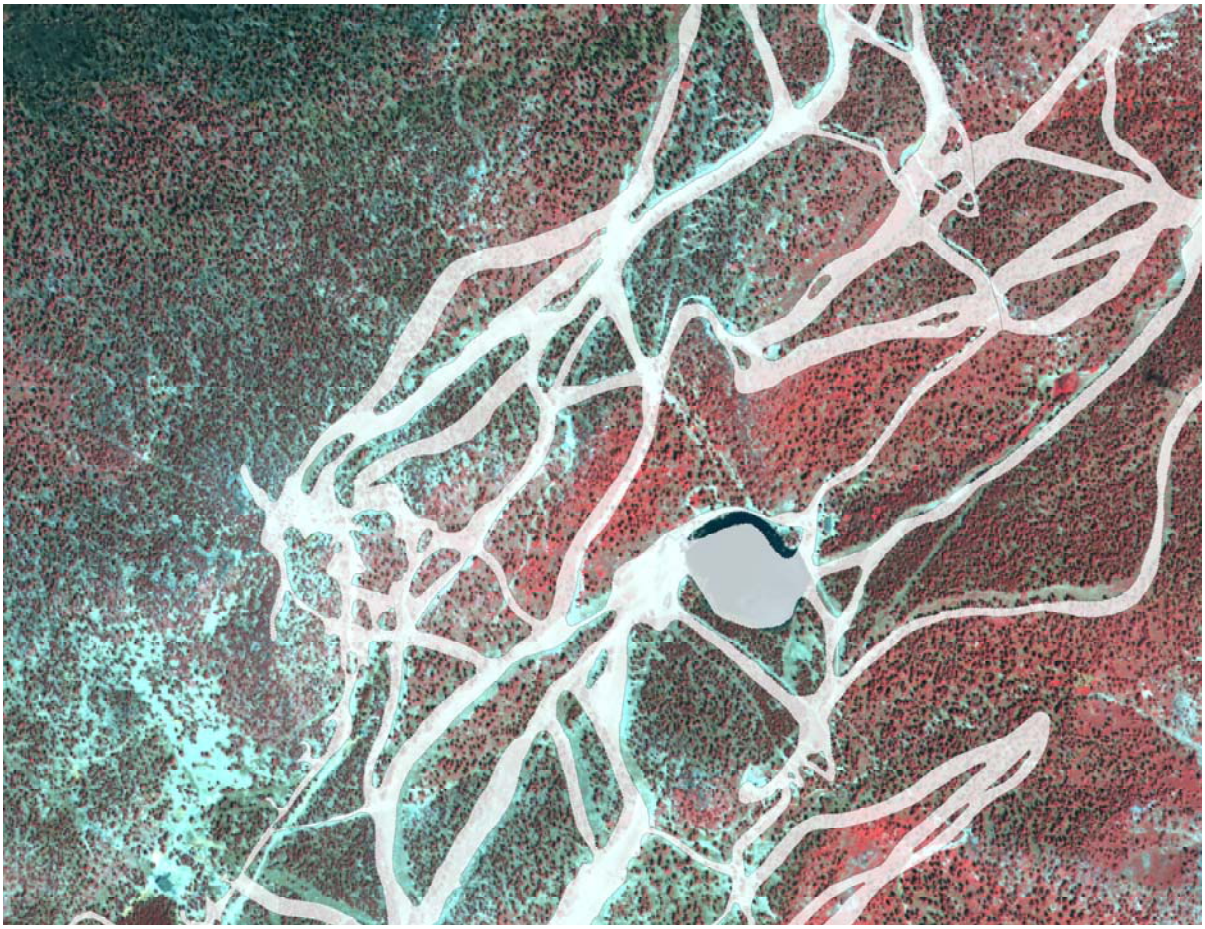

Figure 6. Zoom picture of how some ski runs on file are somewhat consistent with actual conditions. Note the shape and size of the reservoir is in error as well (center).

Digital Elevation Model (DEM) data was downloaded from the Lake Tahoe Data Clearinghouse (http://tahoe.usgs.gov/DEM.html). DEMs are derived from hypsographic data, also known as contour lines, and/or photogrammetric methods using USGS 7.5-minute, 15-minute, 2-arc-second (30- by 60-minute), and 1-degree (1:250,000-scale) topographic quadrangle maps. Typically, DEMs provided by the USGS are in 30m grid cells meaning that the area represented by the DEM is divided into squares that are 30m on each side. As a result, features smaller than 30m are lost in the resolution of the data, that is they will not appear because they are smaller than the resolution of the data. The DEMs acquired for this study were resampled to 10m by the USGS Western Geographic Science Center. These 10m DEMs were generated from the same source data as the 30m standard products (hypsographic DLGs) that have 40 ft contours, but were created at a smaller cell size. Therefore the elevational data has not been refined but elevation information has been interpolated to a finer spatial resolution. DEMs were transformed from UTM zone 10 NAD27 to UTM zone10 NAD83 for use in analyses.

Land use and land cover (LULC) was also downloaded from the Lake Tahoe Data Clearinghouse (http://tahoe.usgs.gov/landcover.html). This land cover data set was produced as part of a cooperative project between the U.S. Geological Survey (USGS) and the U.S.

Environmental Protection Agency (USEPA) to produce a consistent, land cover data layer for the conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. National Land Cover Data (NLCD) was developed from TM data acquired by the Multi-resoultion Land Characterization (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies that produce or use land cover data. Partners include the USGS (National Mapping, Biological Resources, and Water Resources Divisions), USEPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration. Classes are described in APPENDIX 1.

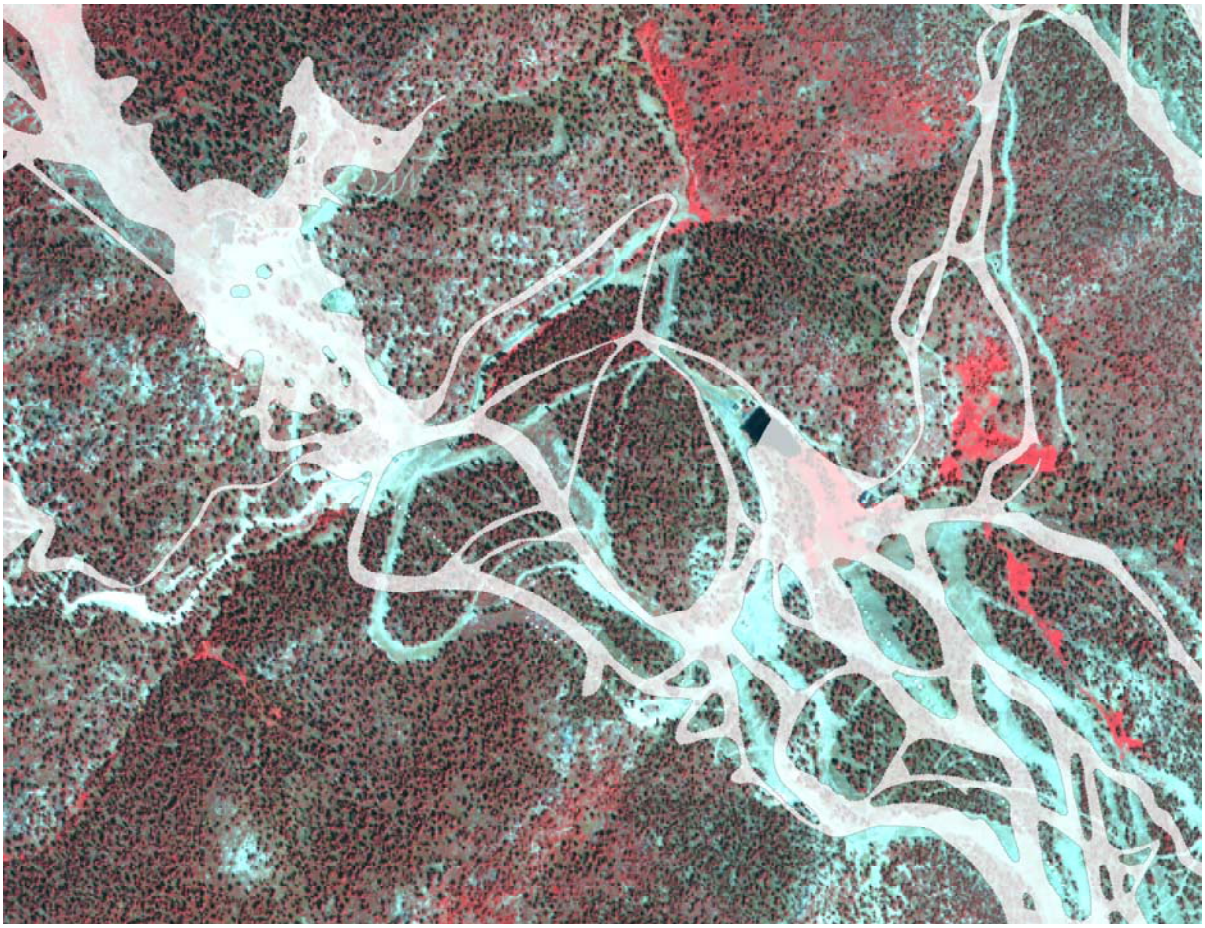

Figure 7. Clearly the ski run layer is not an acceptable layer for use in analysis based on the representative sample shown here. There is considerable lack of truth in location, shape, and extent of indicated ski runs.

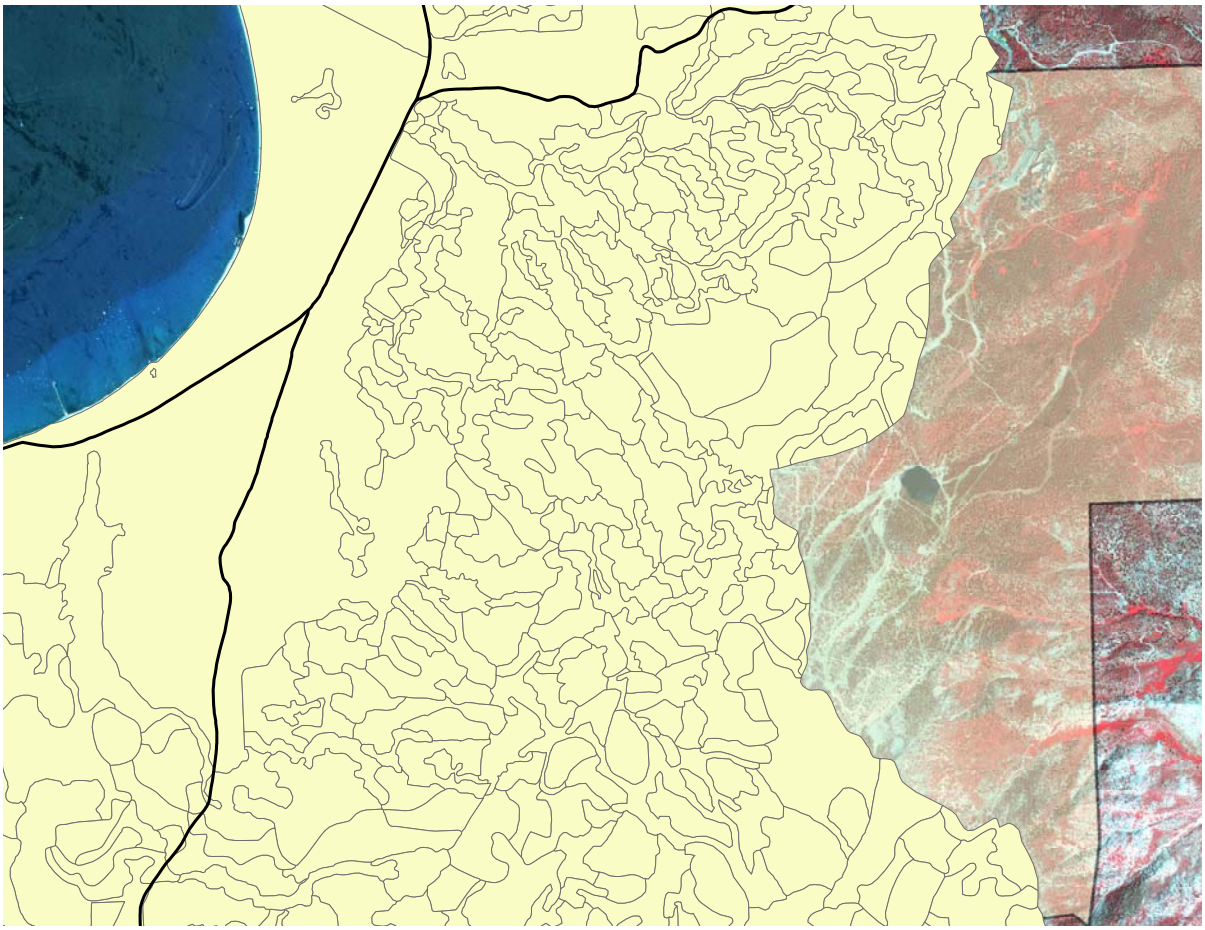

Figure 8. Extent of available data from LTBMU shown using the vegetation layer as an example. Data are not available from this source for the entire study area, only for the jurisdiction within the Lake Tahoe Basin.

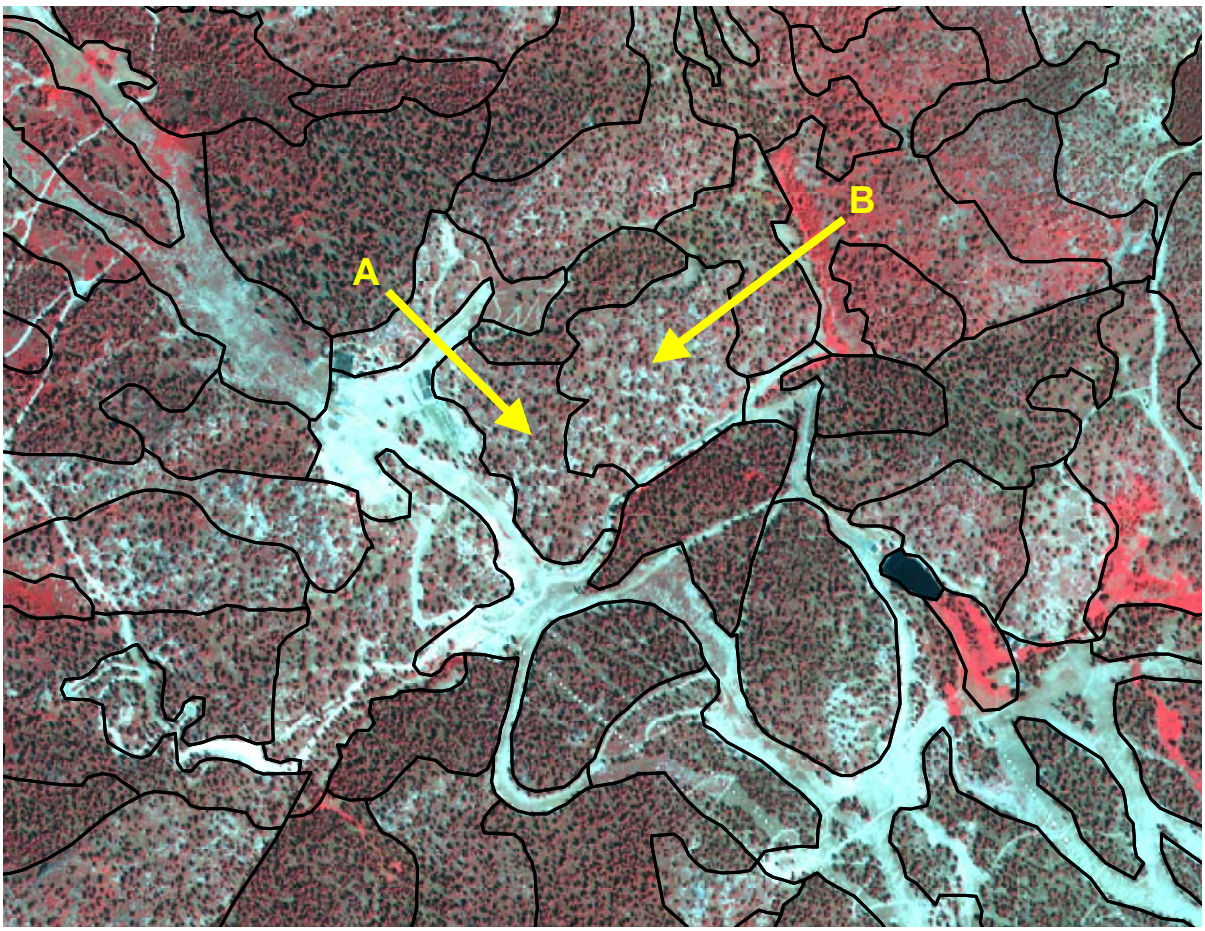

Figure 9. Example of vegetation attribute inaccuracy. Polygon B (Lodgepole pine) is labeled 50% tree canopy cover while polygon A (Jeffery pine) is attributed with 10% canopy cover.

Data generated from Ikonos imagery

Marten habitat was delineated based on a hierarchical rule set, which can also be thought of as assumptions. The first rule was designed to produce a habitat map based on the minimum and most basic data, namely camera station detection. The second was designed based on wildlife habitat relationship model (WHR) theory, considered a "standard" product or method for delineating (modeling) wildlife habitat at the species level and is available from a variety of sources for some vertebrate species including the State of California. A complete discussion of WHR development is beyond the scope of this report but a summary explanation follows for clarification of how marten habitat was delineated. It is important to note that although existing delineations of marten habitat are not well documented it appears that they are in fact WHR based models. To summarize WHR models, the premise is that key elements that comprise a given species' habitat at one or more suitability factors are repeatable and generalizable. That is, if a given species is known to occur or use habitat that can be defined by a set of characteristics, such as range of canopy cover, vegetation species, and elevation restrictions to name a few, then all areas that are comprised of those set of

characteristics are considered habitat. Often WHR models indicate levels of suitability, such as designated suitable habitat, moderately suitable habitat, and unsuitable habitat, but designations vary dramatically based on the extent of the knowledge base about a given species. Some WHR models indicate the proportion of delineated areas that are suitable versus unsuitable. Unfortunately it is typical that WHR models are based on inaccurate and incorrect data and assumptions although the theory behind WHR model development is sound. The difficulty in creating a fairly reliable WHR is the lack of adequate quality baseline GIS data, namely a vegetation or land cover layer. Problems with these critical data layers were discussed in the above section.

The third habitat layer was defined by an expanded data set of known marten occurrences, namely the station detections and snow-tracking data. Rule 3 habitat delineation included habitat defined in rule 1 and contiguous stands where snow tracks were identified as marten. The fourth and final habitat layer was a WHR-based delineation that included all marten detection data, including cameras, track plates, and snow-track data and all similar habitat within the ski area. This is the composite of rule 2 and rule 3 based habitat delineations. It includes all actual known occurrences and areas that share characteristics with the areas where marten were found to occur. The habitat delineation rules are defined as follows:

Rule 1: marten occur in contiguous tracts of habitat defined by the canopy structure immediately surrounding a camera or track plate station where a detection occurred. *This is the most basic and restrictive model and does not account for snow-track data.*

Rule 2: marten occur in any contiguous tract of habitat as defined by rule 1, above, regardless of whether or not a detection station was located in that particular tract. *This assumption is that habitat is generalizable, standard practice and the basis for wildlife-habitat relationship models.*

Rule 3: marten occur in habitat as defined by rule 1, above, and in contiguous tracts of habitat defined by the presence of snow-tracks. Snow-tracks that move through different stand types (i.e., canopy cover, understory composition, etc.) are used identify all of the inclusive stand types as habitat. *This assumption is that the presence of snow-tracks indicate an animal is using that type of habitat, without interpretation of use category, in addition to habitat identified by presence data from detection stations.*

Rule 4: marten occur in any contiguous tract of habitat defined by rules 1 and rule 3 whether or not detections or tracks were found to occur in the habitat identified as such based on similarity to locations of actual detections. *This rule is the most inclusive and follows the premise of WHR models based on camera and snowtrack habitat.*

For all habitat delineations, consistency was critical. The Ikonos imagery was photointerpreted based on canopy cover, relative crown size, and understory using both multispectral and panchromatic bands as well as a fused product. Data were fused using the Brovey transform and integrity of 11-bit data was maintained. Basic statistics generalizing the habitat were calculated such as frequency of canopy cover category and area of each habitat type, defined as above. Canopy cover was delineated into 5% increments and then

binned into four standard categories as follows: 0-25%, 26-50%, 51-75% and 75-100%. Canopy cover was restricted to overstory trees only and did not account for shrub cover of the understory. At a 1m resolution relative crown size of trees was discernible against low growing shrub cover. Individual tree crowns that were greater than 1m in breadth were discernible. Granite and decomposed granite (DG) substrate was easily discernible where vegetation was sparse or non-existent.

Habitat delineated from Ikonos imagery were field verified with ground truth data acquired from multiple sources: 2002 Goshawk surveys conducted by LTBMU biologists, ground truth data acquired during the field work for this project, expert opinion of LTBMU biologists, and from the imagery itself. The 1m fused Brovey transform product is extremely useful for ground truth, as very small clumps of vegetation, individual canopies, rocks, and anthropomorphic and natural features 1m or larger are readily distinguishable and interpretable.

Ski runs, access roads, and snowmobile trails were delineated from the panchromatic imagery. These three types of cleared areas were categorized equally because they receive human and/or vehicular traffic in the form of skiers, hikers, mountain bikers, snowmobiles, snowcats, and trucks. Most of these areas have been formally cleared and are maintained as cleared areas. Certain areas such as Mott Canyon were delineated and included in this layer because of the heavy ski traffic although the chutes although much of the skiable area is not cleared or groomed. This area is patrolled by ski patrol and structures such as gates are maintained by Heavenly. Lift lines that are not typically skied, such as the Gondola, and which retain the downed woody debris biomass were not included in this category because of the lack of traffic, human, vehicular or otherwise.

STATISTICAL AND SPATIAL ANALYSES

Kruskall-Wallis ANOVA

Kruskall-Wallis one-way Analysis of Variance (ANOVA) was run on camera station detection data (time of detection) to determine if there was a difference in the timing of detections that was dependent on the particular station. This is a non-parametric test and formally compares the medians of the data. The Kruskall-Wallis is an extension to the Mann-Whitney U test and is the equivalent of a one-way between-subject ANOVA. All p-values were computed using a Chi-square approximation with significance level of $\alpha = 0.05$.

Data were binned into two categories: day and night. Day and night was determined based on sunrise and sunset during the sample time period. Those detections that occurred after recorded sunrise and before recorded sunset were deemed “day”. Likewise, detections that occurred between sunset and sunrise were deemed “night”. This allowed statistical comparison between the number of recorded detections during daylight hours and after dark for the winter and summer surveys. Data were also binned further into four categories: morning, afternoon, early night, and early morning. This was done for a more refined comparison of the 24-hour day cycle.

One-way repeated measures ANOVA
This test was used to determine if there was a statistical difference in diurnal activity at camera stations. The one-way repeated measures test tests the difference between samples (day, night) and between subjects (camera stations). Repeated measures analyses are more appropriate for this data in that they are designed to eliminate the between-subject variation, that is differences that may be due to uncontrollable factors relating to the camera stations.

Paired samples t-test
Paired samples t-tests were run on camera station detection data (day and night) to determine if there were a significant difference in activity surrounding the times of detections. The question to be answered was *is there significantly more activity during the day or night, during the summer versus the winter, respectively?* This test is similar to z-tests, but does not require knowledge about the shape of the underlying population distribution.

Area and distance calculations
The actual area for each delineated habitat polygon for each of the four rule-based habitat definitions was calculated. Frequency histograms were generated for each canopy cover category, respectively as well. The total linear distance of snowtrack transects and snowtracks themselves was calculated, respectively. All of these calculations were done in a GIS or in a non-spatial database program.

RESULTS

Individual marten were detected at Heavenly Ski Resort within special use permit management boundaries. One camera station (F27, Van Sickle) was eliminated from the analysis because of its proximity to a homeless encampment. This station was vandalized and was unsafe for the field crew to visit. It was located very close to highway 50 and downtown Stateline, NV. Therefore, the results for the 2002 survey includes analysis of a total of 26 stations. Station F18 (Boulder Base) was moved due to vandalism. This station was located on the Nevada side very close to apartments and related urbanization. The camera was stolen.

<u>Camera and track plate detection stations (2002)</u>

Of 26 camera stations, American marten visited a total of 22. Of the six trackplates set up, marten visited four. These four were co-located with cameras which also had marten detections. Of the two trackplates with no detections, the co-located cameras also had no detections of marten. These results are summarized in the Table 3. “Maam detection” indicates whether a marten was detected, either via camera or plat. *Trackplate* indicates whether or not a trackplate was set up at the station and *trackplate detection* indicates whether or not marten tracks were detected at that station.

Table 3. Summary of basic information regarding remote detection stations and success of positive marten detection in 2002.

Station #-name	Set-up date	Detection	Trackplate	Trackplate Detection
F1-World Cup	01/05/02	Y	Y	Y
F2-Avalanche Bowl	01/20/02	Y	N	n/a
F3-Smart's Corner	03/12/02	Y	N	n/a
F4-Roundabout Flats	02/07/02	Y	N	n/a
F5-Mombo	01/04/02	Y	Y	Y
F6-Waterfall	02/07/02	Y	N	n/a
F7-Ridge	01/04/02	Y	N	n/a
F8-Monument	01/04/02	Y	N	n/a
F9-Maggie's Cny.	01/04/02	Y	N	n/a
F10-Mott Cny.	02/07/02	Y	N	n/a
F11-Perimeter	01/06/02	Y	Y	Y
F12-Galaxy Bottom	02/07/02	Y	N	n/a
F13-Galaxy Top	03/11/02	Y	N	n/a
F14-Olympic Top	01/06/02	Y	Y	Y
F15-George's/Pepi's	01/06/02	Y	N	n/a
F16-N.Daggett Top	03/10/02	N	N	n/a
F17-Way Home/075	02/08/02	Y	N	n/a
F18-Base of Boulder	01/06/02	Y	N	n/a
F19-Olympic Trees	02/08/02	Y	N	n/a
F20-Skiways	03/11/02	Y	N	n/a
F21-Dipper Top	03/11/02	Y	N	n/a
F22-Von Schmidt's	02/07/02	Y	N	n/a
F23-Tower 13	02/20/02	Y	N	n/a
F24-Edna St.	01/09/02	N	Y	N
F25-Daggett	02/15/02	N	Y	N
F26-Emp. Parking Lot	03/10/02	N	N	n/a
F27-Van Sickle	03/11/02	N	N	n/a

To better understand the spatial distribution of seasonal detections at camera and track plate stations, all permutations of winter and summer data were mapped (Figure 10). Those stations with no detections at all are shown in red. Four stations had no positive marten detections at all. One was located near Kingsbury Pass summit, two stations were located at the top and bottom of the South Fork Daggett Creek, respectively, and the fourth station with no detections was located off of Edna Street. Fifteen stations had marten detections both in the winter and the summer. These stations were located primarily inside of the Lake Tahoe Basin. Eight stations had marten detections in the winter survey, but not in the summer. These stations were located outside of the Lake Tahoe Basin. This data is represented in tabular form in Table 4.

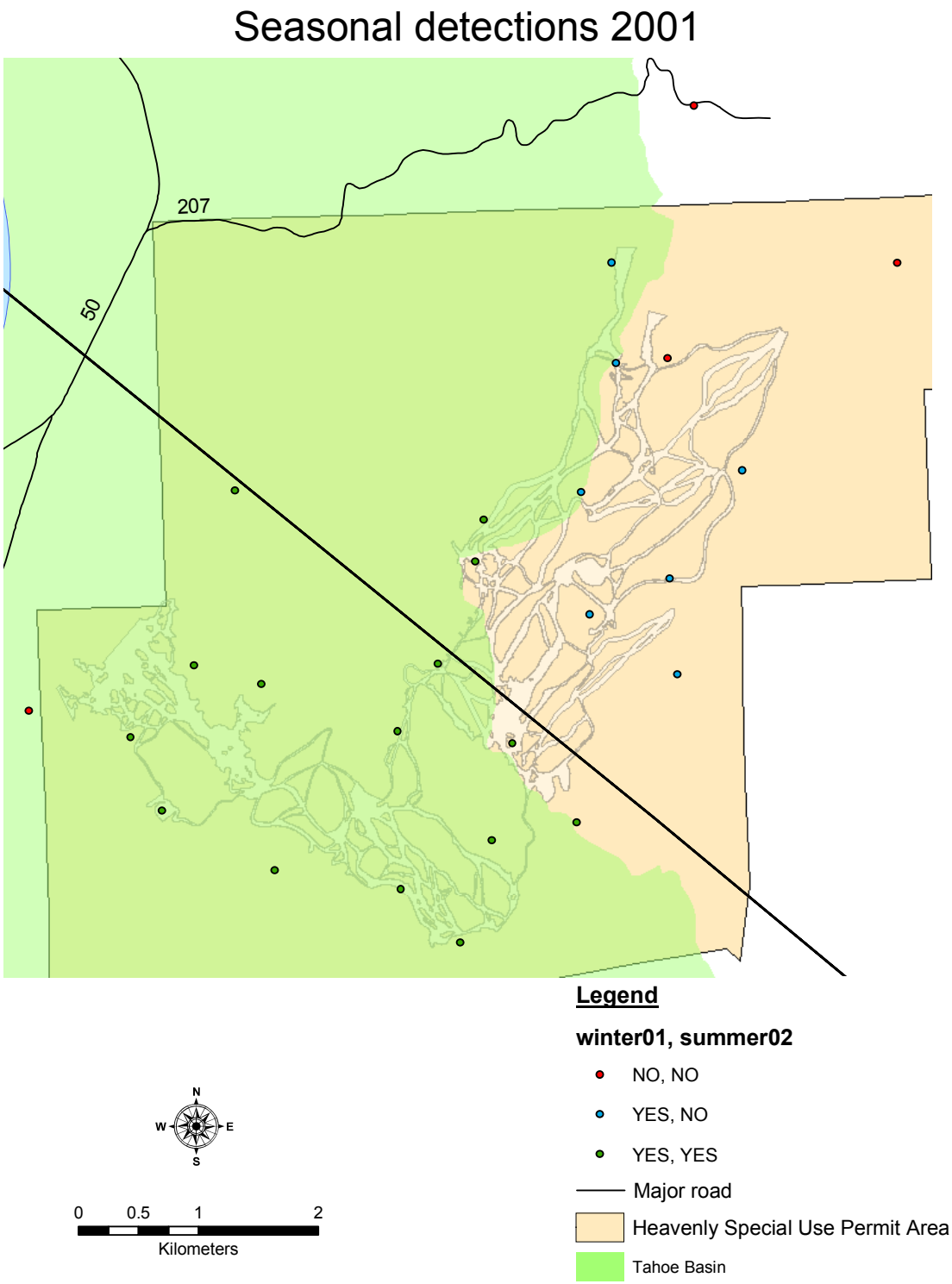

Figure 10. Permutations of detections at camera stations for the 2002 survey.

Table 4. Seasonal detections in 2002.

Station #-name	Detection	Summer	Winter
F1-World Cup	Y	Y	Y
F2-Avalanche Bowl	Y	Y	Y
F3-Smart's Corner	Y	Y	Y
F4-Roundabout Flats	Y	Y	Y
F5-Mombo	Y	Y	Y
F6-Waterfall	Y	Y	Y
F7-Ridge	Y	Y	Y
F8-Monument	Y	Y	Y
F9-Maggie's Cny.	Y	Y	Y
F10-Mott Cny.	Y	N	Y
F11-Perimeter	Y	N	Y
F12-Galaxy Bottom	Y	N	Y
F13-Galaxy Top	Y	N	Y
F14-Olympic Top	Y	Y	Y
F15-George's/Pepi's	Y	N	Y
F16-N.Daggett Top	N	N	N
F17-Way Home/075	Y	N	Y
F18-Base of Boulder	Y	N	Y
F19-Olympic Trees	Y	Y	Y
F20-Skiways	Y	Y	Y
F21-Dipper Top	Y	Y	Y
F22-Von Schmidt's	Y	Y	Y
F23-Tower 13	Y	Y	Y
F24-Edna St.	N	N	N
F25-Daggett	N	N	N
F26-Emp. Parking Lot	N	N	N

Distance from each station to the nearest ski run, lift, or cleared road was measured. Minimum distance was 0.01m and maximum distance was 1969m (~2km) with an average distance of 241m. Mean distance for camera stations with no detections was 937.42m. Mean distance from camera station to nearest run, lift, road, or otherwise cleared and maintained area was 121.38m. The difference in means distance for stations that did and did not have marten detections was not significant ($p = 0.1405$) based on an independent samples t-test using Welch's approximation for unequal variances. Elevation at detection stations ranged between 6482 (F24 Edna) and 10,000 feet (F8 Monument).

Camera and track plate detection stations (1993)

Of 27 camera stations set up in 1993, American marten visited a total of 16 different stations over the entire survey time period. These results are summarized in the Table 5. *Detection* indicates whether a marten was detected, either via camera or trackplate. Summer and winter detections are shown as well. Marten were detected at 12 stations in the winter and eight stations in the summer.

Table 5. Seasonal detections in 1993.

Station #-name	Detection	Summer	Winter
F1-World Cup	N	N	N
F2-Avalanche Bowl	Y	Y	Y
F3-Smart's Corner	Y	Y	N
F4-Roundabout Flats	Y	N	Y
F5-Mombo	Y	Y	Y
F6-Waterfall	Y	N	Y
F7-Ridge	N	N	N
F8-Monument	Y	Y	N
F9-Maggie's Cny.	Y	N	Y
F10-Mott Cny.	Y	Y	Y
F11-Perimeter	Y	N	Y
F12-Galaxy Bottom	N	N	N
F13-Galaxy Top	Y	Y	Y
F14-Olympic Top	Y	N	Y
F15-George's/Pepi's	Y	N	Y
F16-N.Daggett Top	N	N	N
F17-Way Home/075	N	N	N
F18-Base of Boulder	N	N	N
F19-Olympic Trees	Y	Y	N
F20-Skiways	Y	N	Y
F21-Dipper Top	Y	Y	N
F22-Von Schmidt's	Y	N	Y
F23-Tower 13	N	N	N
F24-Edna St.	N	N	N
F25-Daggett	N	N	N
F26-Emp. Parking Lot	N	N	N

Figure 11 illustrates which detection stations had positive marten detections in summer versus winter surveys. Ten stations had no "hits" for marten at all during either winter or summer surveys. These stations were located at the lowest elevations in Nevada and California, respectively, with one exception (F7 Ridge). Four stations detected marten during the summer survey only. Eight stations detected marten during the winter only. Four stations had detections both winter and summer, two in Nevada and two in California.

Combination of 1993 and 2002 survey data (P/A) from camera stations

Using GIS, each snapshot in time can be displayed visually for assisting in analysis and interpretation of results. Figure 12 shows which stations detected marten in 1993 and which stations detected marten in 2002 along with the permutations of each. These data are also presented in Table 6.

Summer detections and winter detections are compared for 1993 and 2002 in Figure 13 and Figure 14, respectively. Again, these data are different display variations of the data presented in Table 6. Four stations had no detections in the winter surveys. These stations were located on the periphery of the ski area and were among the lowest elevations of detection stations. Ten stations that had no detections in winter 1993 had positive marten

detections in winter 2002. Twelve stations detected marten in the winter in both 1993 and 2002. Three stations that had no detections in summer 1993 had positive marten detections in summer 2002.

Table 6. Comparison of seasonal detections for 1993 and 2002. Those stations that had detections in winter and summer for each year or no detections at all are highlighted in yellow. Stations with the same seasonal pattern are highlighted in green. Stations that had no detections in 1993 but then had detections in 2002 are highlighted in cyan.

	1993		**2002**	
Station #-name	*Winter*	*Summer*	*Winter*	*Summer*
F1-World Cup	N	N	Y	Y
F2-Avalanche Bowl	Y	Y	Y	Y
F3-Smart's Corner	N	Y	Y	Y
F4-Roundabout Flats	Y	N	Y	Y
F5-Mombo	Y	Y	Y	Y
F6-Waterfall	Y	N	Y	Y
F7-Ridge	N	N	Y	Y
F8-Monument	N	Y	Y	Y
F9-Maggie's Cny.	Y	N	Y	Y
F10-Mott Cny.	Y	Y	Y	N
F11-Perimeter	Y	N	Y	N
F12-Galaxy Bottom	N	N	Y	N
F13-Galaxy Top	Y	Y	Y	N
F14-Olympic Top	Y	N	Y	Y
F15-George's/Pepi's	Y	N	Y	N
F16-N.Daggett Top	N	N	N	N
F17-Way Home/075	N	N	Y	N
F18-Base of Boulder	N	N	Y	N
F19-Olympic Trees	N	Y	Y	Y
F20-Skiways	Y	N	Y	Y
F21-Dipper Top	N	Y	Y	Y
F22-Von Schmidt's	Y	N	Y	Y
F23-Tower 13	N	N	Y	Y
F24-Edna St.	N	N	N	N
F25-Daggett	N	N	N	N
F26-Emp. Parking Lot	N	N	N	N

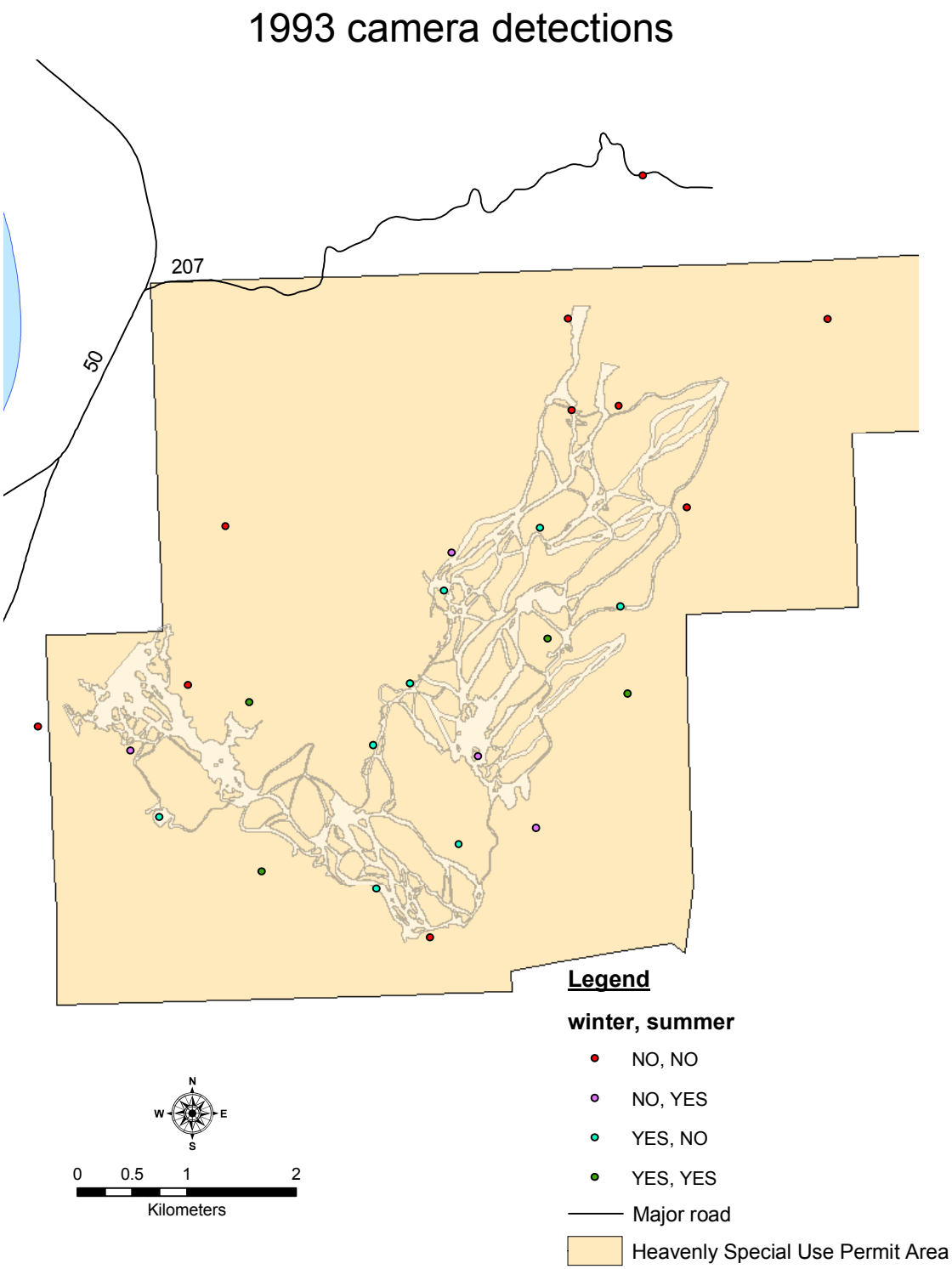

Figure 11. Summer versus winter detections in the 1993 surveys.

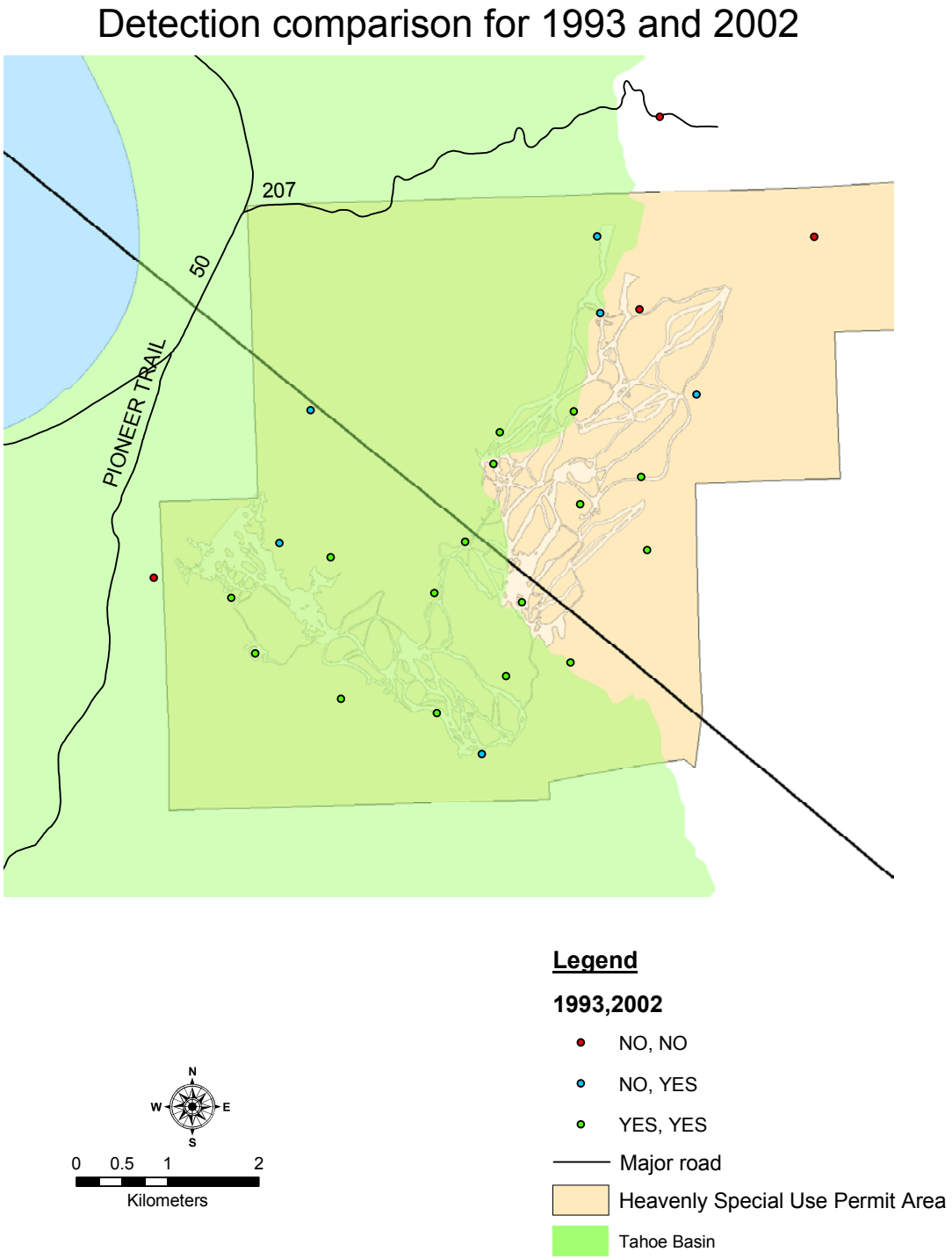

Figure 12. Comparison of detections for the 1993 and 2002 surveys, respectively.

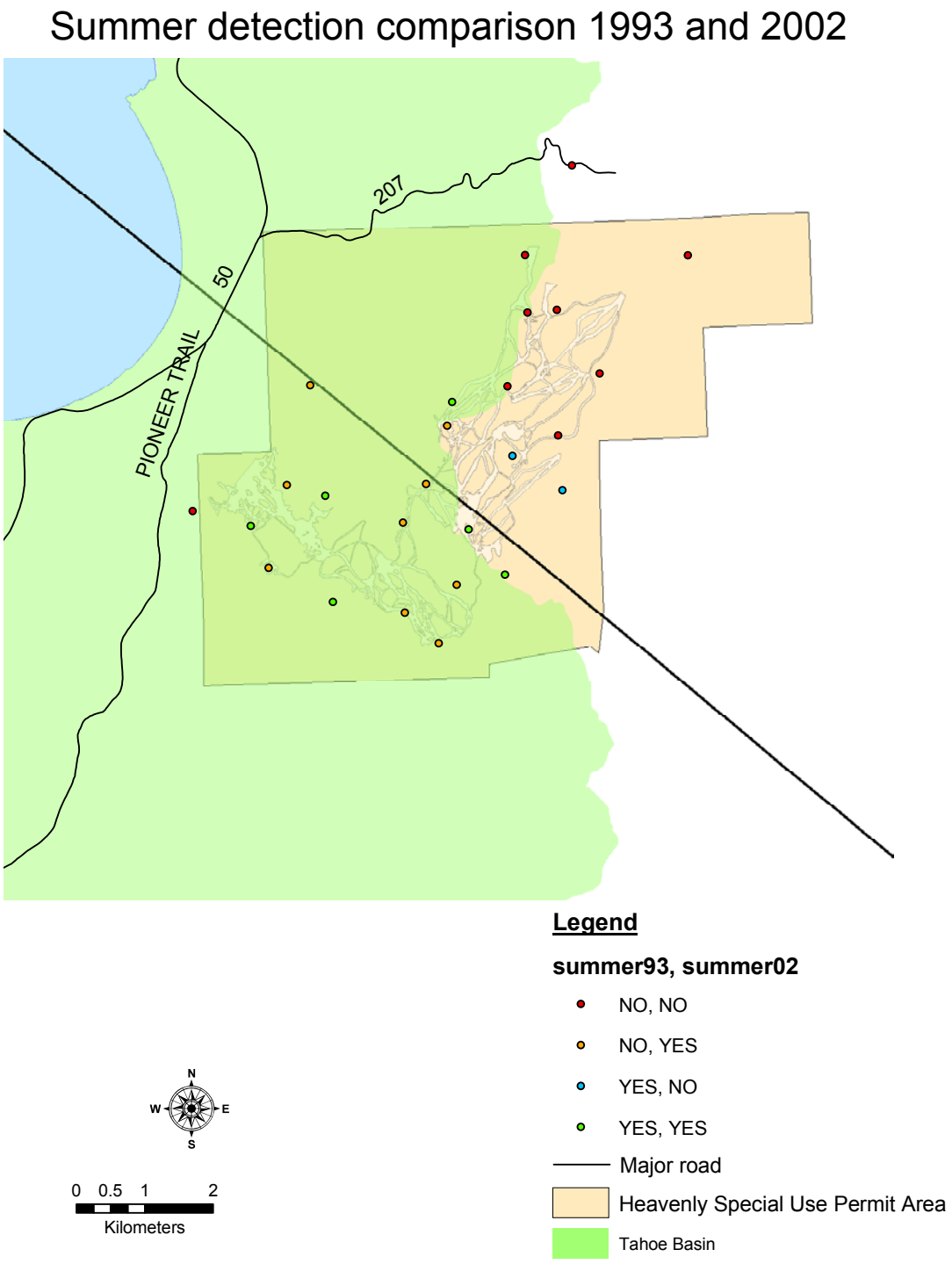

Figure 13. Comparison of detections during summer surveys in 1993 and 2002.

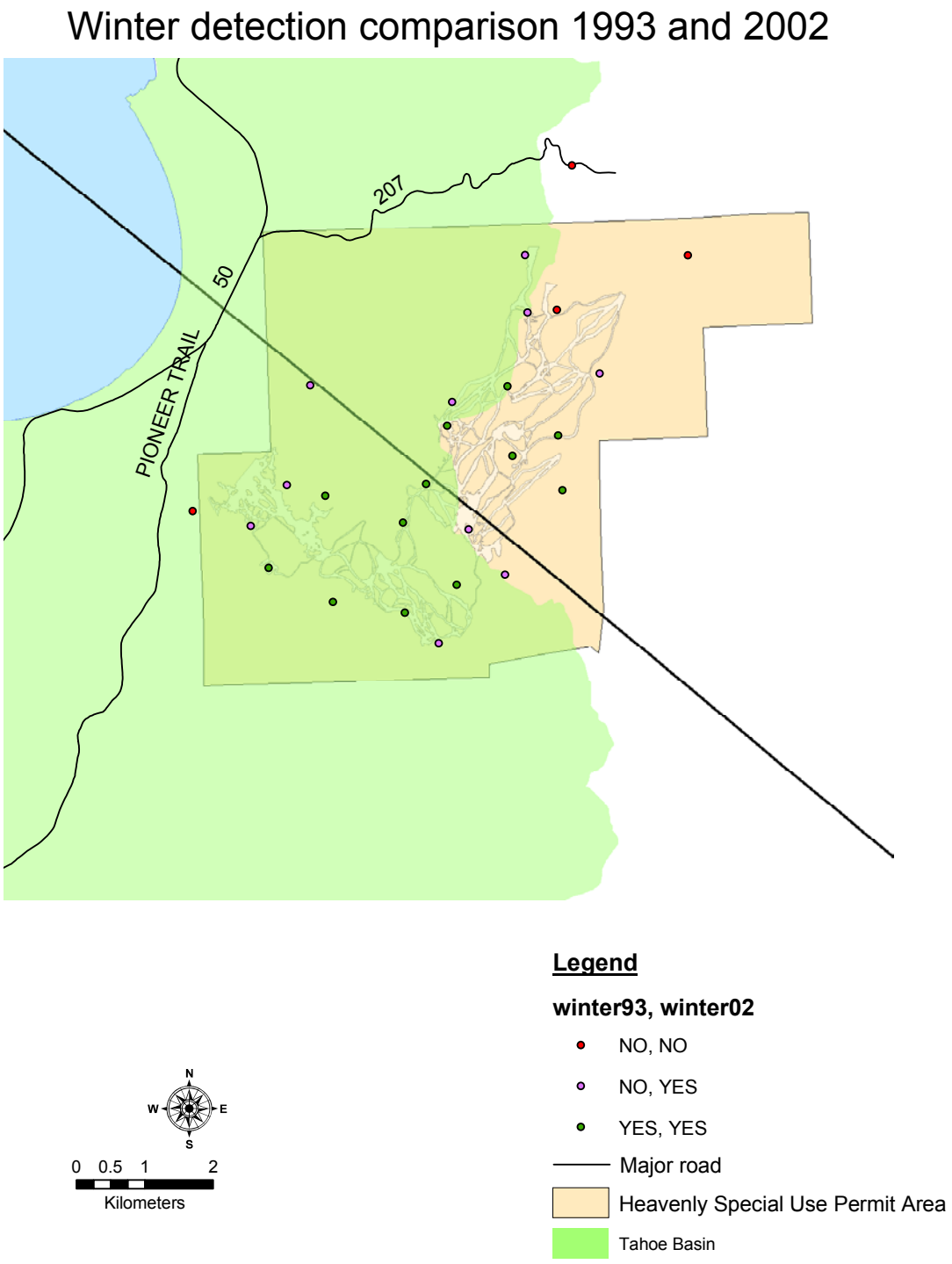

Figure 14. Winter detections in 1993 and 2002, respectively.

Analysis of time series based on camera detections 2002

Winter

The time to detection was plotted spatially to visualize the order in which stations were visited by marten Figure 15 depicts the order in which stations from the first round of surveying were visited. These stations were set up on January 7, 2002. Detections were consistent in time of day for each station. Stations that were "hit" in the evenings, before midnight, were consistently visited at similar times. Stations that had detections in the early morning hours were also typically visited in the early morning hours. The time at which marten were detected included all hours of the day. Figure 16 shows the time of marten detections at each camera station.

Twenty-two camera stations detected marten during the winter survey period. Detection events at stations ranged between one and eleven and the number of different dates marten were detected at a given station ranged between 1 and 7 total days. The number of daytime hits and nighttime hits, calculated against sunrise and sunset, are detailed in Table 7.

Results from the Kruskall-Wallis ANOVA (Table 8) indicated no difference in the timing of detections at camera stations during the winter surveys. That is, no station appeared to have activity at very different times during the night compared to all other camera stations that had activity.

Results from the one-way ANOVA on winter detection data are presented in Table 9. No significant difference was found between the times of detection at camera stations. A very significant difference ($p < 0.0001$) was found between the time of detections at camera stations (day versus night).

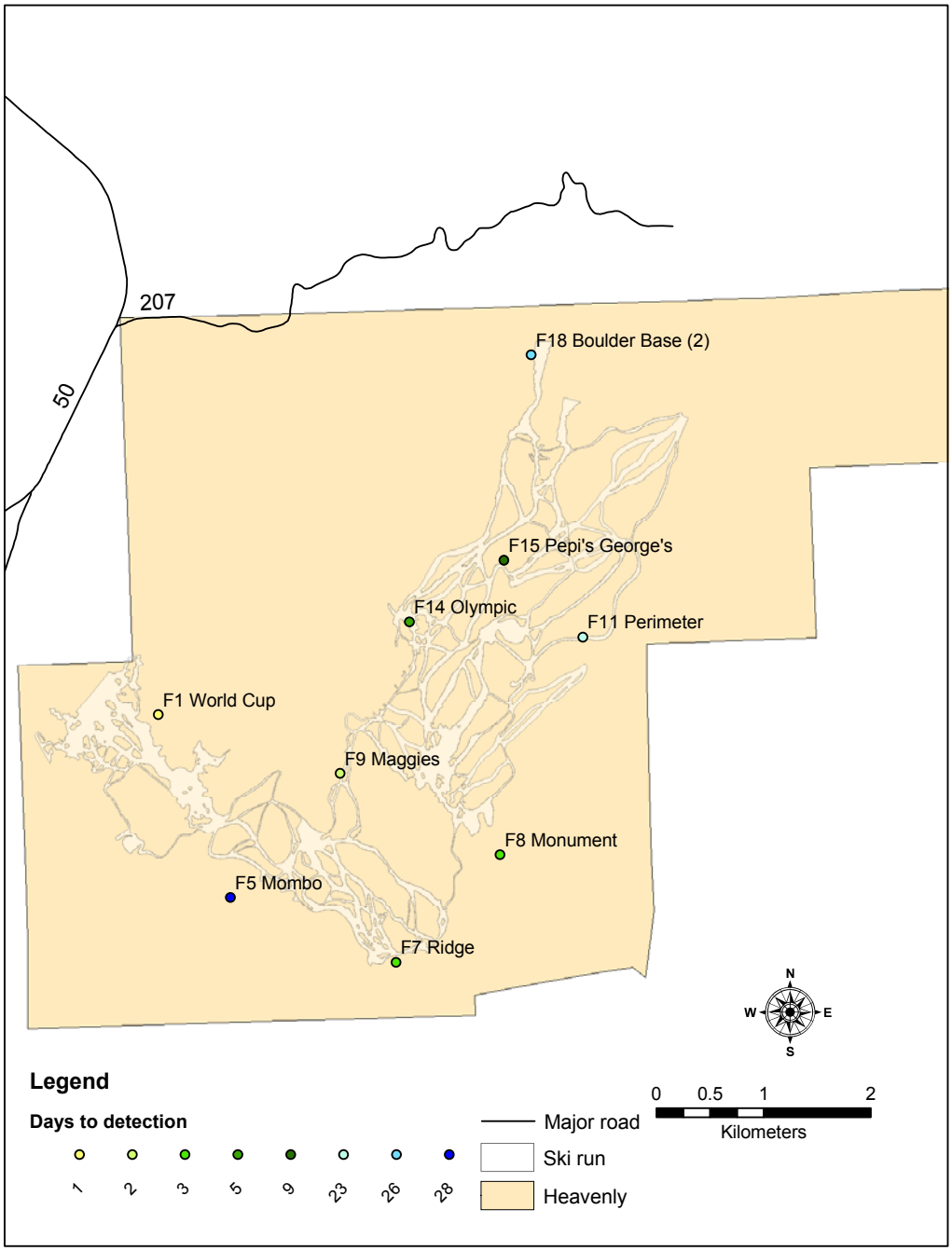

Figure 15. Order in which camera stations had positive detections during the first round of camera stations in the winter survey.

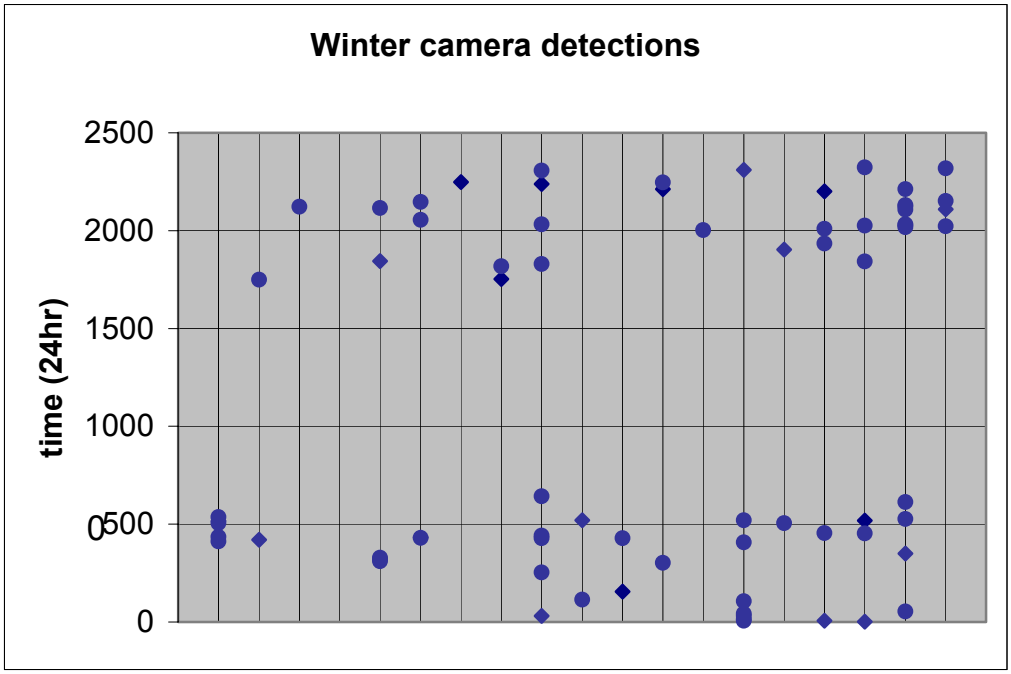

Figure 16. Detection times at stations during winter surveys.

Table 7. Summary of camera detections during summer surveys. Number of discrete detections in the day and night (based on sunrise and sunset) are given by station.

STATION	NO. DETECTIONS	DAY DETECTIONS	NIGHT DETECTIONS
F1	1	0	1
F2	3	0	3
F3	9	0	9
F4	11	0	11
F5	1	0	1
F6	11	0	11
F7	6	0	6
F8	5	0	5
F9	2	0	2
F10	3	0	3
F11	3	0	3
F12	4	0	4
F13	2	0	2
F14	6	0	6
F15	1	0	1
F17	3	0	3
F18	2	0	2
F19	3	0	3
F20	7	0	7
F21	1	0	1
F22	6	0	6
F23	5	0	5

Table 8. Results from Kruskall-Wallis ANOVA on winter survey data. No significant difference in time of detection was found between camera stations.

Station Name	n	Rank sum	Mean rank
F5 Mombo	1	61.5	61.50
F15 Pepi's George's	1	16.0	16.00
F14 Olympic	6	224.5	37.42
F11 Perimeter	3	136.5	45.50
F18 Boulder Base (2)	2	90.0	45.00
F1 World Cup	1	59.0	59.00
F7 Ridge	6	242.0	40.33
F8 Monument	5	256.5	51.30
F9 Maggies	2	164.0	82.00
F2 Avalanche Bowl	3	139.0	46.33
F4 Roundabout Flats	10	498.0	49.80
F17 Way Home 075	3	85.5	28.50
F10 Mott	3	51.0	17.00
F12 Galaxy Bottom	4	271.5	67.88
F13 Top of Galaxy	2	144.0	72.00
F3 Smarts Corner	9	278.5	30.94
F19 Olympic Trees	3	107.5	35.83
F21 Top of Dipper	6	323.5	53.92
F20 Skiways	7	317.5	45.36
F6 Waterfall	12	653.0	54.42
F23 Tower 13	5	346.0	69.20
Kruskal-Wallis statistic	23.64		
p	0.2585	(chisqr approximation, corrected for ties)	

Table 9. Results from one-way ANOVA on winter detection data. No significant difference was found between camera stations but there was a significant difference in time of day of detections.

winter	n	Mean	SD	SE	
day	22	0.000	0.000	0.0000	
night	22	4.318	3.077	0.6559	
Source of variation	SSq	DF	MSq	F	p
Within winter	205.114	1	205.114	43.34	<0.0001
Between winter	99.386	21	4.733	1.00	0.5000
Within cells	99.386	21	4.733		
Total	403.886	43			

Summer

Fifteen camera stations detected marten during the summer survey period. Detection events at stations ranged between one and nine and the number of different dates marten were detected at a given station ranged between one and seven total days. The number of daytime hits and nighttime hits, calculated against sunrise and sunset, are detailed in Table 10. The time at which marten were detected included all hours of the day. Figure 17 shows the time of marten detections at each camera station.

Table 10. Summary of camera detections during summer surveys. Number of discrete detections in the day and night (based on sunrise and sunset) are given by station.

STATION	NO. DETECTIONS	DAY DETECTIONS	NIGHT DETECTIONS
F1	6	1	5
F2	9	6	3
F3	8	0	8
F4	3	0	3
F5	2	0	2
F6	8	2	6
F7	1	1	0
F8	4	3	1
F9	1	0	1
F14	3	2	1
F19	6	3	3
F20	8	3	5
F21	6	3	3
F22	3	1	2
F23	6	6	0

Results from the Kruskall-Wallis ANOVA indicated no difference in the timing of detections at camera stations during the summer surveys. That is, no station appeared to have activity at very different times during the night compared to all other camera stations that had activity.

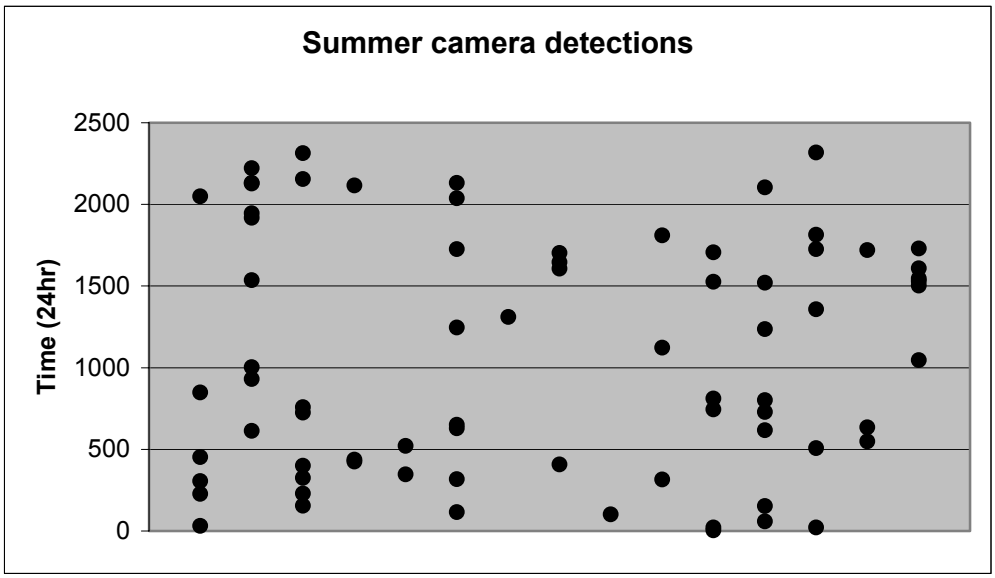

Figure 17. Detection time during summer surveys.

Table 11.Results from Kruskall-Wallis ANOVA on summer survey data. No significant difference in time of detection was found between camera stations.

Station	n	Rank sum	Mean rank
F1	1	61.0	61.00
F2	3	139.0	46.33
F3	9	280.5	31.17
F4	10	504.0	50.40
F5	1	63.5	63.50
F6	12	666.0	55.50
F7	6	244.0	40.67
F8	5	260.5	52.10
F9	2	167.0	83.50
F10	3	51.0	17.00
F11	3	138.5	46.17
F12	4	275.5	68.88
F13	2	147.0	73.50
F14	6	224.5	37.42
F15	1	16.0	16.00
F17	3	85.5	28.50
F18	2	92.0	46.00
F19	3	107.5	35.83
F20	7	320.5	45.79
F21	1	84.0	84.00
F22	6	279.5	46.58
F23	5	353.0	70.60
Kruskal-Wallis statistic	25.99		
p	0.2069	(chisqr approximation, corrected for ties)	

Results from the one-way ANOVA on summer detection data are presented in Table 12. No significant difference was found between day and night detections nor was a significant difference found between camera stations.

Table 12. Results on one-way ANOVA for summer camera data. There was no significant difference in the time of activity at stations during the summer.

summer	n	Mean	SD	SE	
day	15	1.9	2.1	0.53	
night	15	2.9	2.3	0.59	
Source of variation	SSq	DF	MSq	F	p
Within summer	6.5	1	6.5	1.06	0.3212
Between summer	46.2	14	3.3	0.53	0.8734
Within cells	86.5	14	6.2		
Total	139.2	29			

Seasonal camera station comparison

A total of 96 discrete detections were recorded at camera stations in the winter while a total of 74 were recorded during the summer. Frequency distributions (Figure 18) show, by appearance only, that the actual distribution of the detection times does appear to be different by season. Winter detections are clearly bi-modal while summer detection frequencies occurred throughout the entire course of a 24-hour time period. Peak activity during the winter at camera stations occurred between 8pm and 11pm and also between midnight and 8am. No animals were detected at stations in the winter after daylight. To the contrary, during the summer survey, marten were detected throughout the day. There was a relatively high amount of activity between 3pm and 6pm. Like winter survey results, relatively high levels of activity were captured by the cameras between midnight and 8am.

Results from the paired samples t-test on daytime activity are shown in Table 13. There was a significant difference in activity levels during the daytime hours between summer and winter surveys ($p = 0.0026$). The average number of detections during the day in the summer at camera stations was approximately two, while the average during the winter was zero. The 95% confidence interval (0.8 – 3.1) does not include zero, indicating there is no chance that the actual difference in activity is zero.

Results from the paired samples t-test examining nighttime activity are show in Table 14. There was a statistically significant difference between summer and winter surveys in the activity levels at camera stations at night ($p = 0.0188$). Additional t-tests were run using alternative hypotheses to determine if summer nighttime activity was higher or if winter nighttime activity was higher. Results from these t-tests indicated that activity at night during the summer was significantly less than during the winter (1-tailed $p = 0.0094$).

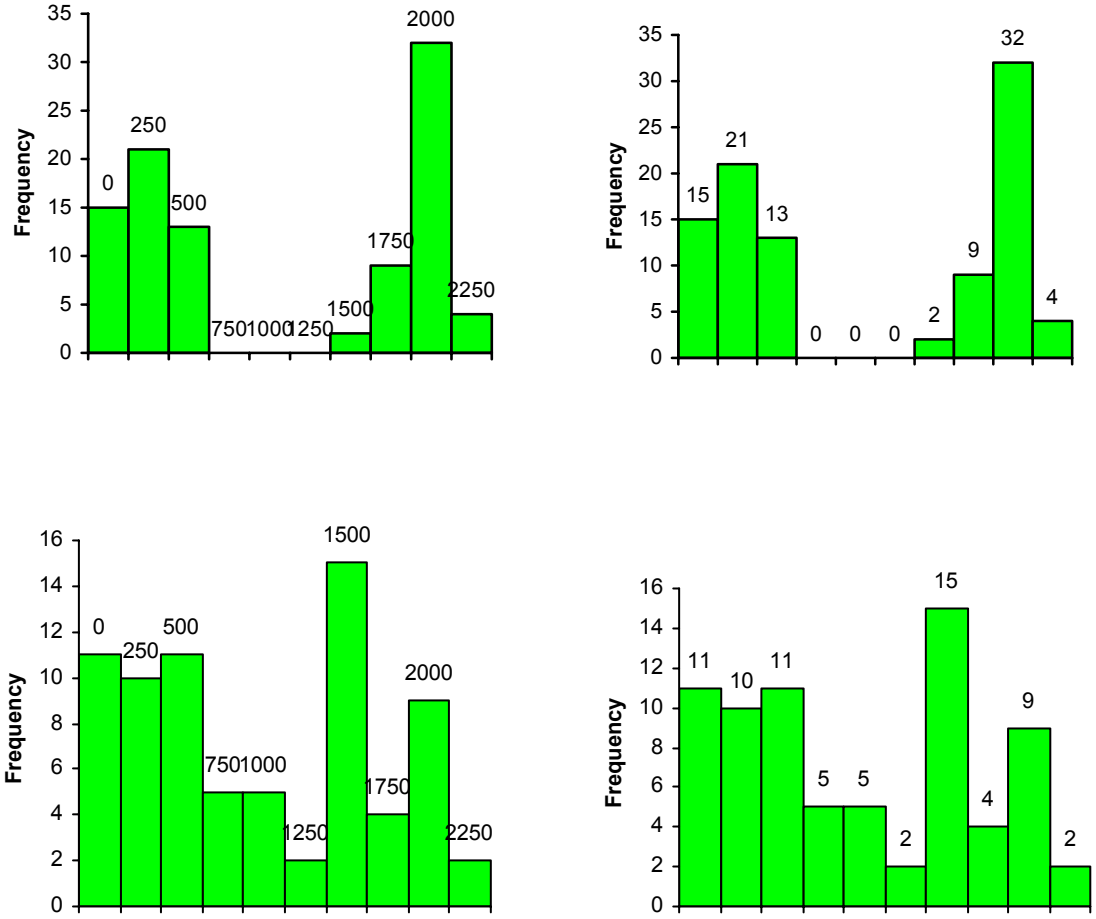

Figure 18. Frequency histogram of the timing of detections during winter surveys (top) and summer surveys (bottom). The bi-modal distribution during the winter is clear. Time ranges indicated above bars indicate no activity at camera stations in the winter between approximately 8am and 3pm. During the summer activity was seen throughout the day and night. Labels on figures on the right indicate count.

Table 13. Results from the paired samples t-test on daytime activity at camera stations.

day	N	Mean	SD	SE
summer	15	1.9	2.1	0.53
winter	15	0.0	0.0	0.00
Difference	15	1.9	2.1	0.53
Difference between means	1.9			
95% CI	0.8	to 3.1		
t statistic	3.65			
2-tailed p	0.0026			

Table 14. Results from the paired samples t-test on nighttime activity at camera stations.

night	n	Mean	SD	SE
summer	15	2.867	2.295	0.5925
winter	15	5.133	3.399	0.8776
Difference	15	-2.267	3.305	0.8534
Difference between means	-2.267			
95% CI	-4.097	to -0.436		
t statistic	-2.66			
2-tailed p	0.0188			

Snowtracking

Snowtracking began on February 14, 2002 and continued as weather permitted until April 21, 2002. Approximately 8.25 km (5.13 miles) of marten tracks were followed. Thirty-four subnivean access points were located. Transects, snowtracks, and subnivean access points are shown in Figure 19. A total of 34 subnivean access points were recorded, 22 of which were 2-way access points where the animal went under the snow and traversed under the snow but exited out from a different location. The remaining 12 access points were terminal, where the individual animal went under the snow and exited from the same location. Dominant overstory species included red fir, white bark pine, western white pine and white fir. Table 15 details the subnivean access data. Table 16 shows the breakdown of the types of access points that were used for each of the two different subnivean access types, terminal or 2-way.

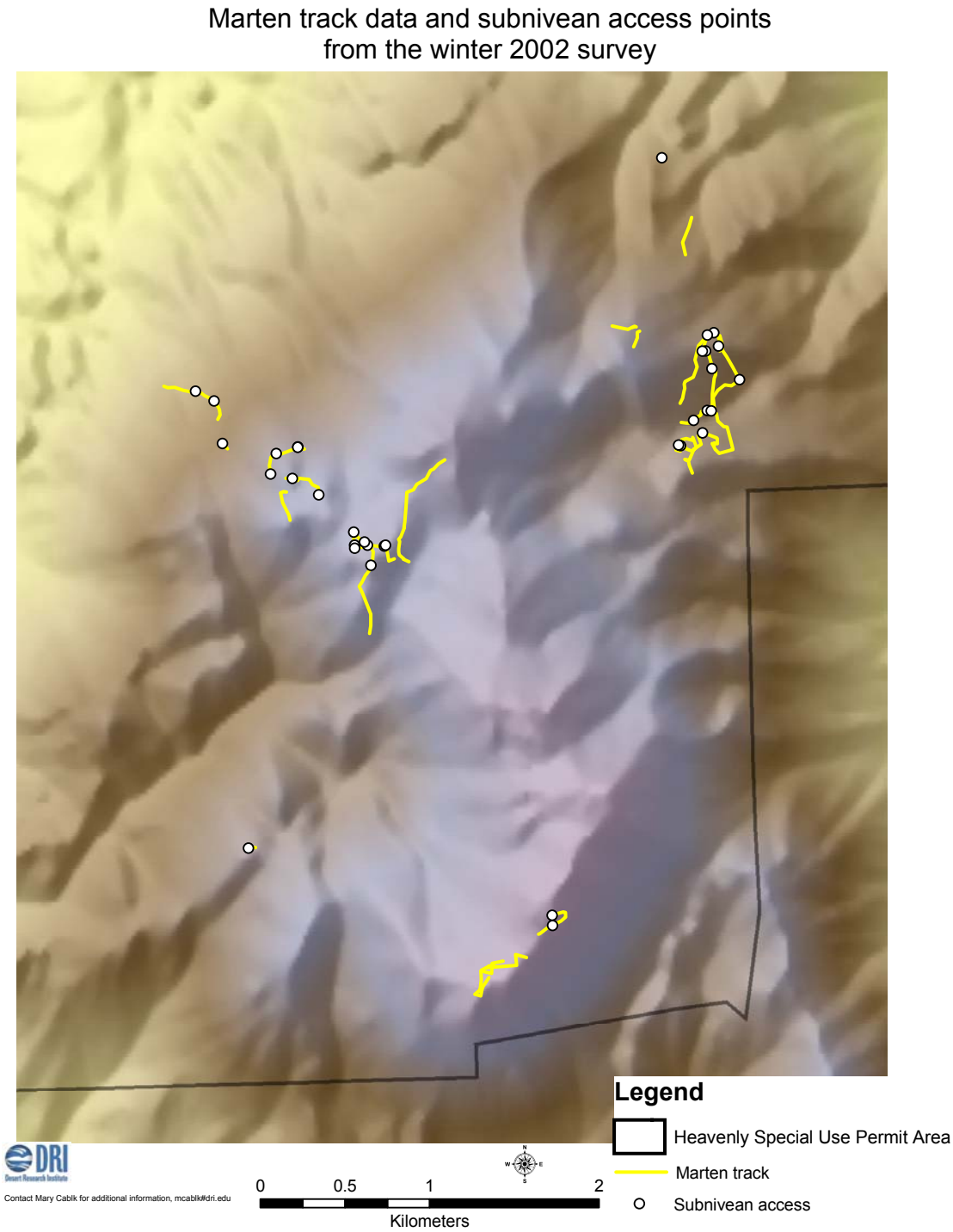

Figure 19. Snow tracks of marten collected during the winter 2002 survey and subnivean access points identified while tracking.

Table 15. Characteristics of the subnivean access points identified while snowtracking.

Type	*Count*	**Access type**	*Count*
2-way	22	Rock	12
Terminal	12	Tree bole	3
		Downed log	6
		Branch	3
		Snow	10

Table 16. Detail of subnivean access points indicating which kinds of access are used for different types of subnivean access.

	Access type				
Type	*Rock*	*Tree bole*	*Downed log*	*Branch*	*Snow*
2-way	10	3	4	0	5
Terminal	2	0	2	3	5

Other species recorded with remote detection methods

Camera stations and track plates record the presence of any visitor, be it human or wild fauna. At least 15 mammal and avian species combined, other than marten and humans, were detected with the camera and track plates. Ten species were recorded based on their tracks. These results are presented in Table 17. Some of these species, such as the snowshoe hare, would not be expected to be detected with baited camera or track plate because they are not carnivores. Mammal tracks identified while skiing transects or following marten tracks are also listed in Table 17. These tracks were not followed. They were only identified and in some cases recorded with GPS location and species type. Clearly, many other mammal species occur within the range of marten at Heavenly. Other forest carnivores that were not identified by tracks or camera and track plate stations included fisher, wolverine, and Sierra Nevada red fox.

Table 17. Species other than marten that were detected at camera and trackplate stations and during snowtracking.

	Latin name	Common name
Camera and Trackplate detections	*Glaucomys sabrinus*	flying squirrel
	Tamiasciurus douglasii	Douglas squirrel
	Spilogale gracilis	spotted skunk
	Tamias spp.	Chipmunk
	Nucifraga columbiana	Clark's nutcracker
	Cyanocitta stelleri	Steller's jay
	Poecile gambeli	mountain chickadee
	Sitta carolinensis	white-breasted nuthatch
	Various	mice species
	Picoides albolarvatus	white-headed woodpecker
	Procyon lotor	Raccoon
	Ursus americanus	Black bear
	Spermophilus lateralis	Golden mantled ground squirrel
	Sphyrapicus thyroideus	Williamson's Sapsucker
	Picoides arcticus	Black backed woodpecker
Snowtracking detections	*Glaucomys sabrinus*	flying squirrel
	Canis latrans	Coyote
	Lynx rufus	Bobcat
	Puma concolor	Mountain lion
	Ursus americanus	Black bear
	Corvus corax	Raven
	Tamias spp	Chipmunk
	Tamiasciurus douglasii	Douglas squirrel
	Lepus americanus	Snowshoe hare
	Peromyscus spp.	Various mice species

Marten habitat delineations

Four maps were generated, one for each of the four rule based habitat definitions. Rule 1, habitat based only on the immediate and contiguous stand in which a marten was detected at a station in 2002, resulted in a total of 363.34 ha (897.83 ac) of marten habitat. Rule 2 resulted in 887.17 ha (2192.24 ac). Rule 3 resulted in 881.83 ha (2179.05 ac) and Rule 4 delineation resulted in 1411.04 ha (3486.76 ac). These results are presented in Table 18. Corresponding maps are shown in APPENDIX 2, respectively.

Table 18. Area delineated as marten habitat based on four different rule-based classifications.

Habitat definition	Area (ha)/Area (ac)
Rule 1	363.34/897.83
Rule 2	887.17/2192.24
Rule 3	881.83/2179.05
Rule 4	1411.04/3486.76

Sixteen different dominant canopy cover categories were defined ranging from no overstory to a pure mix of dominant species. A mix of two species was considered to share dominance when one species was found to comprise > 25% of the canopy and the second species was found to concurrently comprise at least 50% of the remaining canopy with the species comprising the majority of the stand being listed first. For example, a stand that was 50% red fir and 40% western white and 10% lodgepole pine was categorized "mixed red fir western white". The mixed category was stands that had at least three tree species comprising more than 20% of the canopy, respectively. For example, a stand that contained 25% lodgepole pine, 25% western white pine, 20% white bark pine, and 20% hemlocok was categorized "mixed". A stand that was comprised of approximately 30% of each of Jeffrey pine, red fir, and western white pine was also categorized "mixed". Table 19 identifies the area of marten habitat for each of these categories. Figure 20 shows the area of marten habitat in each species category for Rule 1 habitat and Figure 21 plots the area by stand type for rule 1 and rule 2 habitat definitions, respectively, for comparison. Figure 22 shows the area of marten habitat in each species category for Rule 3 habitat and Figure 23 shows the comparison between rules 3 and 4, respectively.

Table 19. Area (HA) by dominant canopy species for each of the 4 habitat layers.

Species	***Rule 1***	***Rule 2***	***Rule 3***	***Rule 4***
Jeffrey pine	7.91	7.91	7.91	7.91
Lodgepole pine	2.56	2.56	13.7	15.00
Mixed	67.8	188.31	134.97	271.01
Western white pine	15.5	75.03	60.56	83.12
White bark pine	86.41	177.06	89.36	194.42
White fir	1.23	2.46	1.23	2.46
Red fir	0	0	13.46	13.46
Mix: red fir/western white	140.44	347.93	140.44	347.94
Mix: red fir/Jeffrey pine	3	3	3	3
Mix: white bark/western white	8.56	54.22	8.56	60.6
Mix: Jeffrey pine/white fir	28.94	28.94	28.94	28.94
Mix: white fir/Jeffrey pine	2.22	2.22	2.21	2.21
Mix: Lodgepole/western white	0	0	5.53	5.53
Mix: Lodgepole/white bark	0	0	17.76	20.1
Mix: western white/lodgepole	0	0	9.04	13.67
None	0	0	342.66	342.66
Total hectares	363.34	887.17	881.83	1411.04

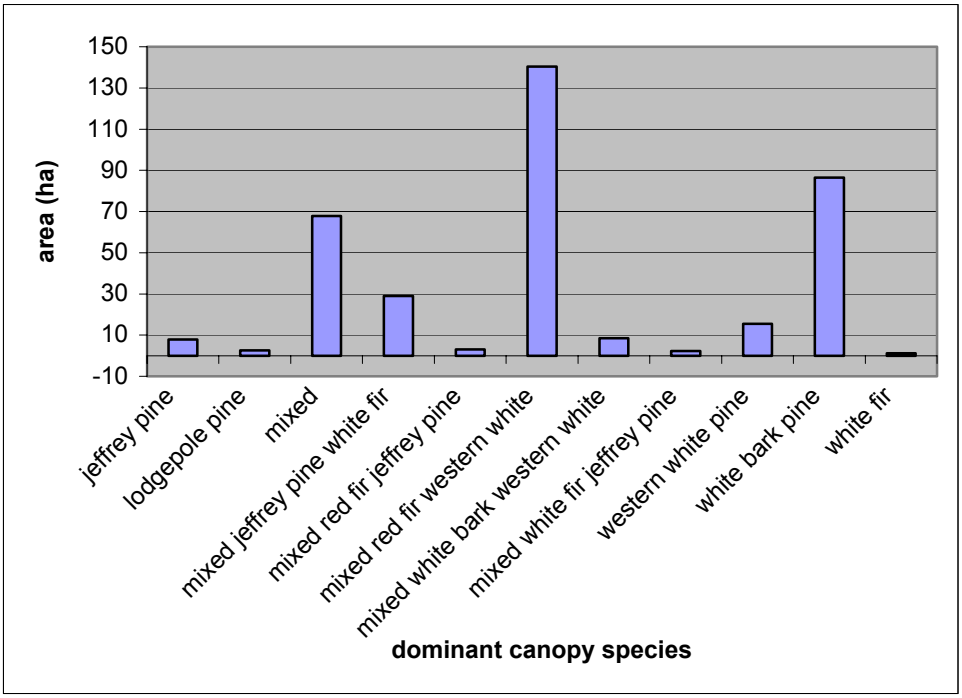

Figure 20. Area (ha) for each stand shown by canopy cover type for Rule 1 habitat.

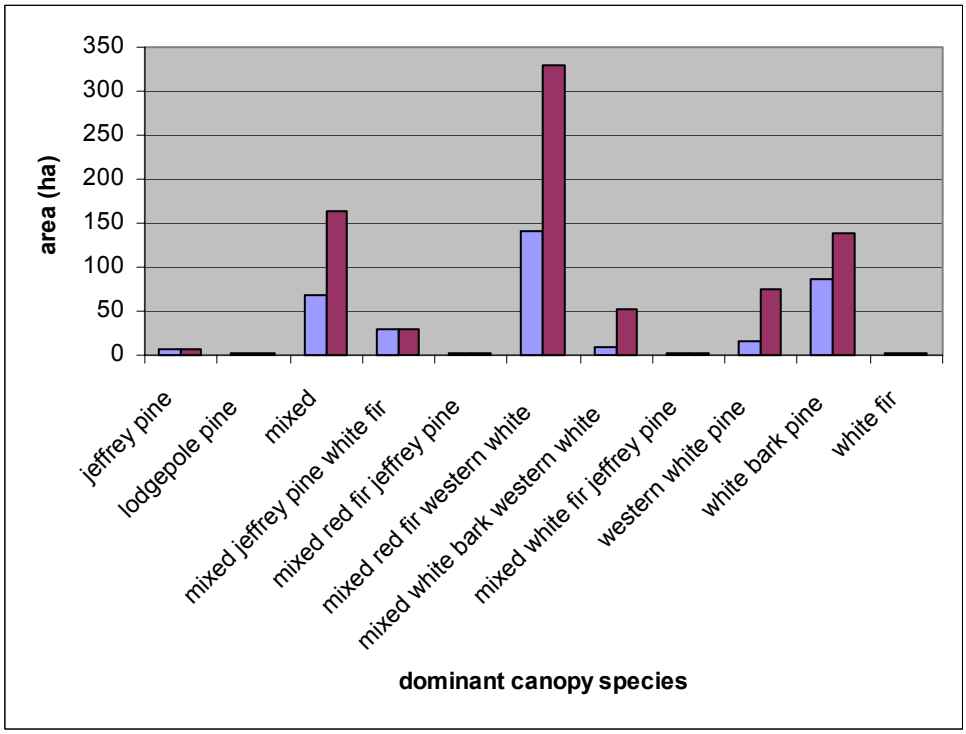

Figure 21. Area (ha) for each stand type of rule 1 (blue) and rule 2 (purple) habitat, respectively.

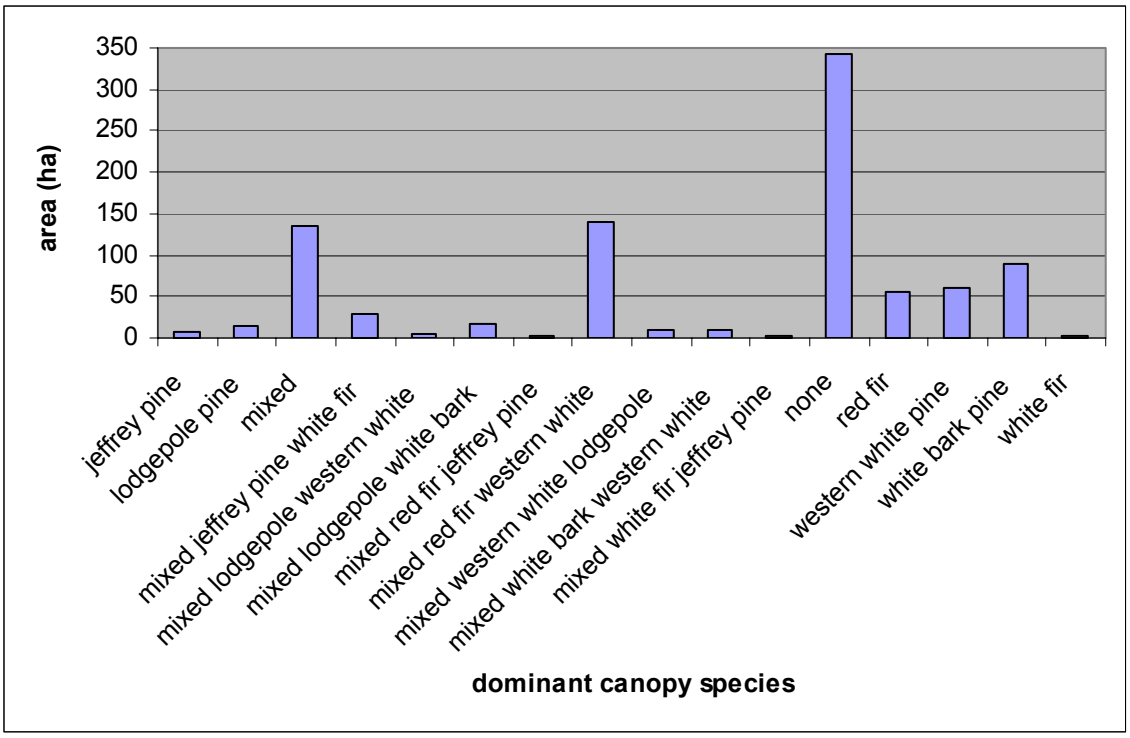

Figure 22. Area (ha) for each dominant cover class for Rule 3 habitat. "None" indicates open area such as ski run.

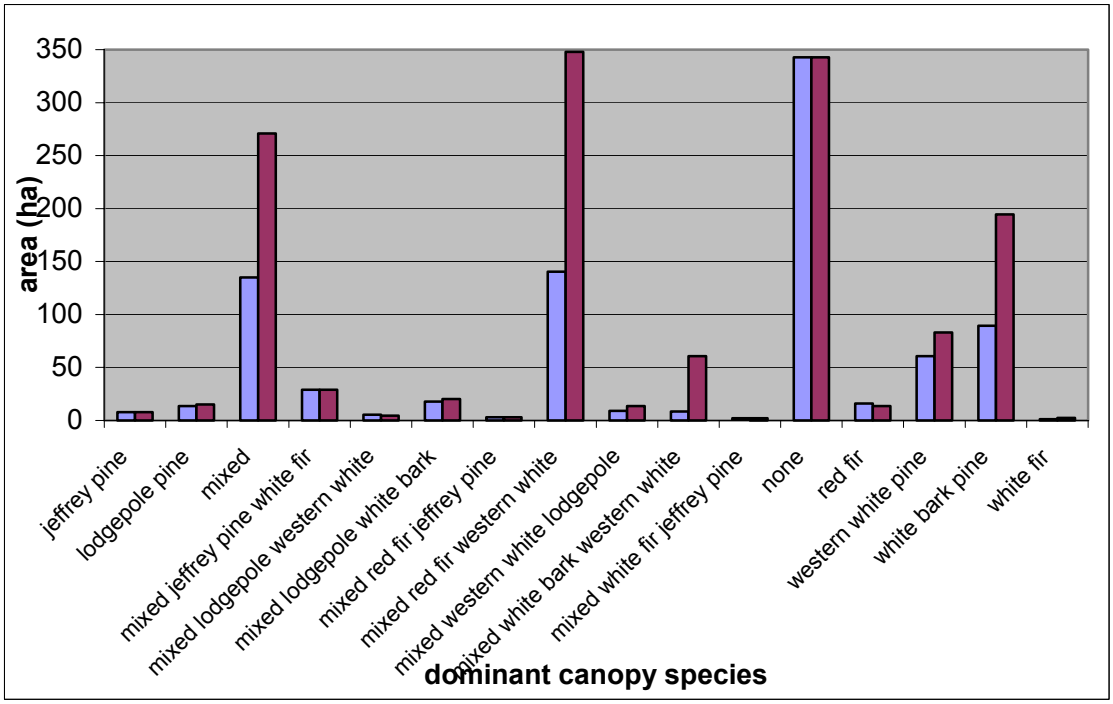

Figure 23. Comparison between area (ha) by dominant cover species for rules 3 (blue) and 4 (purple), respectively.

Canopy cover estimates are shown in Table 20 for habitat delineated from station data alone (rules 1 and 2) and for habitat delineated from both camera station data and snowtrack data (rules 3 and 4). Canopy cover estimates do not change between rules 1 and 2 nor between rules 3 and 4, because no new habitat types are defined between them, respectively. The only additional habitat definitions that are defined are those added based on snowtrack data – the difference between rule 1/rule 2 and rule 3/rule4.

Table 20. Canopy cover estimates for each stand type compared for habitat defined by camera station data alone and by both camera station data and snowtrack data.

Stand type	Mean CC % Station data only	Mean CC % Station & Track data
jeffrey pine	50	50
lodgepole pine	90	27
mixed	48	31
mixed jeffrey pine white fir	20	20
mixed lodgepole western white	n/a	65
mixed lodgepole white bark	n/a	32
mixed red fir jeffrey pine	50	50
mixed red fir western white	65	57
mixed western white lodgepole	n/a	28
mixed white bark western white	50	50
mixed white fir jeffrey pine	75	75
none	n/a	1
red fir	n/a	38
western white pine	25	35
white bark pine	19	17

DISCUSSION

Detection stations in California were located almost exclusively next to what was considered "outside runs". That is, these stations were located on the edge of ski runs that were adjacent to unaltered, relatively unused and large tracts of continuous forest. No stations in California were situated in tree islands or between two or more ski runs or ski lifts. This was a function of the site selection of the 1993 study. There is one exception, station F21 (Top of Dipper), which was very near the CA-NV state line. In Nevada, by contrast, the stations were well dispersed throughout the matrix of forest and cleared runs and lifts. Four stations were located adjacent to what was considered an "inside run", or that were located within a patch of forest that was bound on all sides by ski runs, lifts, or a combination of both. Some interesting results were found based on camera stations and are discussed below.

Clearly marten still occur at Heavenly and can be found throughout the ski area. Because no sampling was conducted beyond the actively maintained ski area boundaries we cannot make any statements regarding relative use of marten at Heavenly compared to marten use of other locations inside the basin or beyond the managed ski area boundary. That is, results from this work apply to Heavenly and not necessarily to other areas in the Lake Tahoe Basin. Because we have no data with which to compare, it is impossible to address questions relating to

impacts on marten specifically from ski area activities at Heavenly because there are no comparable data within the Lake Tahoe Basin in or outside of ski area locations. There are risks associated with fieldwork within the administrative special use permit area that are beyond maintained ski area boundaries. Avalanche conditions are extreme throughout much of the area. Transportation to, from, and within these backcountry areas is difficult without mechanized equipment and even with mechanized equipment may not be easily accomplished. Other marten detection data collected by state and federal agencies in the Lake Tahoe Basin are available but are not comparable for the purposes of this study for a number of reasons. There is no documentation on the sample design of the surveys and second, the dates are not concurrent with this study. What these other data are useful for is indicating where marten have been found to occur within the basin. These data cannot be deemed the extent of marten occurrence within the basin because the basin was not surveyed for determining a representative sample.

In general, results from camera stations indicate that marten are found to occur between 6879ft and 10,000ft elevation. These are within published elevation ranges for marten. Stations that did not have marten detections ranged between 6482ft and 7783ft elevation, still within published elevation ranges for marten.

There are activities that might occur at Heavenly, either currently or to be proposed, that would be expected to impact marten based on existing knowledge of marten life history coupled with results from this survey. Nighttime ski area activities particularly during the winter and daytime ski area activities during the summer are two examples. Inferences of impacts are discussed in sections to follow.

Activity levels of marten at Heavenly

Clearly there are differences in activity that were found to occur based on season, summer versus winter, and based on daytime versus nighttime. Marten at Heavenly were found to be equally active during the daytime and nighttime in the summer. The opposite is true for the winter, in that marten were not active during the day. During the winter, all of the detected activity occurred after dark or before dawn. It would be easy to assume that this difference in activity during the winter must be caused by ski activities (i.e. recreational skiers), however, it is important to consider other facts. First, marten have been found to follow the same activity pattern in non-ski areas (Zielinski, 1983). Therefore ski activities cannot be presumed to cause the nighttime behavioral pattern. Second, there are potential impacts of nighttime maintenance activities during the winter ski season such as grooming and snowmaking, which in combination occurs on the ski slopes every night. Granted, grooming and similar activities are different from recreational skiing, but they are an unnatural, human-related occurrence that might be considered to cause impacts. Where skiing might be described as a continuous wave of disturbance that is not constrained entirely to ski runs, grooming is a discrete and concentrated disturbance. Grooming is not continuous in nature like when skiers are present. Grooming is also restricted to ski slopes and does not occur in forested tracts or tree islands within the ski runs. Grooming involves externalities not associated with skiers, such as particular levels and types of noise, air pollution and photopollution. Data on time and location of grooming activities that occurred concurrently

with marten detections at camera stations would be useful for addressing potential impacts from nighttime maintenance activities at Heavenly.

No activity was recorded during the winter at any camera station and for this reason it appears that the current level of nighttime activity at Heavenly is tolerable by marten. Without data on time and location of nighttime activity, again, no conclusions can be drawn about whether this finding is related to a true lack of impact or whether marten, being highly mobile animals, are simply avoiding anthropogenic disturbances. Marten at Heavenly were found to be more active overall at night during the winter than at night during the summer. One obvious explanation may be that because marten are not active at all during daylight hours, they must conduct all of their activity during the night. During the summer, however, there are more hours being used to conduct all of their activities and thus activity levels decrease at night. It may therefore be surmised that the animals are spreading their activities out over the entire 24 hour measured day period. Recall, however, that there are fewer daylight hours in the winter. The days are "shorter". During the summer there are more hours of daylight than there are hours under darkness.

Other research has found similar activity patterns (Zielinski, 1983) and relates this activity pattern to prey availability. As such, it may be that marten are driven by their energy budget and that other factors relating to the net energy balance are influencing diurnal activity during the summer. Prey type and availability, for example, has been found to be a significant factor in determining seasonal foraging activity and times (Zielinski, 1983). During the winter months, marten feed mainly on Douglas' squirrel, flying squirrel, snowshoe hare, and deer mice. These prey are nocturnal, except Douglas' squirrel which marten capture while the squirrels sleep in their middens. All of these prey species were detected during the 2002 winter camera and snowtracking surveys.

There may also be a secondary factor involved regarding prey base. Ski area activities may be influencing prey richness, abundance, availability, and activity times, which in turn affect marten and other predators' foraging behaviors. Prey species that avoid interactions with humans or are significantly affected by human presence are going to be spatially distributed to reflect areas that receive use by humans, such as skiers. Those prey species that avoid human interactions will avoid those areas or those times of the day that increase the chance of interacting with a human. Predators, therefore, would be expected to also locate themselves where prey occurs, in this example, away from human activity or during times when humans are not present. Other prey species may find benefit from ski area fragmentation, particularly species that rely to some extent on edge habitat. Ski runs and lifts provide edge habitat between forested and cleared area. Where downed woody debris is retained prey may also find refuge and experience benefit from such cover even under open canopies. Where downed woody debris is cleared from the landscape and where vertical stand complexity is minimized, prey may be less abundant and less diverse. All of these are potential factors that play a role in the organization and distribution of prey, which must affect predators such as marten.

Marten were just as active during the day as they were at night during the summer survey. During the summer they were equally as active during daylight as they were after dark,

including the pre-dawn hours. This finding may reflect a more even distribution of resources throughout a 24-hour time cycle, such as prey activity levels and availability. Again, without concurrent data on prey base, these remain only hypotheses rather than supported explanations. During the summer days, marten were particularly active between 3pm and 5:30pm, although this difference was not found to be statistically significant. Additional breakdown of the day into four categories relating to morning, afternoon, evening, and pre-dawn were also analyzed to determine if the apparent increase in activity in the afternoon during the summer were significant compared to other times of the day. No significant difference was found between the four categories nor was a significant difference relating to activity within camera stations. Kruskall-Wallis ANOVA yielded the same results. That is, the apparent increase in activity between 3pm and 5:30pm is not significant relative to any other time of day during the summer survey. Nor is there any difference in the distribution of activity within a particular camera station. There is no reason to believe that any physical factors of the detection station locations influenced whether or not a marten was present. The presence of human scent, the amount of bait used, the amount of time between checking the stations did not influence the activity of any station more or less than any other station.

What the snowtrack data indicates regarding animal movements

The snowtrack data yielded preliminary information previously unknown about marten at Heavenly and marten in general. Although a lot of data were not able to be collected during this study time period, it is hoped that additional and significant data can be collected for more comprehensive analysis. Simple examination of the tracks themselves indicates that marten move through the landscape in different fashions. On the steep slope of the north face where the Gondola lift has been cut, for example, an individual made straight-line movements. This is in contrast to the tracks followed in the vicinity of Perimeter and Galaxy ski runs, which appear more circuitous. Formal pattern analysis of track data is required, however, before robust statements can be made about differences in patterns of movement relative to the landscape.

At the same time the snow tracking data yielded interesting preliminary results. Whereas the highest canopy cover for marten detected at a camera station was 90%, snow tracks were not found in canopy cover greater than 70%. Mean canopy cover where snow tracks were detected was just under 30% whereas mean canopy cover where stations were located was almost 46%. A t-test run on the data from rule 3 (only stands with positive detections via camera station and snow track data) indicated a significant difference between the canopy cover where marten were detected by camera or track plate and where their tracks were found ($p = 0.0069$). That is based on preliminary data, marten travel through stands with much lower canopy cover than would be expected given the results of the camera station data alone. Again, more data will serve to increase the robustness of this analysis.

We now also know that marten will cross open areas maintained as ski runs, lifts, or access roads. This is not inconsistent with published literature. Researchers have reported marten crossing open areas with no overhead cover up to 100m (Ruggerio et al., 1994). During the 2002 survey, marten tracks were observed on several occasions under lift lines. (Gondola, Sky Express, Powderbowl, Waterfall, Galaxy, Gunbarrel and Stagecoach).These individuals

may have been searching for dropped food. This same behavior was not detected on runs, even when snow conditions would have allowed subnivean access. Compaction of snow on runs due to grooming prevents marten from foraging by subnivean access. During the 2002 survey an individual was found, through tracks, to use the cleared area under the Gondola in which to forage. Downed woody debris was left under the Gondola to meet USFS requirements.

The collection of additional snow track data will be extremely useful for refining marten habitat definitions at Heavenly. Snowtracking may be an alternative, more cost effective and certainly less invasive method for addressing home range and some population level questions. Scat analysis can determine gender and potentially differentiate between individual animals. Katherine Ralls of the Smithsonian institute has been successful at these analysis on San Joaquin Kit Fox (Ralls, pers. comm., Ralls et al., 2002). Collection of scat and detailed information about prey will also be useful for expanding the general body of knowledge about marten activities as this data becomes available for analyses. Furthermore it is hoped that with enough intensive snow tracking, a natal den might be discovered if marten are, in fact, successfully reproducing within the ski area. Scat collected in conjunction with a snow track provides detailed information about individual animals – gender, individual identification, subnivean access preferences, habitat and use preferences, diet, and potentially stress based on hormone level analysis. All of this information comes from non-invasive data collection. The animal is never touched by humans, is never pressed to take refuge, and has no chance of dying as a direct result of this survey method.

Comparison of 1993 station detections to 2002 station detections

Overall, marten were detected at all stations in 2002 where they had also been detected in 1993 and in six cases marten were detected in 2002 where they were *not* detected in 1993. Examining the patterns of detections by season, survey results showed different detection patterns between 1993 and 2002. In 2002, there were no recorded detections of marten outside the Lake Tahoe Basin watershed in the summer but two detections outside the Lake Tahoe basin watershed were recorded in the summer 1993 survey. Similarly, inside the Lake Tahoe Basin in the summer we had nine detections (2002) where the 1993 survey had none. In the winter we had ten detections at stations where marten were not detected in 1993. The same four stations had no detections in either the 1993 or 2002 survey. It is unclear whether the unsuitability of these stations is due to physical habitat, proximity to anthropogenic features, elevation, prey abundance, or some other unmeasured factor. Clearly, though, marten do not find these areas acceptable. In general, stations without marten detections are peripheral to the ski area in that marten have access to large untracked tracts of forest. However in three instances the no-detection stations are relatively close to urban development and in one instance (F26 Employee Parking), very close to a highway.

Two years of data collection is insufficient to determine a reliable trend in terms of seasonal differences in detections. However it may be hypothesized that those stations without detections in either year are unsuitable to marten or are unavailable to marten. Given the paucity of years of survey data, it would be premature to formulate theory based on these survey data. For example, based on the two surveys one might predict that marten are

expanding into habitat in the eastern portion of Heavenly, because no detections were previously made at any of the stations closest to Stagecoach, but marten were found to occur in 2002. Yet another survey in subsequent years could yield any result – detections again, or no detections, again. There simply are not enough seasons of data to make any predictions about trends in movement, habitat use, or expansion or contraction of habitat as well as seasonal use patterns.

What can be said is that marten are found throughout Heavenly Ski Area with only a few exceptions. Marten occur within the main ski area, and are crossing runs, lifts, roads, and other cleared and maintained areas at least in the winter. They occur on the outskirts of the ski area as well and although they have access to large untracked regions of forest, they are willing and able to enter into skier territory. Marten are active during the nighttime only during winter months while they are active during the day and night in summer months.

A larger Sierra Nevada wide sampling effort conducted by the USFS at the regional level included one survey plot within Heavenly boundaries during the summer of 2002. A camera station recorded an adult marten with three kits. This survey used artificial scent lure. Our survey did not detect this "family" of marten despite the fact that we had a camera station located approximately 0.65km away. Unlike the larger sampling effort, scent lure was not used in our survey. For this reason we do not expect to have lured animals into habitat where they would otherwise not venture. Individual marten would have to have been in very close proximity to locate the baited stations. In other words, the animals would have to have been in the area for other reasons for them to find the baited stations. At the same time, these animals can learn and become habituated. The presence of human scent may in fact be a draw for marten.

We had greater success getting detections when bait was made available on the outside of the bait cage as opposed to being placed entirely within the cage and therefore unavailable to the marten. This was discovered after the first week of the winter survey. Under the theories of energy expenditure it is possible that individual animals quickly learned that unless they were ensured success of a meal it was not worth the energy to visit the station. By the same token this makes it entirely possible that the animals could have become habituated to the stations and in fact learned that stations equal food in the same manner than animals learn to visit trash bins and dumpsters. In that manner the stations may change the animal's behavior regardless of the lack of lure. This is another reason for using snow tracking; there is no lure and no reward for visiting any detection station.

<u>What can be said about predicting marten occurrences?</u>

At this point in time there is no definitive model that can be used to predict marten presence or absence. There are not enough data about what habitat marten are using for which activities and what the temporal and diurnal preferences of those habitats might be. What can be said is that marten are found throughout Heavenly Ski area and that these animals use a variety of habitat types. Based on the survey results from 2002, we can make statements about what those habitat types are, and those habitat types are described in other sections of this document. Based on the results of this survey and the 1993 survey, we would not predict

to find marten at the lowest extent of the Heavenly special use area nor would marten be expected to occur very close to urban development and major roads. Marten would not be expected to occur outside the Lake Tahoe basin in the lower reaches of the canyons that descend to the valley floor in Nevada.

It is expected that another camera survey would yield similar results but probably not exact recurrences of detections as were found in 2002. Barring any major changes to the extent of development at Heavenly, most camera stations would be expected to have positive marten detections.

Evaluation of remote photographs – comments on individual animals

There are a minimum of three different individual marten at Heavenly, two in the CA side and one in the NV side. This is determined by examining the time stamps on the photographs from the detection stations in space. Figure 24 for example, shows the permutations of times recorded positive detections at each camera station that had exactly two detections on the same date. At least one male and one female are known to occur. A male was positively identified by photograph at station F21 Top of Dipper (Figure 25) and a family of four marten was captured on camera at a single survey location nearby during a summer 2002 survey by the USFS. While we cannot make definitive statements on reproduction because we have no data to indicate where pairing, gestation, or parturition occurred this data indicates that at a minimum, juveniles do occur within the Heavenly Ski area boundaries. Likewise we cannot make statements regarding reproductive success nor can we make assumptions about sink-source situations of Heavenly.

Home ranges

There are at least two different marten at Heavenly, as discussed above based on the timing of detections. Home range sizes for marten have been cited as 3.2-3.6km^2 in the Sierra Nevada (Barrett and Spencer, 1982). While home range shape likely varies based on terrain and other factors, we can estimate how many animals occur at Heavenly based on these home range estimates. There is one known male, photographed at the Top of Dipper (F21). Based on analysis of the timing of detections, we hypothesize that one animal includes the Monument Peak (F8) and Ridge (F7) area. The latter two stations were hit in similar temporal patterns repeatedly. It is also possible that this same individual is the animal that was detected at the Top of Dipper (F21), which is known to be a different individual from F23 Tower 13 (Figure 24). Theoretical home ranges based on an estimated 3.5km^2 area were created to evaluate if it appeared feasible that three different animals exist at Heavenly. Figure 25 depicts home ranges calculated as 3.5km^2 (~350ha) area circles with detection stations at the center of the home range. If the camera stations were actually located on the periphery of the home ranges, then it is entirely possible that what is shown as two different animals in Figure 25 is actually one animal, a male. Furthermore, this male would have had up to seven camera stations within his home range. What is also interesting to see is the fact that the F23 Tower 13 individual home range, as drawn, does not include additional detection stations. Again if this station is placed on the periphery of the estimated home range, then this animal's home range might include an additional two stations and in fact could overlap with the male photographed at F21 Top of Dipper. Snowtracks revealed that at least one

individual was found to travel north under the Gondola, headed towards F23 Tower 13 area from the top of the Gondola. Photographs of animals taken at detection stations showed scarring on individuals. Scarring may be from interactions with other martens, such as fights, or might be residual from predation attack. Regardless, the possibility of competition for resources, including females, should not be eliminated as a potential cause of scarring seen in the photographs. However, it is more likely that if home ranges do in fact overlap, they are male-female overlaps.

While we cannot definitively say how many marten there are at Heavenly based on the existing data, but we can hypothesize based on other studies. Home range sizes in the Sierra Nevada for eastside martens (Inyo and Humboldt-Toiyabe National Forests) have been cited as being at least three times larger than that known for westside martens (Buskirk and Ruggiero, 1994; Buskirk and Zielinski, 1997). In eastside habitat, male home ranges average 2,749 acres (~1,113ha) in size and female home ranges average 1,155 acres (~467ha) in size (Kucera, 1996). That is, marten in more open habitats similar to what is found on the eastern slopes of the Sierra Nevada have home ranges estimated to be approximately 3 times that of marten in more productive forests of the western Sierra Nevada. Based on the limited information we have from the 2002 survey, we expect marten home ranges at Heavenly to more closely match these estimates. Because there is no data on prey for marten, we cannot determine the available resources, which does affect home range size.

Telemetry would provide quantitative data with which to calculate home range size and would definitively address gender and potentially number of animals at Heavenly. At the same time, snowtracking may be an alternative, more cost effective and certainly less invasive method for addressing home range and some population level questions. Scat analysis can determine gender and potentially differentiate between individual animals. Katherine Ralls of the Smithsonian institute has been successful at these analysis on San Joaquin Kit Fox (Ralls, pers. comm., Ralls et al., 2002). Scat collected in conjunction with a snow track provides detailed information about individual animals – gender, individual identification, subnivean access preferences, habitat and use preferences, diet, and potentially stress based on hormone level analysis. All of this information comes from non-invasive data collection. The animal is never touched by humans, is never pressed to take refuge, and has no chance of dying as a direct result of this survey method.

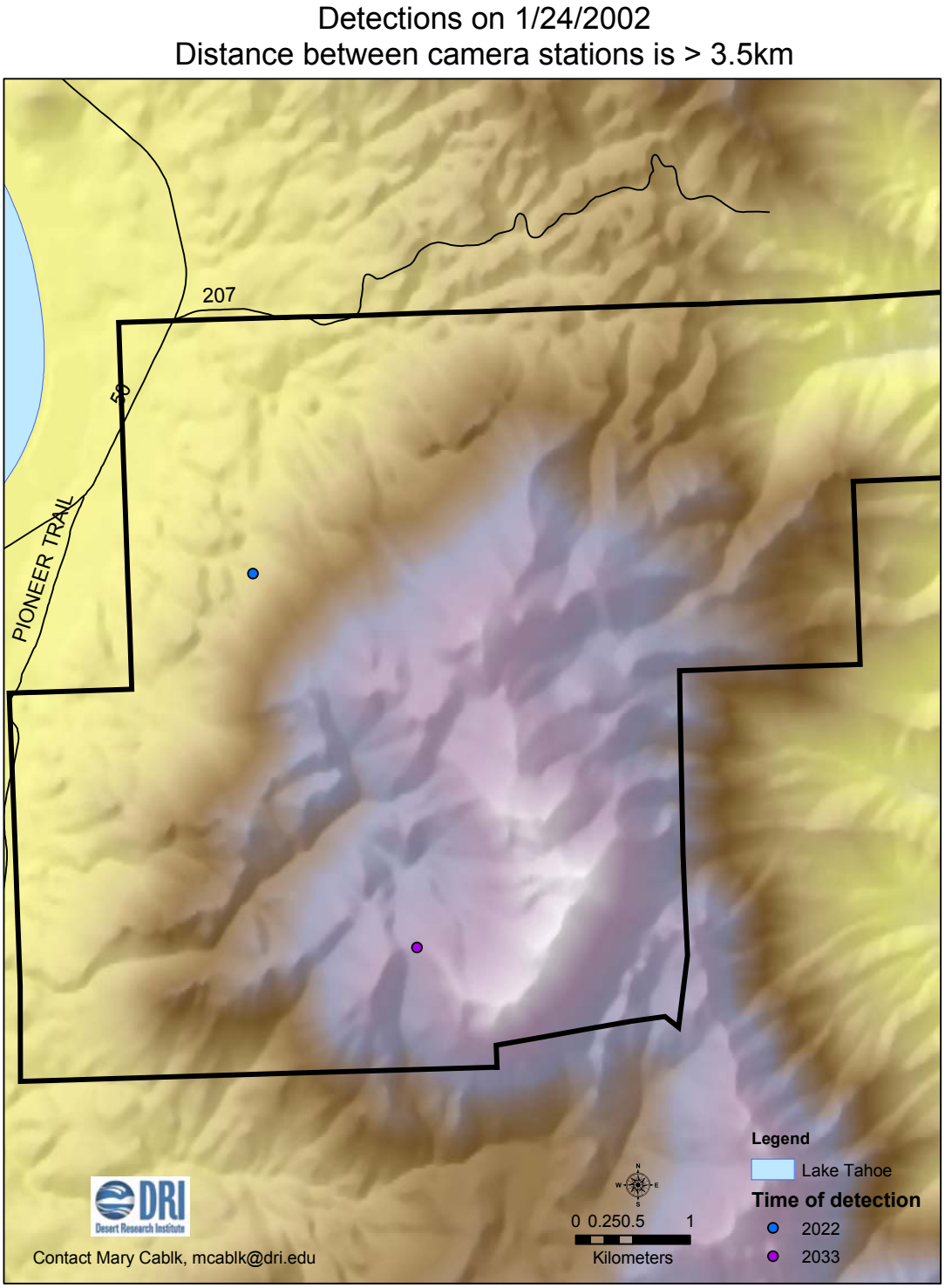

Figure 24. Camera detections that could not physically be made by the same individual marten. The animal would have had to travel over 3.5km straight line distance in 11 minutes.

Figure 25. This photograph clearly indicates the marten is a male.

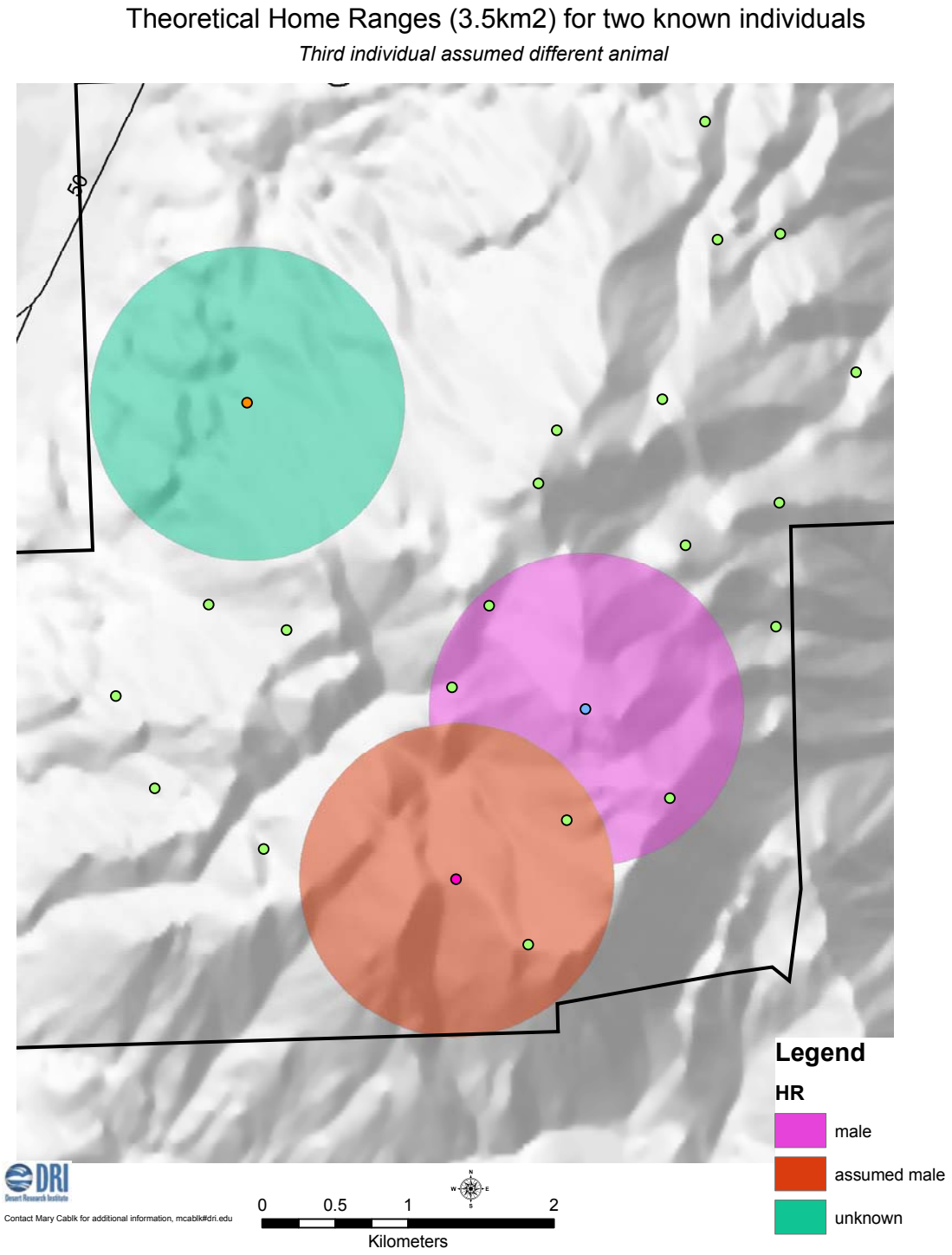

Figure 26. Theoretical home ranges for two known different individual marten (red and green circles) and one hypothesized third individual (pink circle).

Landscape perspective based on Ikonos satellite imagery

The use of Ikonos satellite imagery was critical for successful completion of this project because of the lack of accurate, reliable, recent landscape level data. Preliminary investigations of the Ikonos imagery indicate that quantitative estimates of canopy cover are possible. Discriminating between dominant overstory species may not be possible for a number of reasons. First, there is a high degree of similarity of physiology between the conifer species. That is, even with the near-infrared band the conifers "look" the same. There are some physical differences in canopy that can be detected based on texture but texture is difficult to extract using algorithms applied to digital imagery because texture is not entirely a function of spectral separability. Although there are some distinctions that are clear in the 1m imagery, such as white bark pine, differences in mixtures of canopies are indistinguishable for the most part. For example, some stands had hemlock interspersed and were easily identified on the ground. These same hemlocks were not differentiable in the imagery. Likewise, the difference between western white pine and red fir, although very different species in appearance, are not distinct even in 1m Ikonos imagery. Further investigation may yield different results and some distinctions may be possible, but at this time digital classification at the species level without the use of ancillary data is not possible.

The use of ancillary data may enable species level classification to be accurate enough for common use. Based on the ground truth efforts of this study there is reason to believe that the use of aspect and elevation in combination with the spectral imagery may yield reliable results at the species level. Jeffrey pine, for example has definite elevation constraints as does white fir. Likewise white bark pine occurs only at the highest elevations with maximum exposure. The mixing zone, where white bark co-occurs with lodgepole pine, western white, and even hemlock, may remain difficult to delineate even with ancillary data.

Habitat status

The forest stands at Heavenly are a complex mixture of species. There are few pure stands of one dominant tree and mixtures of stands vary with elevation and aspect. Stands may be dominated by red fir with second dominance being western white pine but switch dominant species (western white with secondary red fir) with increasing elevation without change to percent canopy cover. This makes habitat delineation a more difficult task, especially given the constant canopy cover. The question arises: Is canopy cover more important than species composition? If so, should the entire stand be delineated as one stand type although relative species composition varies? Or is species composition more important and some hard boundary should be drawn to differentiate the relative species compositions regardless of similar canopy cover? In review of existing literature, both canopy cover and species composition are important but no studies have placed relative importance rankings when differences are so slight. At Heavenly, these mixed stands that exhibit subtle differences are the norm rather than the rule.

Similarly, there are many occurrences where a certain mixture occurs as a stand but the percent canopy cover varies. Again, is the change in canopy cover enough to merit some linear differentiation between what is marten habitat by employing a threshold limit? For

example, a mixed stand of western white pine and white bark pine with some lodgepole pine may vary from 50% canopy cover but decrease with aspect to 30% canopy cover. We have little data on whether or not a canopy cover threshold is appropriate, although there is some in the Von Schmidt Flats area. Snowtracking is the best, if not the only method appropriate for answering such questions and beginning to formulate such thresholds.

Compared with current habitat definitions, the marten at Heavenly are using an expanded set of landscape conditions than has been reported for the Sierra Nevada. One reason for this finding is that little research has been conducted on marten within the Lake Tahoe Basin. Surveys conducted by the Nevada Division of Wildlife, for example, have been unsuccessful at detecting marten only a short distance from Heavenly (NDOW, pers. comm.). California Department of Parks, on the other hand, has reported marten occurrences based on camera detections and snow tracking on the western side of the Tahoe Basin. Unfortunately, no quantitative analyses have been conducted on this data nor has definitive studies been focused in these areas. However, officials from NDOW, California Department of Parks, TRPA, USFS, and DRI have begun the process of sharing data and information in an effort to better delineate marten habitat and habitat preferences within the Tahoe Basin. This is an important effort towards joint stewardship on the part of these agencies and organizations.

It is clear from the results of this survey that marten are using a wide range of habitat as defined by canopy cover and dominant overstory species. Unlike marten populations that occur on the western slopes of the Sierra Nevada or in the Cascades Range of the Pacific Northwest, marten at Heavenly are found to use much of the landscape within the managed ski area. There are exceptions to the range within Heavenly. Marten do not appear to occur at lower elevations outside of the basin in Nevada nor do marten appear to occur in relatively close proximity to urban, particularly commercial, development at lower elevations within the basin. Marten clearly cross ski runs and lifts. They also utilize fairly open areas with very low canopy cover, provided the trees in that area are mature. Although initial snow track data are preliminary in terms of sample size, additional analyses of movement patterns might yield differences in movement patterns of open versus more dense canopied areas. No statements can be made regarding how animals are using the habitat within Heavenly without additional snow track data and/ or telemetry studies. Questions remain regarding habitat use by activity, such as foraging, resting, or dispersal.

Marten have been tied to habitat types defined by canopy cover and vegetation species composition based on relationships of those habitat types with preferred prey species (Ruggerio et al., 1994). Again, at Heavenly, marten seem to defy published preferences in the literature and this is likely due to variation in principal prey species. For example, snowshoe hare tracks were identified above 9300ft along the ridgeline above Canyon lift in a relatively open area. The snowshoe hare tracks crossed into a ski run and doubled back on the side from which the animal came. Similarly, flying squirrels have been cited to comprise a large component of marten diet in the winter. Because flying squirrels are nocturnal it is not unusual, then, that marten would also become nocturnal simply as a function of prey availability.

In general researchers cite xeric, conifer dominated forests as being preferred and suitable habitat for marten. Ruggerio et al. (1994) also add that complex forest structure near the ground is critical. However, the stands that had positive camera detections for marten do not necessarily meet this critical criteria. Complexity in certain areas, such as the white bark pine dominated upper extent of the mountain, existed in non-vegetative form (rocks, boulders). It has been found that rock outcroppings in east side habitat are used as resting dens and travel corridors by marten. (Kucera, 1996). The clumped nature of white bark pine growth might be considered complex but not in terms of multiple understory layers.

As reported in the literature, marten were found to use lodgepole pine and red fir. Although marten have been cited to avoid Jeffrey pine associations (Ruggerio et al., 1994) we found that marten did use mixed stand with Jeffrey pine. Typically these stands also contained red fir and western white pine as well. Mixed forest types which dominate the Heavenly landscape are used by marten. Mixed forest types may provide higher complexity in terms of ground cover and may provide more diverse and abundant prey base for marten.

Habitat rule definitions

Each of the four habitat definitions yield different maps of marten habitat and likewise different amounts (area) of habitat. Rule 1 is the least inclusive marten habitat delineation and is not valid but is worth evaluating as part of the process of delineating habitat. Rule 1 is not valid because the stands in which detection stations were located are not large enough to support a marten, because there would be no way for marten to breed if this rule were true, and it is highly unlikely that there are as many marten as there were positive detections. Rule 1 was based partially on the premise that marten do not cross open areas. For marten to reproduce they must make physical contact and to make physical contact they must enter into a territory occupied by a receptive member of the opposite sex which would require crossing an open area. Furthermore there are not enough resources in each of the delineated habitat polygons to sustain either a single marten or a family of marten. Minimum home range size requirements, as discussed above, have been cited under the most productive systems as 350ha. The average size of delineated habitat polygon under rule 1 habitat delineation is 16ha, with a maximum size of 72ha.

Rule 1 is a defensible starting point however, from which to build a suitable habitat map for marten at Heavenly. Under rule 1 a total of approximately 363 ha within the ski area boundaries are suitable for marten. Expanding this to the WHR model the total area of marten habitat more than doubles. Neither of these models accounts for minimum patch size which without the snow track data would be difficult to assess and set. Snow track data indicate that marten do in fact cross open areas such as ski runs. For this reason we can be confident that marten do have a means of accessing and traveling through very small and potentially isolated stands of trees, such as “tree islands” within ski runs.

Camera stations were located in 11 different overstory species categories and for this reason there are 11 different overstory species categories in rules 1 and 2. Canopy cover in these stands ranged between 5% (white bark pine, highest elevations) to 90% (lodgepole pine, mid-elevation). Looking at each habitat type (Figure 27), lodgepole pine and white fir had the

highest canopy cover densities followed by the mixed white fir/Jeffrey pine and mixed red fir western white.

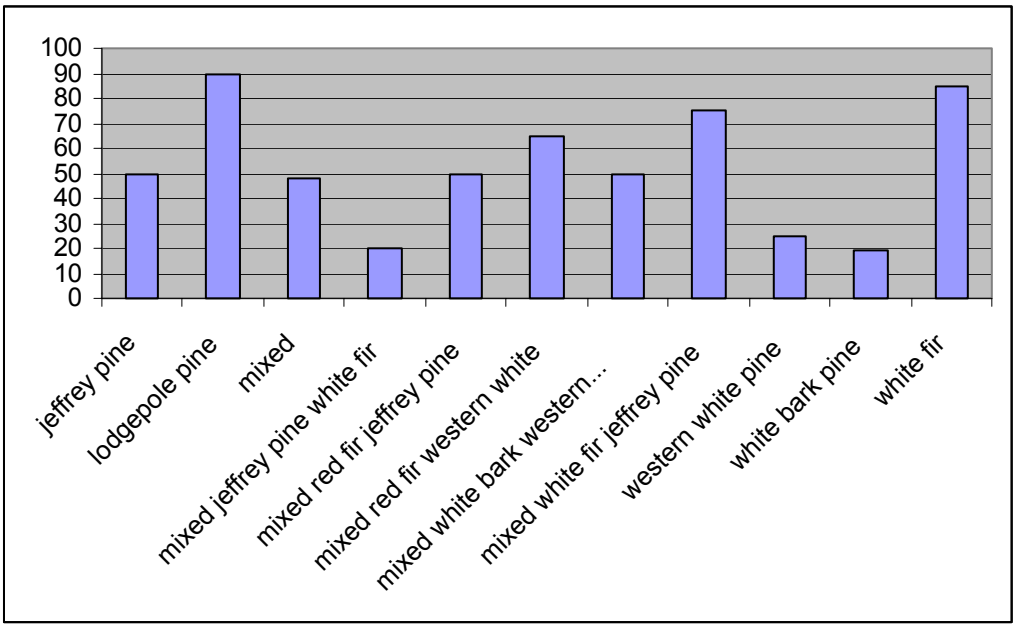

Figure 27. Mean canopy cover (%) for rules 1 and 2 for each overstory stand type.

Using data from the camera and track plates only (rules 1 and 2) it is clear that mixed red fir/western white pine comprises the majority of marten habitat by area of stand category, followed by mixed species overstory and white bark pine, respectively. This refers to the amount of acreage available as marten habitat and does not indicate habitat preference by marten. Only a few stand types served to expand the total area of marten habitat, namely mixed, mixed red fir/western white pine, mixed white bark pine/western white pine, western white pine, white bark pine and white fir. These are the stand categories that are found with the same canopy cover in areas beyond those immediately sampled by a camera station.

When we account for snow track data in combination with the detection station data (rule 3), an additional almost 560 ha of habitat are added to the marten habitat map. Because marten tracks were found to cross ski runs and open areas, the largest habitat category becomes the zero canopy cover. Clearly, open ski runs and roads are not prime marten habitat, but marten are using open areas. In one instance, an individual marten was found to be foraging alongside and within a cleared area serving the gondola. This animal was not avoiding the open area, it was using the area under the lift to forage. This behavior was indicated by multiple tracks on different dates under multiple and different lifts.

Under the rule 3 habitat definition, mixed red fir/western white pine and mixed forest stands comprise the second and third largest acreage of marten habitat. The average canopy cover for these stands was 57% and 31%, respectively (Figure 27). White fir remains the smallest habitat acreage available at Heavenly, most likely because it is a pioneer species and is a lower elevation species as well. Rule 3 habitat definition is similar to rule 2 in terms of total

area of habitat, but the habitat types are very different between the two. Eleven different stand types were identified under rule 2 (the same as for rule 1) but with the inclusion of snowtracking data an additional five species composition categories were added. The reason the amount of acreage can be similar is that under rule 2 any habitat that is similar to the stands in which positive detections occurred but under rule 3, only detection station data and stands that contained snowtrack data are included.

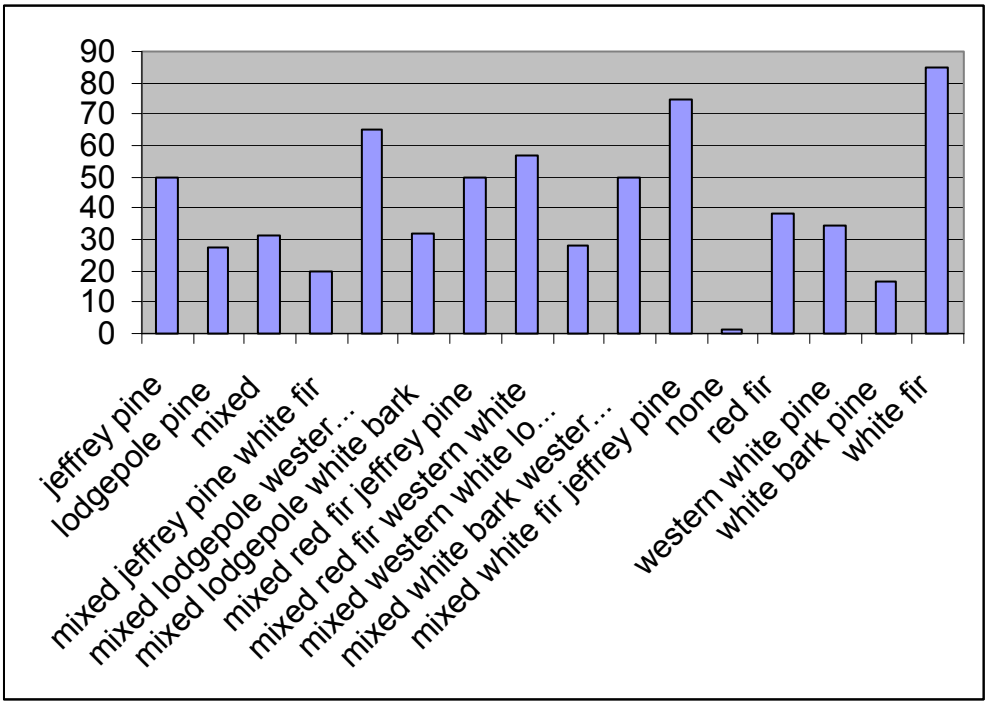

Figure 28. Canopy cover (%) for rules 3 and 4 for each overstory stand type.

Snowtrack data changes the habitat definitions both in terms of species composition and canopy cover (mean and standard deviation). Habitat defined by only camera stations is inherently biased by the means used to locate where the stations will be installed. Furthermore, no additional habitat information can be assessed because the stations are stationary. What snowtracking offers is a more realistic and accurate assessment of where marten occur. Marten were found to occur in five additional stand types that would otherwise not have been identified because camera stations were not placed in those stand types. This is most obvious in comparing canopy cover estimates for lodgepole pine. Figure 29 shows the comparison in mean canopy cover for each overstory type. Only one camera station was placed in a lodgepole pine stand and that stand was very dense, with an estimated 90% canopy cover. However, marten tracks were found in additional lodgepole pine stands with much lower canopy cover. Therefore, overall mean canopy cover estimates (mean 27%) are lower than what otherwise would have been reported. With additional snowtracking data the relative amount of activity spent in stands with varying canopy cover estimates can be assessed for a more robust interpretation of this kind of data. For example, suppose marten are found to spend the majority of their time in lodgepole pine stands greater than 75% canopy cover but are found to travel through stands with less than 30% canopy cover

infrequently. This information can be used to refine current habitat delineations and assign suitability.

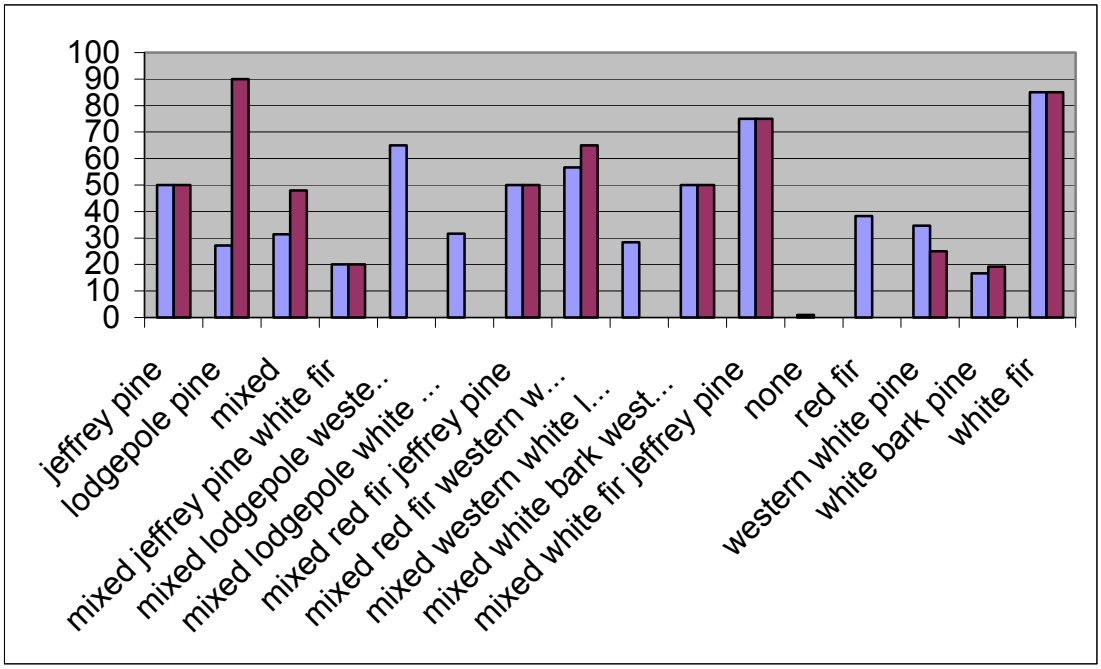

Figure 29. Comparison of mean canopy cover by stand type between habitat defined by detection station only (purple) and habitat defined by detection station and snowtrack data (blue).

Rule 4 is the most comprehensive delineation of marten habitat. A little more than 1,411 ha of habitat were delineated at Heavenly and this habitat is located throughout the special use permit area. A total of sixteen different overstory species composition types were identified. In evaluating the total acreage for each species category do not be mislead by the relatively high amount of "none" category, essentially runs, lifts, roads, and other maintained cleared areas. The "none" category is included because marten do cross these areas and based on the snowtracking data are using features of these areas for subnivean access. These open areas should not be considered generically prime habitat for marten rather, they should be considered one type of habitat that has specific use.

Of the forested cover types mixed red fir/western white pine is most available to marten in terms of acreage. The mean canopy cover estimate for this stand type was 65% under rule 4 (57% canopy cover based on camera station data alone). The mixed red fir/western white forest type is what is traditionally cited as suitable habitat and this finding is consistent with results from the 1993 survey. True mixed stands, with more than three overstory species are abundant throughout the mid-elevations of Heavenly. Mixes of pine, fir and hemlock are not uncommon. We found stands with consistent canopy cover often held gradations of western white pine, white bark pine, lodgepole pine, and red fir with occasional Jeffrey pine and hemlock interspersed. At lower elevations white fir will also be included in the mix. As discussed above, these diverse stands are very available to marten and are used by marten based on both camera station and snowtracking data. Much of Heavenly is at high elevations

and as such a large proportion of the landscape supports white bark pine. Pure white bark pine stands at Heavenly are fairly uniform in terms of canopy cover and the mean difference between canopy cover of these stands was similar (15% and 17% for rule 1 and rule 4, respectively). White bark pine was the third most abundant forest cover type used by marten.

Arguably there exists bias in snowtracking. Not all tracks can be located, some tracks will be identified and followed because they are identified first while others that exist go undetected and undocumented. Certainly tracks will exist and disappear before they can be identified. Tracks cannot be followed to their resolution for a number of reasons including safety, weather conditions, and constraints associated with working in remote areas to name a few. However, the additional data that could be collected would provide information useful in refining the current marten habitat delineation.

The importance of an educated staff – collaboration is imperative
Ancillary information should not be disregarded if collected by knowledgeable individuals. Reports from ski patrol or other Heavenly employees on marten sightings are worth investigating, such as reports of animals in huts or in and around the mid-station of the tram. Likewise, marten tracks were observed in the Monument vicinity when the camera station was installed. The tracks were straight-line combinations forming a grid throughout the plateau below Monument Peak where the station was located. No data were collected on those tracks but clearly there was some level of activity in that open, sparsely vegetated area. Unfortunately, such anecdotes cannot be integrated into quantitative analyses but these reports are useful for formulating additional hypotheses and for assisting with interpretation of analysis results. For example, would the detection at the Monument station be considered an unlikely event and due to draw from the station bait? Based on the knowledge that at least one marten was present before the station was installed (identification of tracks as noted by investigators) and that detections were found in similar habitat at other areas of the ski area, the answer is no, the detection is not an unlikely event. Marten at Heavenly are using areas that have not been considered suitable habitat in the past based on surveys conducted in other locations outside of the Lake Tahoe Basin.

If most of Heavenly's special use permit area is deemed suitable marten habitat, management becomes more difficult. At this point we know that there is a lot of area that marten are using or may use, but how that habitat is used and what its relative ranking or importance is, remains unknown. Habitat use and relative importance likely varies with season. What is critical for birthing and rearing young may not be the same habitat used for foraging in winter months. Likewise habitat may shift and expand depending on the gender of the individual and time of year. During breeding season suitable habitat for males includes those areas where females occur. How females select habitat during that time and what, exactly what that habitat includes, is unknown. Because there is a documented case of a male individual and a female individual, additional research into marten reproduction is warranted to better refine habitat preferences and reproduction within Heavenly ski area.

MANAGEMENT RECOMMENDATIONS

1. Create accurate and updated digital data layers that represent current ground conditions for use beyond this survey project. Important data layers would include canopy cover, species composition, road cuts/ski runs/ski lifts, and downed woody debris. These layers should be updated in a timely manner, such as within 5 year time frames. The road layer should be updated more frequently.

2. Work with forest managers on adjacent lands to share these data layers. Wildlife clearly does not respect political boundaries. Furthermore, how can the LTBMU claim to manage all of Heavenly as a special use permit area without complete coverage of critical data layers? By implementing recommendation #1, above, this important task would be much easier to accomplish.

3. Continue data collection using non-invasive snow tracking. Create an expanded survey design in terms of variables measured. Include scat collection and record sign of foraging and if possible what prey. Use the snowtracking data to refine current habitat maps to suitability maps.

4. Eliminate trash as food sources for any wildlife. Install signs alerting and educating the public about the problems of feeding wildlife.

5. Do not allow expansion of nighttime recreational activities at Heavenly beyond those that currently occur that involve artificial lighting. Based on winter activity patterns nighttime activities would impact marten and potentially prey sources.

6. Daytime activities should be restricted in terms of geography and number of visitors. Again, refinement of the current (2003) marten habitat map would serve to assist in determining appropriate areas for summer, daytime activities.

7. Educate the Heavenly personnel, as they are a very valuable asset for collecting ancillary data. They are also a willing resource and should be utilized as much as possible.

8. Conduct a small mammal survey to evaluate prey abundance and availability at Heavenly. Extend the survey trap lines beyond the existing managed ski area for comparisons relating to ski area activities.

9. Because marten are found to use most areas at Heavenly but there is no information on the relative importance of those areas nor is it known what is suitable and what is marginal habitat, further studies should be conducted to place habitat in these contexts. Expansion that involves clearing areas, cutting live or dead timber, or the removal of understory vegetation should be considered activities that may present significant risk (i.e. seriously impacting) to what may be critical if not suitable marten habitat. Susan wants “expansion” defined.

10. Locating den sites should be actively pursued to the extent recommended by the Sierra Nevada Framework.

11. Continue the practice of leaving downed woody debris when cleared to maintain understory complexity and provide habitat for prey species.

12. Additional surveys outside of Heavenly boundaries (i.e. the area outside of the "out of bounds" roped area)and outside of the Heavenly special use permitted area is critical to evaluate habitat selection of marten and seasonal use patterns and should be actively pursued.

13. Recognize that only conducting camera/track plate surveys at any time frame will not a) allow managers to recognize a problem in the marten population or b) provide enough time to intervene with any downward population trend.

Suggestions for Further Study

Most of the management recommendations necessitate additional research. Although management agencies and private corporations tend to be limited in research funds, in the situation of wildlife additional high quality, quantitative research can only serve to facilitate cooperation and collaboration between Heavenly and the USFS. Refinement of the marten habitat delineation map can be accomplished with snow tracking data and the USFS has committed towards that effort for an additional year at least in terms of data collection. Furthermore, additional snow tracking efforts can easily serve to gather data that can be preserved and analyzed in the future as opportunities to do so arise. The collection of scat, for example, may allow retrospective studies which can serve as baseline, for defining number of marten, gender, and if female, stress level. At the same time simply identifying subnivean access type and location is important data for furthering our understanding of marten ecology. Finally, carnivore researchers have been interested in the need to understand the impacts of fragmentation on marten. The effects of fragmentation from most anthropogenic causes are unknown, although it is expected that fragmentation does impact marten. Any data that would further our understanding of the impacts of anthropogenic activities, particularly those that reshape and the change the characteristics of the landscape, would be valuable.

ACKNOWLEDGEMENTS

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APPENDIX 1

NLCD Land Cover Classification System Land Cover Class Definitions

Water - All areas of open water or permanent ice/snow cover.

11. Open Water - All areas of open water; typically 25 percent or greater cover of water (per pixel).

12. Perennial Ice/Snow - All areas characterized by year-long cover of ice and/or snow.

Developed - Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).

21. Low Intensity Residential - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to100 percent of the cover.

23. Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay - Prennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits - Areas of extractive mining activities with significant surface expression.

33. Transitional - Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland - Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

52. Non-natural Woody - Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other - Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland - Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains - Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow - Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

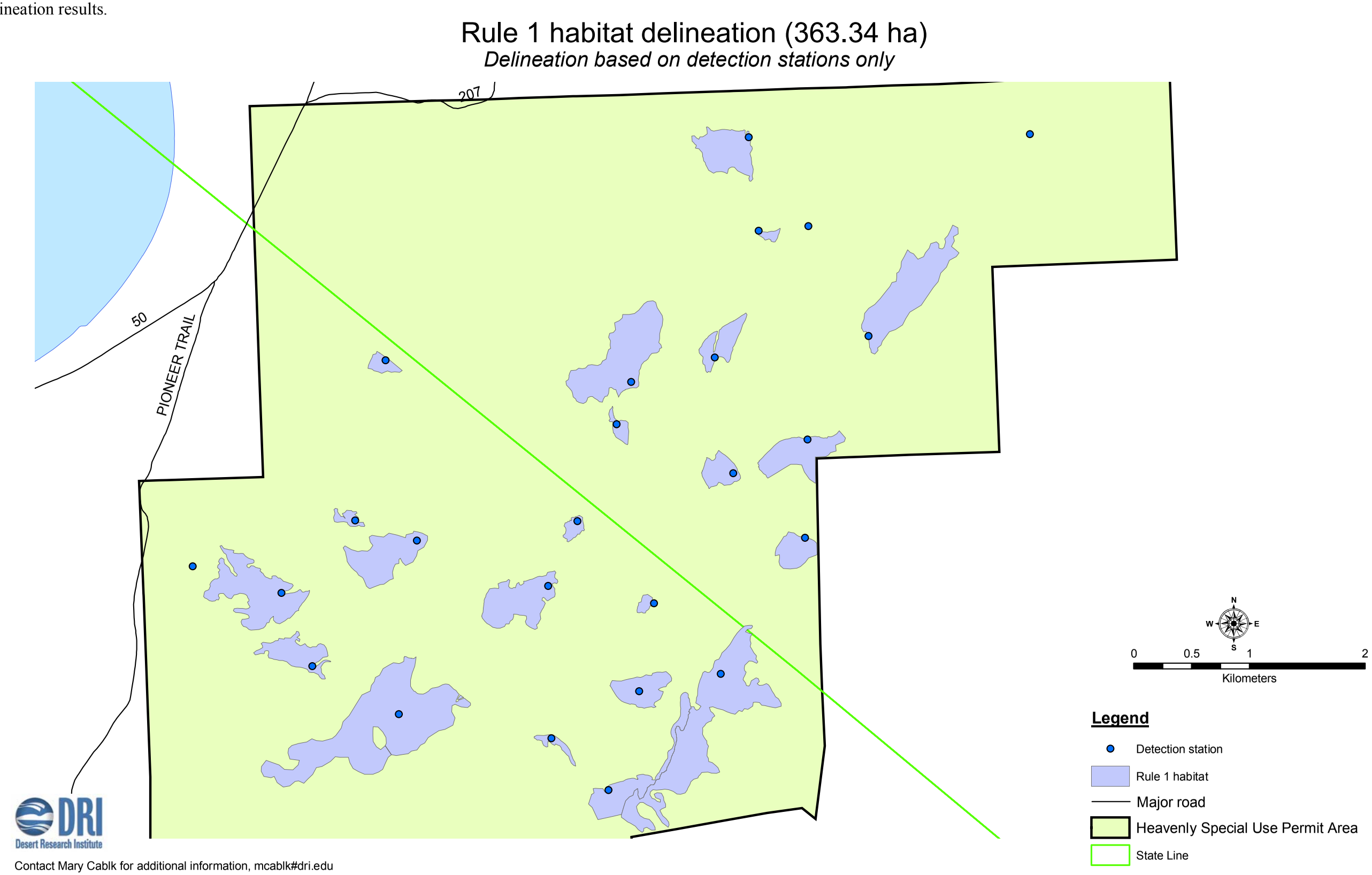
85. Urban/Recreational Grasses - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.

91. Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

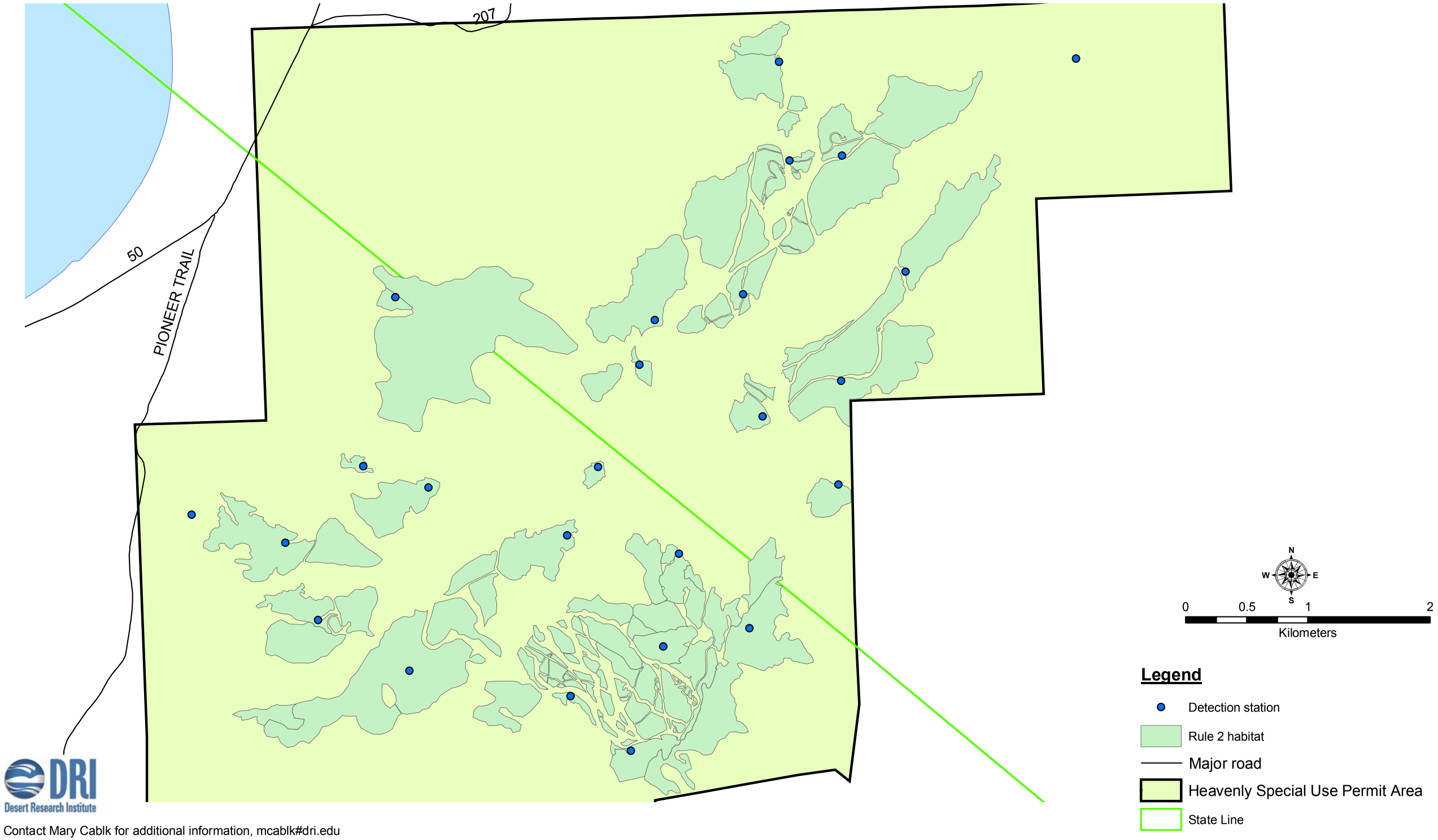
92. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

APPENDIX 2
Rule based habitat delineation results.



Rule 2 habitat delineation (887.17 ha)

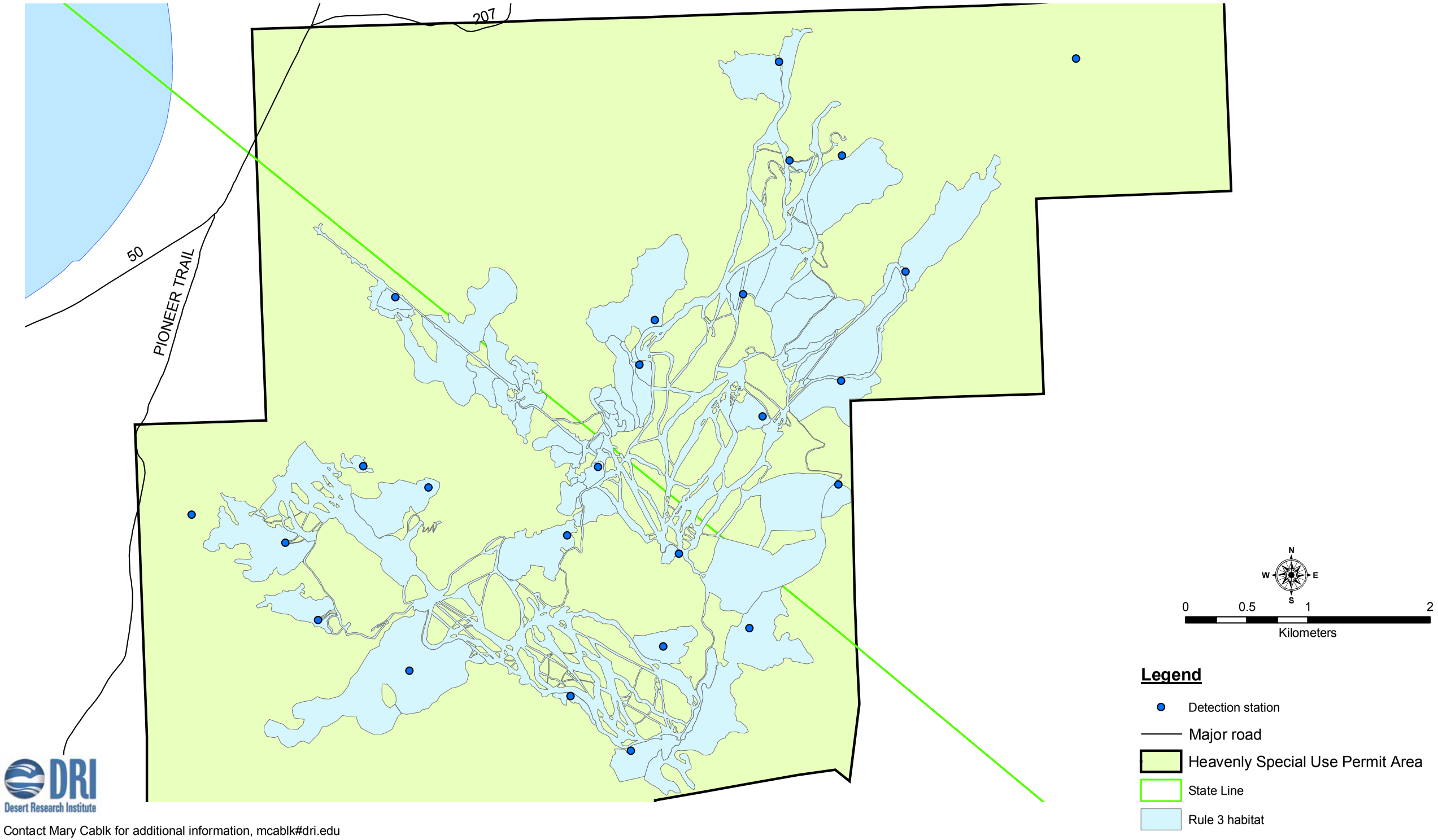
WHR for marten based on detection stations



Contact Mary Cablk for additional information, mcablk#dri.edu

Rule 3 habitat delineation (881.83 ha)

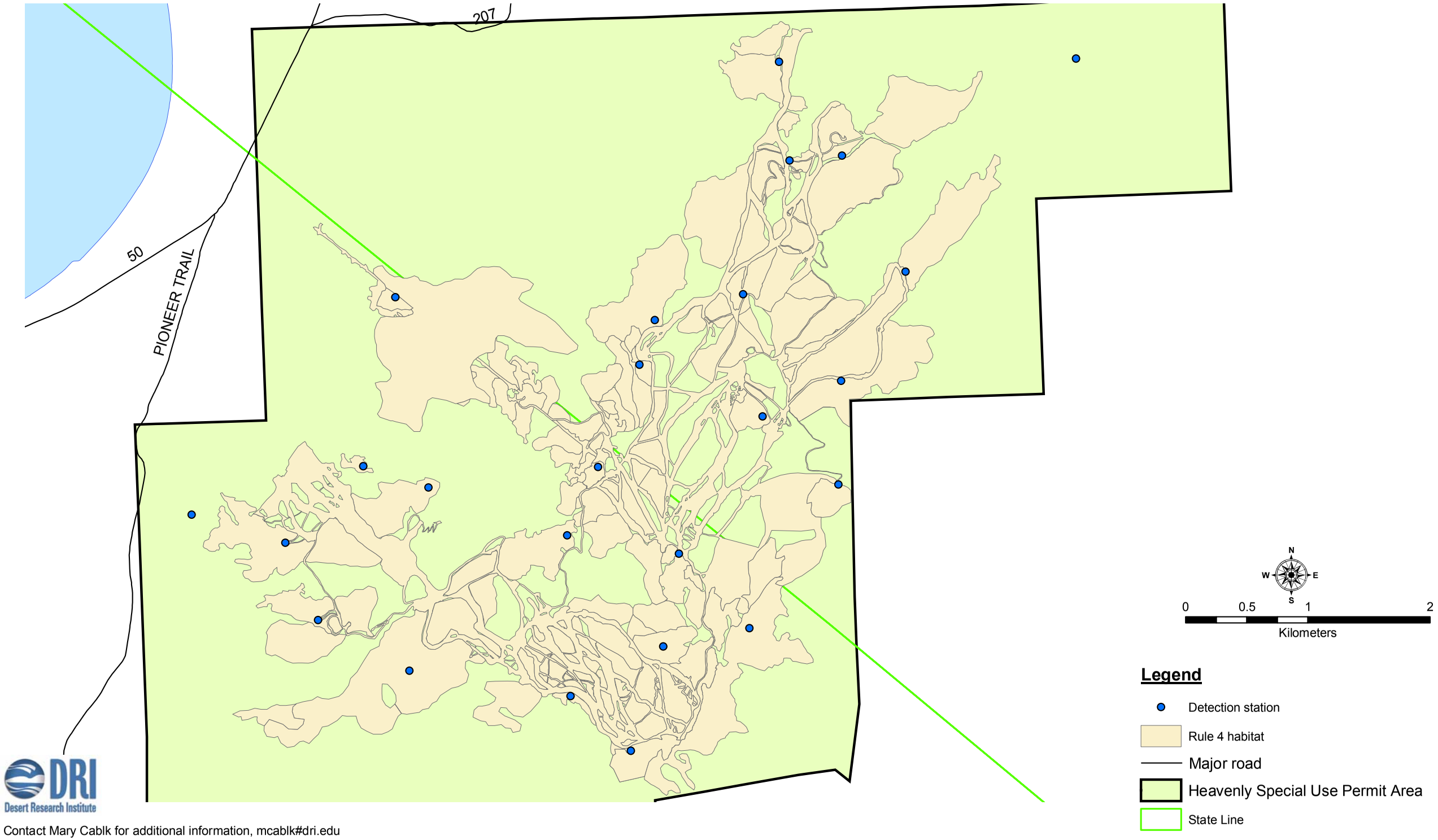
Delineation based on detection stations and snow track data



Contact Mary Cablk for additional information, mcablk#dri.edu

Rule 4 habitat delineation (1411.04 ha)

WHR for marten based on all detection data



Contact Mary Cablk for additional information, mcablk#dri.edu