Multi-Species Inventory and Monitoring:

A Foundation for Comprehensive Biological Status and Trend Monitoring in the Lake Tahoe Basin

Final Report

Lake Tahoe Basin Management Unit

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Executive Summary

Introduction

The Multi Species Inventory and Monitoring (MSIM) Project was a comprehensive forest-wide multiple species inventory and monitoring effort intended to establish baseline conditions for a wide range of wildlife, plants and their habitats within the Lake Tahoe Basin Management Unit (LTBMU) and to inform the development of a long-term status and trend monitoring and evaluation program. This report marks the first attempt to evaluate MSIM monitoring protocols (originally developed for the Sierra Nevada Forest Plan Amendment, (USDA 2001)) in terms of their ability to monitor changes in population metrics (e.g., site occupancy and abundance) for groups of species at the forest-wide scale based on empirical data.

The primary objectives of this project were to:

- Establish baseline status of wildlife, plants and their habitats in the Lake Tahoe basin, including many species of concern
- Evaluate the effectiveness of the project design for long term status and change monitoring
- Determine whether there are species or species groups that can serve as biological indicators for long-term monitoring
- Identify wildlife habitat relationships

Study area and methods

The project was implemented in the Lake Tahoe basin, in California and Nevada, from 2002 to 2005. Eighty-percent of the land area in the basin is managed by the US Forest Service - Lake Tahoe Basin Management Unit; approximately 180,000 acres. The Lake Tahoe basin contains the largest alpine lake in North America and is located on the east–west boundary of 2 major biogeographic provinces. The basin encompasses an elevational range from 2000 to nearly 3500 m (6229 to 10881 ft).

Seven terrestrial wildlife, plant and habitat sampling protocols were implemented at 105 representative sites on national forest lands throughout the Lake Tahoe basin (forest-wide network), and 3 aquatic vertebrate and habitat sampling protocols that were implemented at 148 representative lake, pond and meadow sites throughout the basin (lentic-aquatic network).

Site occupancy (or proportion of sites occupied) and average abundances (for some species groups) were calculated to describe current population status of wildlife and plant species. Probability of detection (or detectability) was the metric used to evaluate the effectiveness of MSIM protocols for detecting species targeted by each protocol. Sampling adequacy and short-term changes (i.e., annual) in site occupancy were also evaluated to assist in forming recommendations for the sampling design of future long-term monitoring.

Key Findings

Findings from this project apply to the diversity of land types occurring on National Forest System lands (primarily dominated by coniferous-forest vegetation) and lentic-aquatic habitats (e.g., meadows, lakes, ponds, etc) in the Lake Tahoe basin due to the sampling focus within these 2 domains.

Objective 1: Status of Wildlife, Plants and Their Habitats

Wildlife Status and Distribution

Detections

- A total of 189 wildlife species were detected (135 birds, 38 mammals, 4 amphibians, 6 reptiles).
- Fifty-five of the 65 special status species (i.e., TES species, FSS, and Pathway 2007 proposed species of concern, species of interest and species groups of interest) were detected
- Eight wildlife species not previously documented as occurring in the Tahoe basin (according to the Watershed Assessment) were detected by sampling.

Wildlife	Number of detections	Detection locations in the Tahoe basin
Canyon Wren (*Catherpes mexicanus*)	2	East-southeast
Savannah Sparrow (*Passerculus sandwichensis*)	3	South-southeast
Great Basin pocket mouse (*Perognathus parvus*)	2	South and West
Gray fox (*Urocyon cinereoargenteus)*	1	Southeast
Ringtail cat (*Bassariscus astutus*)	3	East
Hoary bat (*Lasiurus cinereus*)	2	East-southeast and South
Long-legged myotis (*Myotis volans)*	13	North, Northeast, West and East
Western red bat (*Lasiurus blossevillii*)	3	South

- Relatively few species were detected at a large proportion of sites.
- The majority of species in all species groups (except bats) were detected at relatively few sites overall (<20% of sites sampled).
- Detection frequencies indicate high levels of rarity in the basin.

Distributions

- Overall songbirds, aquatic reptiles and bats were the most widely distributed species throughout the Tahoe basin, while medium/large carnivores tended to have the most restricted distributions in terms of the number of sub-watersheds where they occurred.

- The most species-rich subwatersheds for each species group (based on average number of species detected per site) were as follows: 1) birds: Lake Tahoe East Shore – Northern half, 2) bats: Lake Tahoe East Shore-Northern and Southern halves, 3) small mammals and carnivores: Cascade-Taylor-Tallac, and 4) amphibians and reptiles: Ward-Blackwood.
- An average of 95 and 68 species across all species groups were detected per subwatershed at terrestrial and aquatic monitoring sites, respectively.
- Species richness at the subwatershed scale was generally positively associated with habitat diversity within the watershed, except for the Cascade-Taylor-Tallac and the Upper Truckee-Trout subwatersheds; the former had greater and the latter lower species richness than would be expected based on habitat diversity.
- Sites in the northeastern and northern portions of the Lake Tahoe basin contained the greatest total richness per watershed (total richness per watershed/# sites sampled per watershed).

<u>Birds</u>

- Thirty-seven special status bird species (primarily Pathway 2007 proposed SOC or SOI) were detected, of which many were detected at both forestwide and lentic monitoring sites, although lentic sites harbored a greater number (33 of 37).
- Abundance estimates for birds at individual survey stations ranged from an average of < 1 to ~6 individuals, although most species averaged < 1 individual per survey to each station.
- Up to 14 bird species may have experienced moderate to marked changes in abundance relative to historical records from the early-mid 1900s (see Table below)

Species	**Observed change**	**Confidence in observation**
White-crowned sparrow	decline	likely
Ruby-crowned kinglet	decline	likely
House finch	decline	likely
Hermit warbler	decline	possible
Red—breasted sapsucker	decline	possible
Blue grouse	decline	possible
House wren	decline	possible
White breasted nuthatch	increase	likely
Brown-headed cowbird	increase	possible
Cassin's vireo	increase	possible
Mourning dove	increase	possible
Band-tailed pigeon	increase	possible
Pine grosbeak	increase	possible
Red crossbill	increase	possible

- Brown-headed Cowbirds, an invasive species with the potential to negatively impact many songbird species, were detected at 62% of forest-wide sites and 28% of lake, pond and meadow sites; cowbirds were detected in all major sub-watersheds.
- Local abundance estimates were derived in this project for select bird species identified as focal species for coniferous forests in the Sierra bio-region (CalPIF 2002); these estimates may be useful as baselines for future local and regionwide monitoring.

Mammals

- Forty-six mammal species were detected.
- The most common small mammals at terrestrial sites (present at >95% of sites) were deer mice and Douglas' squirrel, two important food sources for many carnivores, including three Forest Service Sensitive species (California Spotted Owl, Northern Goshawk, and American marten).
- Bushy-tailed woodrat and Northern flying squirrel, two additional primary prey of top carnivores were detected at 12 and 16% of sites, respectively.
- The most common medium/large carnivores encountered at terrestrial sites were black bear and American marten.
- Mule deer is the only special status mammal species, and it was detected at 13 sites.
- The most common bats were long-eared myotis, big brown and little brown myotis and the silver-haired bat.

Amphibians and Reptiles

- Seven amphibian and reptile species were detected.
- The most common amphibian was the pacific treefrog and the most frequently encountered aquatic reptile was the western terrestrial garter snake.
- Since 1997, the long-toed salamander, common garter snake and western terrestrial appear to be stable or slightly increasing in site occupancy, while the pacific treefrog, western toad and sierra garter snake decreased slightly in occupancy, however none of these trends were statistically significant.
- Mountain yellow-legged frogs were absent from sampled lentic monitoring sites, however this species was once relatively abundant throughout the Tahoe basin and all of the high Sierra, historical records exist for at least 15 locations in the Tahoe basin, including locations on the east, south and north shores.
- Bullfrogs, an exotic and invasive species, were detected at 7 sites, dispersed throughout 3 subwatersheds in the southern and eastern part of the Tahoe basin.

Plant Status and Distribution

Detections

- We detected a total of 460 vascular plant species (12 trees, 57 shrubs, 311 herbs, 69 grass-like plants and 11 ferns), none of which were special status species.
- Seventy-two plant species detected in this MSIM effort had not been previously recorded in project related surveys by LTBMU botanists over the past 5 years.
- Nine plants (primarily invasive weeds) detected were not documented as occurring in Tahoe basin according to the Watershed Assessment and should be considered in future land management and monitoring actions

Plants
Convolvulus arvensis
Grindelia squarrosa
Medicago sativa
Poa bulbosa
Goodyera oblongifoli
Linanthus nuttallii ssp. pubescens
Trifolium longipes var. nevadense
Festuca idahoensi
Piperia leptopetala

Distribution

- Trees and shrubs were the most widely distributed plants throughout the sub-watersheds in the Tahoe basin, while herbs, grass-like plants and ferns were the most restricted in their distributions throughout the basin.
- Most conifers were detected at > 60% of sites, with the exception of ponderosa pine (2%), incense cedar (12%) white bark pine (15%), juniper (20%) and mountain hemlock (32%).
- The majority of shrub and herbaceous species (55% and 74%, respectively) were detected at less than 5% of sites, indicating a high degree of rarity in the basin.
- The most species-rich subwatershed (based on average number of species detected per site) was Ward-Blackwood.

Forestwide Habitat Condition

Habitat types

- Fourteen habitat types (CWHR) were represented by the terrestrial monitoring sites: 9 tree, 3 shrub, 1 herb-dominated and 1 urban type.
- Field habitat typing was moderately to highly inconsistent with GIS assigned (IKONOS v.4) habitat types. Wet meadow, Jeffrey pine and lodgepole pine habitats had the greatest levels of concurrence between field generated habitat typing and GIS (68%), red fir and white fir habitat

had moderate levels of concurrence (~40%), and aspen, montane chaparral, mountain riparian, sagebrush and sierran mixed conifer had low levels of concurrence (0-13%).
- Approximately 20% of terrestrial sites contained at least one of four stations dominated by CWHR seral stage 6; containing the largest trees and the most structurally diverse habitat based on CWHR habitat classification. Seventy-three percent of these stations with old growth characteristics occurred within designated old forest emphasis areas in the Lake Tahoe basin, whereas only ~50% of stations sampled fell within old forest emphasis areas.

Vegetation structure
- Quadratic mean diameter values averaged 19.5 inches per site (s.d. = 5.6); and stand density index values averaged 195 stems/acre (s.d. = 102) across all sites.
- Canopy cover values averaged 50% cover (s.d. = 20%) across sites sampled in LTBMU, and canopy cover was less variable among sites in the same subwatershed than among sites within the same habitat types across the basin.
- Of 37 sites sampled for tree regeneration via seedling/sapling counts, we observed tree regeneration (presence of live seedlings/saplings) at 95% of sites. An average of 229 (s.d. = 286) seedlings (< 1 inch dbh) 75 (s.d. = 52) saplings per acre were observed.
- Live vegetation was observed most frequently (~50% of transect points sampled) between 0-1 meters from the ground surface compared to all other height intervals, and relatively few sites had trees that exceeded 25 meters (~75 ft).
- Snag densities varied by size class, and were greatest on average for small (5-11 in dbh) and medium (11-24 in dbh) sized snags (~4 snags/acre each). Snags in both of the largest size classes (24-30 and > 30 in dbh) averaged approximately 1-1.5 snags/acre.
- Ratio of small-medium sized snags (<24 in dbh) to large snags (> 24 in dbh) was approximately 4-5:1 on average.

Coarse woody debris and ground cover
- Overall, coarse woody debris (> 3 in diameter) biomass averaged 15.5 tons per acre and was highly variable (s.d =18.2 tons/acre).
- Ground cover was dominated most consistently by litter (~ 50%) with other cover types (e.g., shrubs, rock, grass, bare ground etc) less common overall.
- Litter depth values varied much more dramatically by habitat than by the other 2 strata (sub-watersheds and wildfire threat zone)

Vegetation conditions

- Red fir, white fir and Sierran mixed conifer habitats were the most dense, structurally diverse habitats and contained the greatest tree/snag densities, coarse woody debris biomass, and litter depths of all habitats sampled in LTBMU.
- The Ward-Blackwood-Eagle Rock, East Shore-South and Upper Truckee-Trout sub watersheds appear to have the greatest old growth contributing features: high large tree/snag densities and high large coarse woody debris biomass.
- Sites in the WUI threat and defense zones contained higher coarse woody debris biomass, litter depth, small and medium tree and snag densities (<24 in dbh) than sites outside defense and threat zones in the general forest.
- Management activities are often dependent upon the use of vegetation data for planning, evaluation and/or monitoring. Vegetation data collected as part of this MSIM effort could be used to help improve such GIS datasets used for land management planning in the Lake Tahoe basin.

Habitat metric evaluation

- The following habitat condition metrics had the least variability (coefficient of variation (CV) < ~100%) among sites: proportion of live vegetation per height interval (vertical structure), basal area, canopy cover, quadratic mean diameter and stand density index.
- Coarse woody debris biomass, tree and snag densities, litter depths and percentage ground cover estimates were more highly variable (CV > 100%), demonstrating the greater spatial heterogeneity of these habitat features in the Tahoe basin.
- Several habitat metrics were also important for describing site occupancy for a number of wildlife and plant species: canopy cover, vertical structure, basal area, ground cover and coarse woody debris volume.

Lentic Habitat Condition

- The landscape surrounding lentic monitoring sites most consistently comprised the following habitat types: lodgepole pine, Jeffrey pine, red fir, subalpine conifer and less frequently white fir, sagebrush and mixed chapparel; however, patterns varied by sub-watershed.
- Silt was the most common substrate in both the littoral zone and in the upland adjacent to the shoreline of lentic monitoring sites.
- Logs were prevalent, but were typically not abundant in the littoral zone at most sites.

- Availability of logs for cover in the upland was low overall, but greatest on average and most variable at small lakes compared to larger lakes or meadows.
- Emergent plants were both prevalent and abundant at lentic sites; present at over 90% of all sites.
- Sites on average contained 60-80% herbaceous cover in the upland, followed by shrub cover (30-50%) and tree cover (20-30%).
- Small lakes appeared to have the lowest percentage of vegetative cover in the upland compared to all other lentic sites.
- On average lentic sites had a single inlet and a single outlet, with the exception of large lakes which tended to have an average of 2 inlets and one outlet.

Objective 2: Design effectiveness for Long-term monitoring

Protocol effectiveness

- For all species groups, we detected 70-98% of species expected to be detected with surveys.
- When considering all species occurring in the Tahoe basin (within all available habitat types), the MSIM project proved very effective at detecting the majority of small mammals, carnivores, bats, reptiles and amphibians occurring in the Tahoe basin (70-98%), but was less effective at detecting the complete assemblage of plants (primarily grasses, herbs and ferns) and birds occurring in the Tahoe basin (35-62%).
- Low abundances for most bird species makes detecting significant changes in abundance values difficult. Compiling results across multiple stations (total abundance vs. average per station) may generate abundance estimates that are more efficient to monitor over time.
- Quadrat sampling contributed greatest to the detection of plant species composition at terrestrial monitoring sites, followed by line intercept and point intercept sampling.
- Line intercept sampling appeared to produce the most reliable estimates of plant cover in this project, compared to both quadrat and point intercept sampling.
- Comparison of 2 measurements of plant abundance, frequency of occurrence among quadrats and mean cover across quadrats, indicated that frequency of occurrence measures were less variable and possibly a better candidate metric for detecting significant changes over time than cover estimates.

Species detectability

- A total of 69 wildlife species were detected with moderate-high probability of detection with MSIM surveys ($\geq$ 50% chance of detecting the species at sites where it occurs)
- As expected, the most common species had the highest detectabilities, and were also species associated with the dominant habitats sampled: coniferous forest and small lakes and ponds.
- Birds and small mammals had the greatest total number of species with moderate to high detectability of all species groups sampled: 47 birds and 11 small mammals. However, each species group had at least 1 species with moderate to high detectability.
- Amphibians, garter snakes and bats had the highest proportion of species within their respective species group with moderate to high detectability.
- Results of a cost to benefit analysis indicated that bird point count surveys were the most cost-effective -- the greatest number of species with moderate to high detectability per unit of survey cost.
- Aquatic amphibian and reptile surveys, small mammal trapping and carnivore surveys followed bird surveys in cost-effectiveness.
- Bat mist-netting surveys were the least cost-effective, however recent advances in acoustic sampling for bats indicate that this alternative protocol may be worth consideration for future monitoring of bats.
- Point count sampling methods were much more effective at detecting Douglas' squirrel, American pika and yellow-bellied marmots than Sherman live trapping methods (e.g., species detectability was greater and/or more reliable)
- Pitfall trapping methods were more effective at detecting shrews and mountain pocket gopher than Sherman live trapping (e.g., species detectability was greater and/or more reliable); therefore, pitfall traps could be used as the primary detection protocol for these species in future efforts.
- Eight special status species were detected with high detectability (> 80% chance of being detected when present): Mallard (MIS), Brown-headed Cowbird (proposed species of interest (SOI)), Lincoln's Sparrow (SOI) and White-headed Woodpecker (SOI), American marten (FSS), Black bear (MIS), little brown bat (SOI) and the silver-haired bat (SOI).

Sampling Adequacy

- A total of 36 species among all species groups were sampled adequately to detect a significant decrease of 20% or more in *site occupancy:* 24 birds, 6 small mammals, 4 bats, 1 amphibian, 1 carnivore and no plants.
- A greater number of bird species were sampled adequately to detect population declines in abundance than site occupancy (32 versus 24),

whereas the opposite was true for small mammals (3 versus 6, respectively).

- Results indicated that appropriate stratification of sample sites could increase the number of species adequately sampled to detect significant changes in population status through increases in analysis power.
- Most species groups were sampled adequately for detecting changes of 20% or more in species richness per site assuming a sample size of 100 sites, including:
    - Terrestrial sites: Birds, small mammals and carnivores, but not bats (estimated to require >150 sites)
    - Aquatic sites: Birds and amphibians, but not reptiles (estimated to require > 200 sites)
- Annual implementation costs of multi-species survey protocols on a per site basis are as follows:
    - Terrestrial bird point counts: $1012
    - Aquatic bird point counts: ~$1012
    - Small mammal Sherman live trapping: $2880
    - Trackplate and camera surveys for carnivores: $2328
    - Bat mist-netting surveys: $4660
    - Bat acoustic surveys (estimated): $150-500
    - Pitfall trapping surveys: $1000
    - Aquatic amphibian and reptile surveys: $450
    - Plant surveys: $500
    - Habitat surveys: ~$500

Objective 3: Evaluation of Biological Indicators

- Of biological indicators recommended by Manley and McIntyre (2006), 35 birds, 8 small mammals and 2 carnivores had high detectability (>80% chance of detecting the species where it is present) with standard protocols used in the MSIM project.
- Birds and small mammals with high detectability in this project were also representative of a variety of functional roles in the ecosystem; 21of 22 ecological sub-groups of birds and all 11 sub-groups of small mammals (as defined by Manley and McIntyre 2006) were represented among species with high detectability.
- Only a few subgroups were represented poorly among highly detectable species, primarily because of the overall low number of species in those subgroups as a whole in Lake Tahoe.
    - Birds: few exotic species, rare species, nectivores, corvids, air foragers and shrub nesters had high detectability
    - Small Mammals: few rare species, canopy associates, or specialists had high detectability.

Objective 4: Wildlife Habitat Associations

Terrestrial habitat associations

- Many of the habitat metric groups proved to be important to wildlife species site occupancy, including: tree and snag densities, spatial location in the basin, habitat context, vertical structure, canopy cover, ground cover and disturbance
- The relative importance of each habitat variable varied by species group based on the number of species associations (see Table below)

Species Group	Habitat variables significantly associated with the most species
Birds	spatial variables (e.g., elevation, watershed location) and habitat context (e.g., habitat matrix surrounding each site)
Small mammals	habitat context and tree and snag densities
Carnivores	tree and snag densities, and secondarily tree size, basal area, slope, coarse woody debris and spatial location
Bats	habitat context and vertical structure

- The following habitat metric groups were significantly associated with occurrence of the greatest number of plant species: spatial variables, canopy cover and year of survey. Secondarily important habitat variables to plant occupancy were: soil type, amount of litter and ground disturbance.

Lentic habitat associations

- Aquatic-associated amphibian and reptile species varied in their preferred site characteristics.
  - Long-toad salamander and Pacific treefrog occurred more frequently at smaller-sized sites.
  - Western toad occurred more frequently in drier environments with a greater abundance of riparian vegetation, similar to the Sierra garter snake.
  - Western terrestrial garter snake appeared to occur more frequently at larger-sized sites at lower elevations.
  - Common garter snake was associated with low elevation and high precipitation, suggesting that it was most frequently occurring at lower elevations on the west side of the basin.
- The presence of fish appeared to have a negative effect on Long-toed salamander and Pacific treefrog occurrence, though some co-occurrence of fish and amphibians was observed. Western toad was detected too infrequently to evaluate their co-occurrence relative to fish.
- Forest cover type within 200 meters of sites and precipitation were positively associated with the persistence of amphibians and reptiles at individual sites.

- High elevation and high development within 50 m of sites were negatively associated with amphibian and reptile persistence.

Recommendations

Management recommendations summarized below are based on the current project results and are intended to assist in the refinement of the basin-wide multi-species inventory and monitoring program.

Monitoring Design and Protocols

Overall design

- Monitoring should be designed for maximum flexibility over time, meaning it is able to adapt to changing species of concern and interest, changing landtype and planning unit delineations, and even changing vegetation types (conversions of white fir stands back to Jeffrey pine).
- The spatially stratified random sampling design used in this project facilitates the use of the data in a diversity of applications useful to management, thus it is recommended that this type of design be retained as the core of a future basin-wide monitoring program.
- The proportion of sites occupied by individual species highly influences the statistical power to detect population change over time. Further evaluation of pre and post-stratification options for improving statistical power through changes in proportion of sites occupied is recommended. Post-stratification should be used in lieu of pre-stratification whenever possible to maximize flexibility in applications of the dataset.
- Additional monitoring sites should be allocated to habitats/strata with few samples in the MSIM dataset, (e.g., wetlands, marshes, riparian, lower montane forests) if future monitoring is intended to detect and monitor the complete assemblage of species in the Tahoe basin, primarily in reference to birds and plants.
- Incorporate non-USFS land ownership types in the sample of monitoring sites, and form partnerships with other agencies and land owners to develop a comprehensive monitoring plan for the entire Tahoe basin.
- Retention of all or most of the existing MSIM sites in future monitoring designs will enable change detection with the next round of data collection.

Animal species

- At minimum species with high probability of detection (> 80% chance of being detected when present) should be considered for incorporation into a monitoring program and as potential indicators of ecosystem integrity.
- Bird point counts, small mammal trapping, and baited camera and trackplate stations yielded valuable and reliable information for three major species groups. These survey protocols provide data on species with a breadth of life history characteristics, habitat associations, and trophic levels. They are recommended as core elements in the future monitoring program.
- Raptor surveys were not evaluated as part of MSIM, but they represent an important component of the forest ecosystem. Existing single-species surveys should consider expanding the suite of species solicited during surveys, such as the full suite of owl species occurring in the basin.
- One comprehensive survey protocol, acoustic surveys for bats, should be considered for inclusion into a monitoring program as the technology progresses (e.g., more accurate identification of individual species).
- Consider a stratified sampling scheme (with known probability of selection) for aquatic-associated amphibians, targeting known occupied sites and other sites to improve precision of estimates of occupancy and population size and statistical power to detect change.
- Retain some documentation of fish occurrence and relative abundance as part of aquatic monitoring programs.
- Integrate lentic, lotic and forestwide monitoring programs so that monitoring data on biota can be combined to provide a more complete picture of distribution, occupancy, and population status for species that use both types of aquatic habitats.

Plant species and vegetation

- Keep the basic design used in MSIM to retain consistency with the nationwide Forest Inventory and Analysis program (FIA), but add quadrat sampling along additional transects to improve detection probabilities for herbaceous species (thereby improving accuracy of composition and richness metrics).
- Include some measure of fine fuels (< 3 inch diameter) in vegetation measurements in response to concerns about fire risk and threat.
- Utilize measurements of plant frequency (e.g., number of occupied quadrats) in leui of estimates of cover at individual sites as the primary monitoring metric when suitable to meet program monitoring objectives for plants; frequency measures proved to be less variable and more powerful for detecting change.
- The frequency of occurrence, range of conditions, or variability of particular vegetation variables (e.g., coarse woody debris, tree/snag

densities, etc.) should be considered potential metrics in addition to the standard "average" for a vegetation or wildlife habitat monitoring program. Habitat variability at many scales is important to the biological integrity of a functioning ecosystem.

Additional data analysis opportunities

- Evaluate statistical power of detecting changes in the various richness and abundance components of the recently proposed Index of Biological Integrity-IBI (Manley and McIntyre 2006) with various levels of sampling effort.
- Estimate detectability (i.e., probability of detection) and sampling adequacy for species in riparian ecosystems (based on an existing dataset) to determine if riparian habitats are a suitable strata for monitoring population status of species not well sampled at either terrestrial or lentic aquatic sites as determined in this project.
- Evaluate the proportion of the landscape and each vegetation type exhibiting various levels of old growth characteristics, and use these results to derive desired conditions for old growth in the basin.
- Generate reference conditions for primary habitat characteristics in each major vegetation type, and again use these results to derive desired conditions for wildlife habitats in the Tahoe basin.
- Explore how MSIM and Forest Inventory and Analysis (FIA) data can be used to improve vegetation mapping in the basin using state-of-the-art statistical techniques for assigning vegetation characteristics to landscape pixels being developed and tested by the FIA program.

Adaptive management: monitoring the monitoring program

- Develop an analysis plan as part of the future monitoring strategy that specifically identifies remaining uncertainties and how new monitoring data can be used to reduce uncertainties and improve monitoring.
- Validate estimates of statistical power and sample size requirements as soon as possible as monitoring progresses.
- Evaluate the statistical power and sample size requirements of trend analysis as an alternative to change analysis as soon as monitoring progresses and sufficient repeat observations exist at monitoring sites.

Information gaps

- A decision support mechanism has yet to be designed and tested as part of a forest-wide monitoring strategy. Decision support tools are critical part of monitoring programs in that they typically require explicit documentation of assumptions and uncertainties associated with the selection and interpretation of monitoring metrics, and identify how managers and decision makers can use monitoring results to inform management.

Chapter 1: Introduction and Project Design

Background

The Multi Species Inventory and Monitoring (MSIM) Project is a comprehensive forest wide multiple taxonomic and species inventory and monitoring effort intended to establish baseline status and trend conditions for a large group of wildlife and plants and their habitats within the Lake Tahoe Basin Management Unit (LTBMU). The MSIM project was initiated in 2002 in order to fulfill monitoring and evaluation requirements established by the National Forest Management Act (NFMA 1976), support the forest plan revision process, begin active engagement in an Adaptive Management Strategy set forth by the Sierra Nevada Forest Plan Amendment (USDA 2001), and contribute to the development of biological resource monitoring protocols for both region-wide and nation-wide application.

The NFMA (CFR 36 219.6) requires development and implementation of a monitoring and evaluation plan as part of the unit land and resource management plan. In particular, the planning regulations specify that the roles of monitoring and evaluation are 1) "to determine whether plan implementation is achieving multiple use objectives", 2) "to determine the effects of …management activities…on the productivity of the land" and 3) "to determine the degree to which…management is maintaining or making progress toward the desired conditions and objectives for the plan". Prior to this MSIM effort, no comprehensive monitoring efforts were in place on LTBMU lands (or anywhere else in the nation) to determine whether forest plan implementation was achieving desired outcomes for biological resources at the forest wide scale.

Similarly, the forest plan revision process, as dictated by NFMA, requires that a broad-scale comprehensive evaluation of existing social, economic and ecological conditions be conducted upon revision of the land management plan. Hence, the need to implement a basin-wide biological inventory in LTBMU in support of the ensuing forest plan revision process became evident. Key aspects of forest plan development and revision that rely on knowledge about current ecosystem conditions include: 1) identifying existing and desired ecosystem conditions and guidelines for achieving those desired conditions, 2) evaluating the suitability of areas for various land uses as it is influenced by existing ecosystem condition or potential and 3) recognizing or proposing "Special Areas" on the forest that have unique biological characteristics. Without a comprehensive forest-wide dataset from which to pull supporting information, effective forest planning would be incomplete.

Additionally, the Adaptive Management Strategy set forth in the Sierra Nevada Forest Plan Amendment (USDA 2001), consistent with the 2005 planning regulations (36 CFR 219.6), stresses the need for a well developed strategy to allow for adjustments to management over time in response to new information. The proposed Adaptive Management Strategy (USDA 2001) identifies the need for effective monitoring of ecosystem responses to both individual and collective management actions and effective interpretation of the resultant information for managers. An effective adaptive management process should provide for continual opportunities to adjust management as necessary to ensure biological integrity and ecological sustainability. Effective monitoring is defined to include the following components: implementation monitoring, status and change monitoring, cause and effect monitoring and research. The Adaptive Management Strategy specifically identified the Multi Species Inventory and Monitoring approach as an efficient way to meet large scale status and change monitoring needs as part of an effective monitoring program. Therefore, implementation of MSIM protocols and subsequent interpretation of the resultant monitoring data (in this report) contribute to implementation of this Adaptive Management Strategy as directed by the Sierra Nevada Forest Plan Amendment.

Lastly, Multi Species Inventory and Monitoring protocols have recently been developed into a national technical guide for large scale comprehensive monitoring (Multiple Species Inventory and Monitoring Technical Guide: www.fs.fed.us/psw/programs/snrc/featured_topics/msim) in an effort aimed at improving consistency of inventory and monitoring for the National Forest System (NFS). Pilot implementation of MSIM sampling design and analysis approaches is a critical step towards development of MSIM for both regional and national application. Data collected in LTBMU during 2002 as part of the MSIM project contributed to the development of this national technical guide.

The MSIM project and associated products (Manley et al 2005) constitute the first attempt to evaluate MSIM monitoring protocols in terms of their true ability to monitor changes in site occupancy for suites of species at both the region-wide and forest wide scales based on empirical data collected in the field. The MSIM approach was designed to take advantage of the efficiencies associated with multi-taxonomic sampling to describe status and change in condition of multiple species, as opposed to the single species monitoring approaches most often implemented. Assumed efficiencies of the multi-species approach include : 1) cost efficiency associated with collecting data on large suite of species at once versus conducting multiple single species focused surveys, 2) robustness to changes in the special status or “focal” species lists such that when management focus changes to new or alternate species the data are already available and 3) redundancy of sampling several species within a taxonomic group or functional guild instead of a single indicator allows us to better understand ecosystem status or condition.

Project Description

Multiple Species Inventory and Monitoring protocols were originally conceived as part of the Sierra Nevada Forest Plan Amendment (USDA 2001) as a means of monitoring the large number of species of concern throughout the Sierra Nevada in an effective and cost efficient manner. MSIM protocols consist of a number of standardized non-lethal survey techniques for several classes of vertebrates, vascular plants and habitat condition. Protocols were focused on detecting the presence (and abundance of some target species groups) of a diversity of species at each monitoring site. Implementation of MSIM protocols throughout the Lake Tahoe Basin Management Unit was expected to fulfill both short and long term information needs pertaining to wildlife and plant populations and their habitats (e.g., determining current status of populations and their habitats, developing desired conditions for wildlife, plants and their habitats, and initiating long term monitoring of wildlife populations).

A total of seven MSIM protocols were implemented at 105 forest wide monitoring sites, and 3 protocols at 148 lentic aquatic monitoring sites, over 3 years (2002, 2004-2005). Data from this project were intended to provide baseline status and distribution data for wildlife, plants and their habitats within LTBMU and to aid in the development of a comprehensive biological resource monitoring program at the forest-wide scale. This project was funded in part by Washington Office National Forest inventory and monitoring funds (2002), LTBMU and Region 5 base program funds (2002, 2004), and by the Southern Nevada Public Lands Management Act (2005-2006, SNPLMA05 project 5-39A).

Objectives

The MSIM project was intended to meet the following objectives:

- Establish baseline conditions for a wide range of wildlife and plant populations and determine compositional and structural characteristics of their associated habitats on lands managed by the Lake Tahoe Basin Management Unit (LTBMU).
- Evaluate the effectiveness of the project design for long term monitoring of wildlife and plant populations and their habitats at the forest-wide scale
- Identify species and/or species groups to serve as indicators of environmental condition
- Determine general habitat associations with wildlife and plant species detected and identify multi-scale habitat associations for marten and long-toed salamander.

Study Area

The Lake Tahoe basin is located in California and Nevada (Figure I-1). The 880 km^2 (88,000 ha or 218,000 acres) Lake Tahoe basin, considered for designation as a National Park three times, contains the largest alpine lake in North America and is bounded by the crest of the Carson Range on the east and the Sierra crest on the west. The basin encompasses an elevational range from 2000 to nearly 3500 m (6229 to 10881 ft). The majority of the basin (80% of the land area) is managed by the US Forest Service - Lake Tahoe Basin Management Unit. Private land ownership encompasses a disproportionate amount of land area at the lowest elevations within the Tahoe basin (< 7,000 ft). Based on a review of the primary sources of data for the basin, Manley et al. (2000) determined that 312 vertebrates and 1077 vascular plants were present in the Lake Tahoe basin. The vertebrates consisted of 217 bird and 59 mammal species, with the remainder consisting of a small number of amphibians (5 species), reptiles (8 species), and fish (23 species). Of these species, there are at least 11 known invasive and exotic vertebrates and 15 exotic/invasive plant species that currently reside in the Tahoe basin and are a potential threat to the biological integrity of the Lake Tahoe region. The Lake Tahoe basin is located on the east–west boundary of 2 major biogeographic provinces (the Sierra Nevada and the Great Basin; Udvardy 1975), and in the vicinity of the north–south juncture of 4 smaller-scale bioregions (Mono-Inyo to the southeast, South Sierra to the southwest, North Sierra to the northwest, and Modoc Plateau to the north; Welsh 1994). The location of the Lake Tahoe basin at this confluence of zoogeographic zones results in a diversity of environmental conditions and a unique array of flora and fauna around the basin, as well as some distinct distributions of biota around the basin.

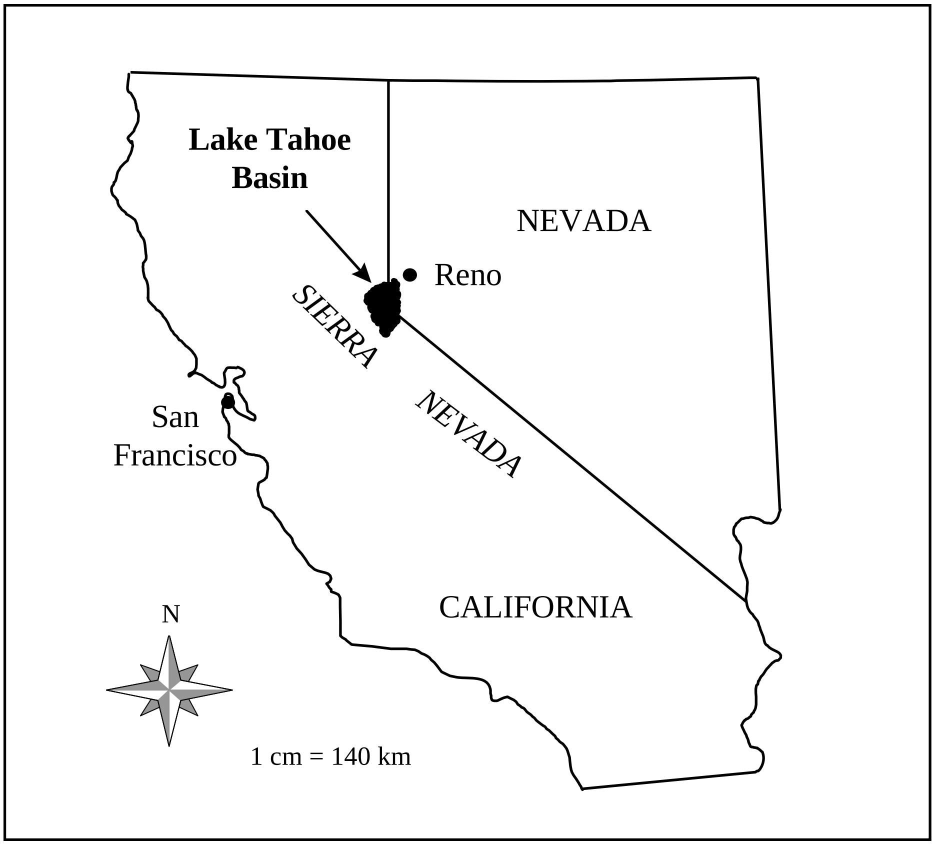

Figure I-1. Location of the Lake Tahoe basin monitoring area.

Murphy and Knopp (2000) described the basin as having 3 major vegetation life zones: montane (<7,000 ft), upper montane (7,000 to 8,500 ft) and subalpine (>8,500 ft). Within the 3 vegetation types these authors outlined 6 major forest types, based on the area covered by each type. In the lower montane vegetation zone the most common forest type is mixed conifer (e.g., Sierran mixed conifer), followed by the white fir, Jeffrey pine and lodgepole pine forest types. The most common forest type within the upper montane vegetation type is Jeffrey pine, flowed by the white fir, red fir and lodgepole pine types. The only forest type in the subalpine vegetation zone is subalpine woodland (e.g., subalpine conifer). The forest types listed above are defined by the classification system of Sawyer and Keeler-Wolf (1995). The mixed conifer forest type contains white fir (*Abies concolor*), Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), and incense cedar (*Calocedrus decurrens*) at densities such that no species is dominant. The Jeffrey pine forest type is dominated by Jeffrey pine but also contains white fir and incense cedar at lower densities. The sub-alpine woodland type may be dominated by any of several species, but in the Tahoe basin primarily western white pine (*P. monticola*), mountain hemlock (*Tsuga mertensiana*), whitebark pine (*P. albicaulis*) and lodgepole pine (*P. contorta*).

The Lake Tahoe basin consists of approximately 63 subwatersheds (Hydrologic Unit Category level 7) and contains a wide variety of aquatic habitat types within these sub watersheds, from springs, seeps, fens, wet meadows, ponds and marshes to alpine snowmelt streams, and large mainstem rivers (Murphy and Knopp 2000). Lentic aquatic habitats in the Tahoe basin (lakes, ponds, wet meadows, fens, marshes, seeps and springs) have been rated of higher concern than lotic habitats based on their rarity, current and historic level of disturbance, and the level of protection afforded them (Murphy and Knopp 2000). Out of over 500 waterbodies existing within the Lake Tahoe basin, the majority comprise small ephemeral or perennial ponds in the southwestern portion of the Tahoe basin.

While the majority of the landscape within the Lake Tahoe basin is coniferous forest (primarily terrestrial habitat), aquatic habitats (lentic-ponds, lakes and meadows; and lotic-streams/riparian) contribute disproportionately to the biodiversity in the Tahoe basin. Therefore the MSIM survey effort was initiated at both terrestrial and lentic habitat types (wet meadows, ephemeral and perennial ponds and lakes) throughout the Tahoe basin in order to meet the project objectives.

Sampling Design

Forest Wide Monitoring Network

A total of 105 monitoring sites were established on national forest (NFS) land in the Lake Tahoe Basin Management Unit (LTBMU) to form a spatially and ecologically representative sample from which we could initiate long-term multi species wildlife and habitat monitoring. We termed this suite of monitoring sites the "forest wide monitoring network" to be indicative of the sampling frame for which we wanted to make inferences or conclusions, based on monitoring trends over time (e.g., forest scale status and trend monitoring).

The sampling approach used to generate the forest wide monitoring network of 105 sites was originally intended to overlap with the nationally established Forest Inventory and Analysis (FIA) hexagonal sampling grid to be consistent with the foundation developed in the Sierra Nevada Forest Plan Amendment (USDA 2001). However, due to potential for site disturbances associated with intensive wildlife sampling at FIA sample points and the limited number of FIA sample points existing in the Lake Tahoe Basin (26 established FIA sites), we chose not to sample at FIA sampling points directly. Instead, we identified a similar stratified random sampling approach, using FIA hexagons as the primary spatial strata, utilizing "off-set" FIA points where available, and randomly assigning additional site locations within these hexagons (process described below) to ensure representation of LTBMU lands throughout the Lake Tahoe basin. Based on preliminary analysis of the efficacy of this approach for long-term monitoring of species of concern across the Sierra Nevada, it was estimated that approximately 100 sites (we chose 105 sites) within LTBMU would be sufficient to adequately sample and monitor long-term trends (i.e., detect ≥ 20% change in site occupancy with ≥ 80% statistical confidence) for the majority of species (Manley, pers. comms).

FIA hexagons form a continuous sampling grid across the continental United States and constitute the basis of sampling for assessing and monitoring the condition of our nation's forests. Each FIA hexagon occupies 2400 ha (6000 ac); 63 contain national forest system lands within the Lake Tahoe basin. First, we selected 26 site locations that were "offset" from the 26 previously established FIA sample point locations (one site location in each of 26 hexagonal grid cells). Offset FIA sites were a random distance and direction from true FIA locations; these 26 sites represented one randomly located site within each of 26 hexagonal grid cells.

To select the additional 79 monitoring sites, we allocated sites to individual FIA hexagons based on the proportion of National Forest land area within each hexagon: 0 to 12% = no sites, 13 to 37% = 1 site, 38 to 62% = 2 sites, 63 to 87% = 3 sites, and > 87% = 4 sites. "Offset" FIA sites were first allocated to their respective hexagon, and additional sites (if needed based on NFS land area in the hexagon) were randomly selected on NFS lands within each FIA hexagon. Finally, to ensure sample unit integrity/independence; no sites were selected within 500 meters of any other sites regardless of hexagon boundaries in order to eliminate overlap of sampling effort among sites.

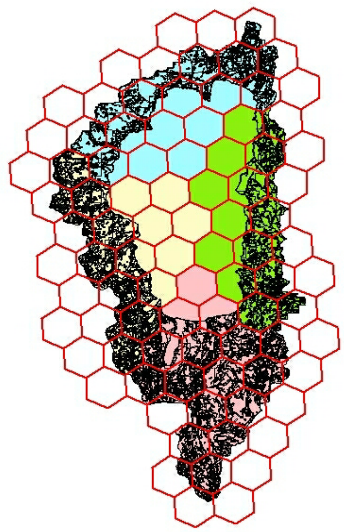

Figure I-2. FIA hexagon grid forming the basis of the sampling frame for MSIM monitoring sites in the Lake Tahoe Basin Management Unit. Shading represents each of the 4 basin orientations used for stratification of sampling: blue = north, green = east, pink = south and yellow = west.

Due to logistical considerations necessary to conduct such comprehensive monitoring surveys, we recognized that we would be limited to surveying approximately 30-60 sites per year depending on the protocols being implemented. Therefore, we planned to survey monitoring sites over multiple years; approximately 1/3 of the sample in each of 3 years. We selected sample sites for each year to constitute a representative random subset of the total 105 sites (i.e., completely randomized panel design). The choice to sample independent sub-sets of new monitoring sites in each of the 3 years, instead of re-sampling the same limited set of sites over the 3 years, allowed for greater spatial representation of the baseline "status" of LTBMU (105 sites versus 30-60 sites). Furthermore, sampling for multiple consecutive years as part of a "sampling period" reduces the effect of annual variability on the detection of long-term trends for species groups that are temporally dynamic (e.g., small mammal populations).

Such broad sampling resulted in a baseline dataset well suited for characterizing current wildlife and habitat status and conditions throughout LTBMU, but still maintained our ability to monitor long-term trends once repeated surveys are conducted at sites in the future. Additionally, because annual sampling constituted a random subset of the total suite of monitoring sites, each year represented an independent sample across LTBMU, therefore short term (i.e., annual) changes in species site occupancy can also be observed, but changes would need to be sufficiently large to be detected at such short time scale.

This spatially stratified random sampling approach was sufficient to produce a sample of monitoring sites that was representative of national forest lands in the Lake Tahoe basin based on habitat type (Figure I-3), major sub-watershed (Figure I-4), fuel hazard risk zone (Figure I-5) and that was spatially well distributed throughout LTBMU (Figure I-6). Similarly, national forest land (e.g., LTBMU) within the Tahoe basin is generally associated with a lack of development, and as expected, one quarter of all 105 sites had no development within 500 meters of the central monitoring station, and 90% of sites had less than 5% of the area within 500 meters developed. As a result of this proportionate representation across the landscape, MSIM monitoring sites primarily represent the dominant landscape across LTBMU (e.g., undeveloped coniferous forest, large watersheds and conditions outside the wildland-urban defense and threat zones) and therefore are best utilized for tracking reference conditions of these dominant forest types.

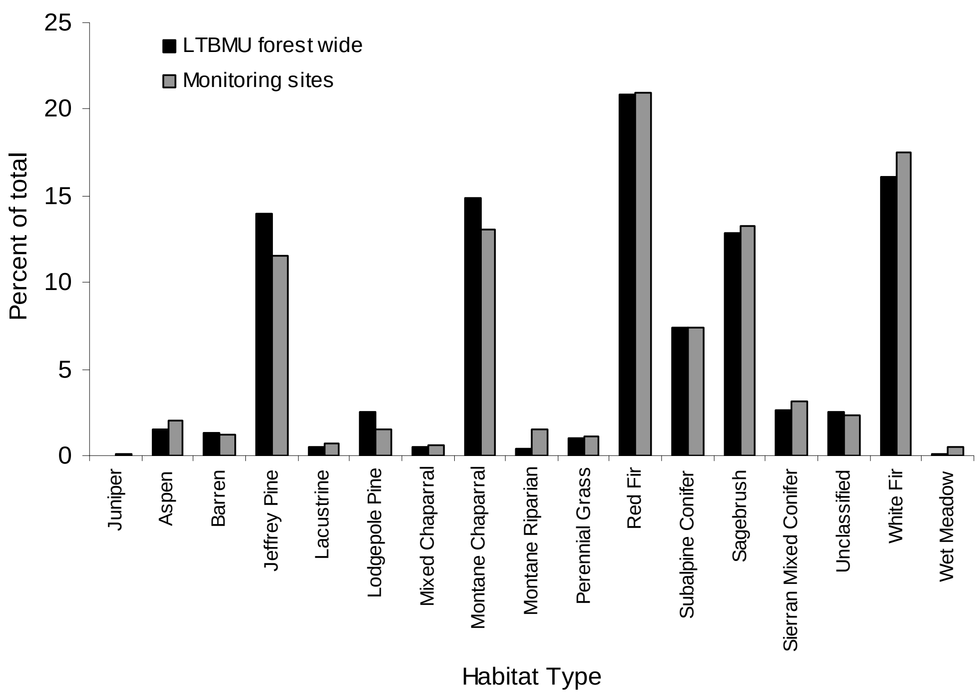

Figure I-3. Percent of total national forest land area in the Lake Tahoe basin (LTBMU forest wide) and percent area within 300 meters of the 105 MSIM monitoring site locations (Monitoring sites) occupied by various California Wildlife Habitat Relationship (CWHR) habitat types (based on IKONOS v.4).

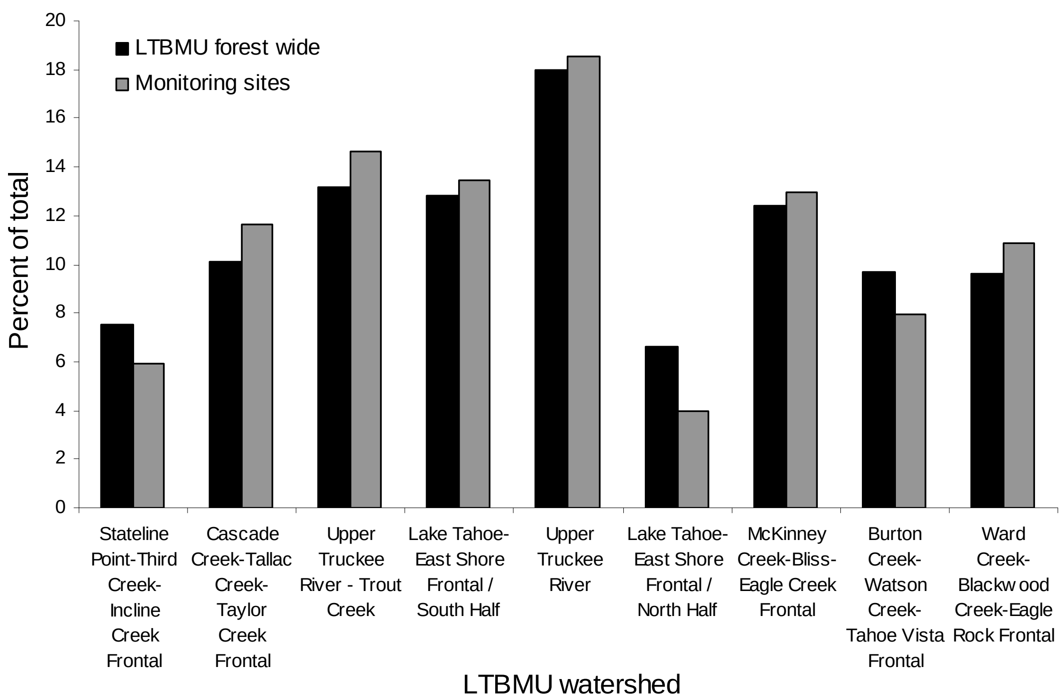

Figure I-4. Percent of all national forest lands in the Lake Tahoe basin (LTBMU forest wide) and percent area within 300 meters of the 105 MSIM monitoring site locations (Monitoring sites) in the 9 major HUC (Hydrologic Unit Class) level 6 watersheds within the Lake Tahoe basin.

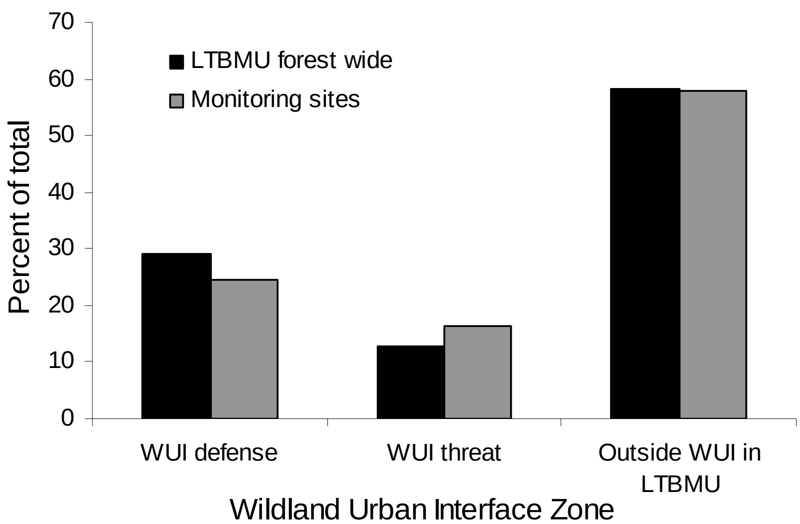

Figure I-5. Percent of national forest lands in the Lake Tahoe basin (LTBMU forest wide) and percent area within 300 meters of the 105 MSIM monitoring site locations (Monitoring sites) in the Wildland Urban Interface (WUI) fuels reduction defense and threat zones within LTBMU and outside the defense and threat zones in the general forest of LTBMU.

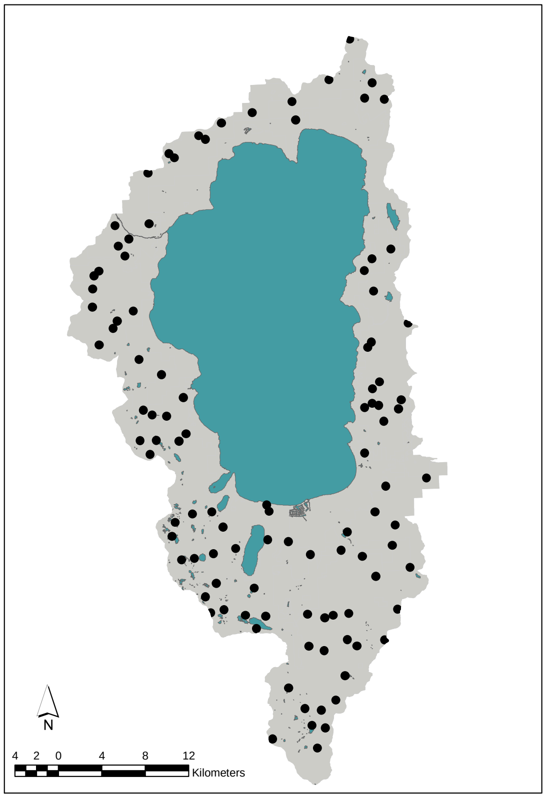

Figure I-6. Spatial distribution of 105 MSIM forest wide network monitoring sites surveyed in the Lake Tahoe Basin Management Unit, 2002-2005.

Lentic Habitat Monitoring Network

A second set of 148 lentic monitoring sites were selected to form a spatially representative and ecologically diverse sample of lentic aquatic habitats within the Lake Tahoe basin from which to serve as the basis of long-term wildlife and habitat monitoring. The lentic habitat monitoring network included monitoring sites on all land ownership types in the Tahoe basin and was not restricted to national forest land; hence inferences from this sample can be drawn regarding lentic aquatic wildlife and habitat status and trends throughout the Lake Tahoe basin.

The sampling approach used to generate the MSIM lentic habitat monitoring network of 148 sites was based on the approach of a previous survey of aquatic habitat biodiversity in the Lake Tahoe basin during 1997 and 1998 (Manley and Schlesinger 2001). Manley and Schlesinger (2001) selected 88 lentic habitat sites stratified by the following environmental factors: elevation, size and basin orientation (i.e., side of the basin); and attempting to distribute the sample equally across all categories. We adopted 84 of these 88 sites as part of the lentic habitat monitoring network in order to monitor trends at these sites by comparing survey results from the MSIM project. The remaining four sites from the 1997 and 1998 surveys were unavailable for sampling 2002-2004 (e.g., dry, drained for development or no access granted to private property) and were judged unlikely to become available for future monitoring, hence they were not included in the lentic habitat monitoring network.

Similar to the forest wide monitoring network, it was estimated that a minimum sample of 100 sites would be necessary to adequately monitoring species and habitats at lentic sites. Therefore, we selected additional lentic sites using the same approach as defined by Manley and Schlesinger (2001). We selected 64 additional sites due to funding availability and ease of implementation of lentic aquatic survey protocols, for a total of 148 lentic sites surveyed during 2002-2004. MSIM lentic vertebrate and habitat sampling protocols were easier to implement than those implemented at the forest wide monitoring network, hence the larger sample size for the lentic monitoring network.

The resulting distribution of MSIM lentic habitat monitoring sites across sampling categories is shown in Table I-1. While we attempted to select a similar number of sites within each orientation by elevation and size category, this was not always possible due to lack of available sites within the Tahoe basin from which to choose from. For example, only 9 large lake sites exist on the westside of Lake Tahoe at low elevation, hence we were restricted to a maximum of 9 sample sites for that category (Table I-1).

Table I-1. Distribution of 148 lentic habitat monitoring network sites relative to three primary environmental strata: elevation, size, and orientation; and the percent of all existing lake sites within each category in the Tahoe basin that are represented in the lentic monitoring sample.

	Lakes						**Meadows**		
	High (>7500 ft)			**Low (<7500 ft)**			**High (>7500 ft)**	**Low (<7500 ft)**	**Total**
Sample Site Category	**S (<1 ac)**	**M (1–10 ac)**	**L (>10 ac)**	**S (<1 ac)**	**M (1–10 ac)**	**L (>10 ac)**	-	-	
Total sample (#)									
Eastside	15	10	6	11	9	2	8	4	
Westside	11	15	14	10	6	9	6	12	
Basinwide	26	25	20	21	15	11	14	16	148
Total sample (% of all Tahoe basin sites)									
Eastside	33.3	100.0	85.7	37.9	64.3	33.3	19.0	7.4	33.3
Westside	9.1	39.5	82.4	18.9	35.3	100.0	26.1	40.0	9.1
Basinwide	15.7	52.1	83.3	25.6	48.4	73.3	21.5	19.0	15.7

Lentic monitoring sites are distributed throughout the Lake Tahoe basin (Figure I-7) however; site density is greatest in the southwestern portion of the

Lake Tahoe basin, mimicking the high proportion of lentic aquatic habitats present at high elevation on the west-side of the Tahoe basin (Figure I-8). Lentic habitat monitoring sites were fairly representative of approximately 50% of all sampling categories. However, the lentic monitoring network slightly overrepresented medium sized lakes on the east side of Lake Tahoe, large lakes on the west side and meadows at low elevation on the west side; and underrepresented small lakes on the west side of Lake Tahoe, and meadows at low elevation on the east side (Figure I-8) based on reference to currently available waterbody GIS layers for LTBMU (waterbody coverage).

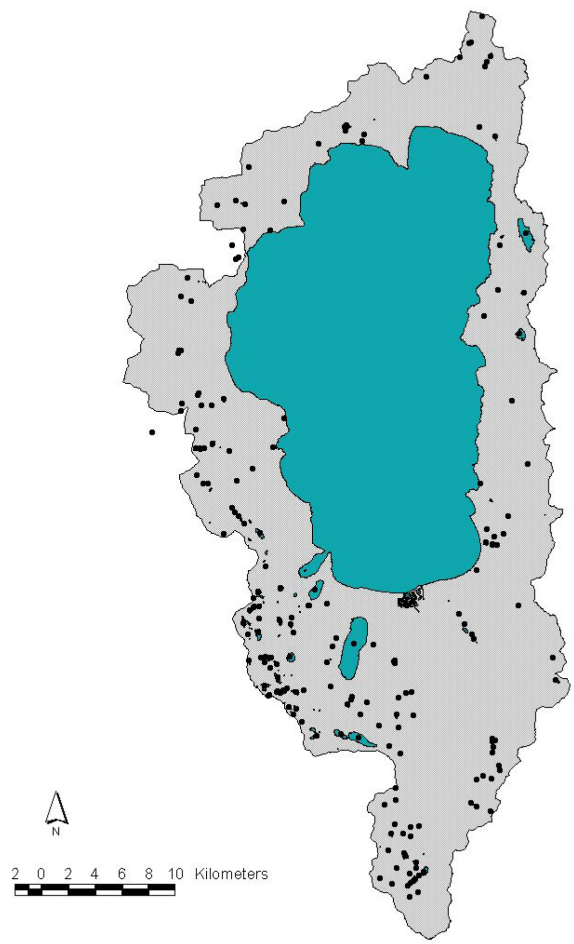

Figure I-7. Distribution of all 148 lentic habitat monitoring network sites in the Lake Tahoe basin.

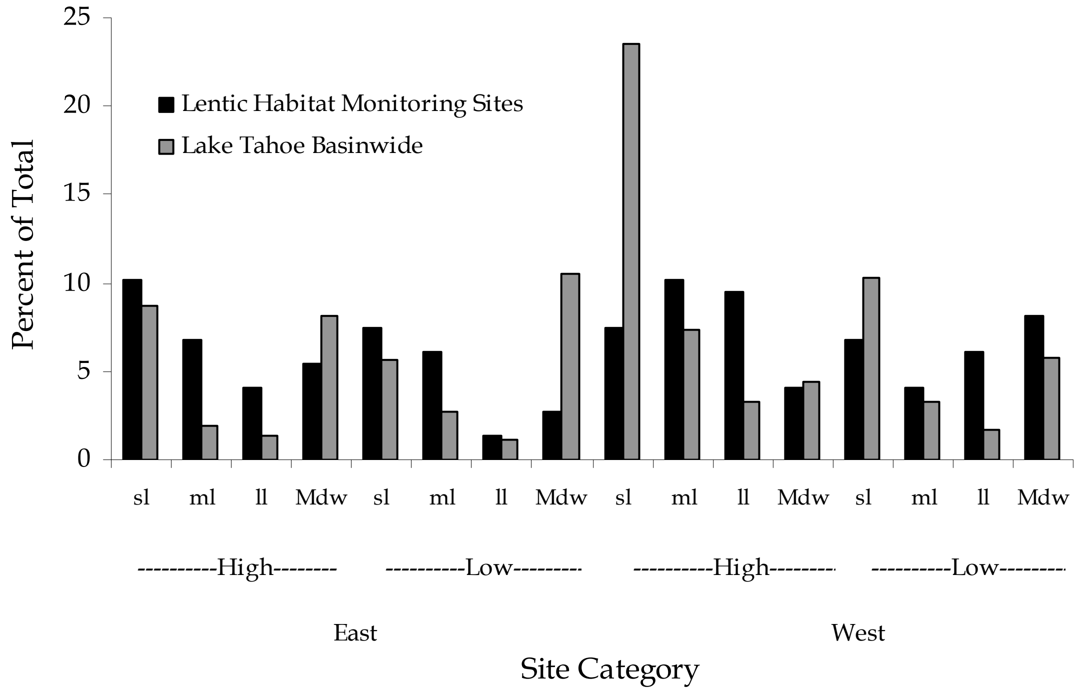

Figure I-8. Proportional distribution (%) of all lentic habitat monitoring sites in the Lake Tahoe basin within each of the sampling categories relative to the proportional distribution (%) of sites within the estimated total sample of sites in the lentic habitat monitoring network. Sampling categories are based on the following environmental strata: 1) orientation [East/West- based on line between R17E/R18E Mt Diablo Meridian]; 2) elevation [High (>7,500 ft) and Low (≤ 7,500 ft)]; and 3) habitat type [sl = small lake (<1 ac), ml = medium lake (1-10 ac) ll = large lake(> 10 ac), and Mdw = wet meadow].

Protocols Implemented

Forest-wide monitoring network

At forest wide monitoring sites we implemented a set of 5 standardized non-lethal multiple species detection protocols for population site occupancy monitoring: 1) bird points counts (Appendix 1-1), 2) Sherman live trapping (Appendix 1-2), 3) carnivore track plate and camera surveys (Appendix 1-3), 4) bat mist netting (Appendix 1-4), 5) pitfall traps and cover boards (Appendix 1-5), as well as botanical surveys (Appendix 1-6) and surveys of habitat conditions (Appendix 1-7).

Because survey protocols differed in complexity and intensity of effort, we implemented some protocols at a larger or smaller subset of sites in each year depending on logistical constraints (Table I-2). However, we still maintained independent subsets of sites for each protocol in each year. A few protocols were not implemented at all 105 sites due to either high levels of effort required, low levels of efficiency experienced in 2002, limited capacity to implement or because the large spatial scale of sampling did not require all sites to be sampled. These included bat mist-netting, pitfall trapping, and carnivore trackplate/camera surveys, respectively.

Table I-2. Survey effort (i.e., number of MSIM monitoring sites) and targeted species groups for protocols sampled in each year of survey at the MSIM forest wide monitoring network sites, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005. Total n is the sample size of unique forest wide monitoring sites surveyed across all 3 years.

		MSIM Forest Wide Monitoring Network Sites Surveyed			
Protocol	**Target Species**	**2002**	**2004**	**2005**	**Total n**
Bird Point Counts	Song birds	40	40	25	105
Sherman Live Trapping	Small mammals (excluding bats)	40	40	25	105
Track Plate and Camera Surveys and associated habitat	Forest carnivores	22	-	58 (39)[a]	61
Bat Mist-netting and Acoustic Sampling	Bats	22	-	-	22
Pitfall Trapping and Cover boards	Terrestrial amphibians and reptiles; Shrews	9	-	-	9
Botanical Surveys	Plants	40	-	65	105
Terrestrial Habitat Condition	Vegetation structure and composition	40	28	37	105

[a] Only 39 of the 58 sites surveyed by the carnivore track plate and camera and habitat condition survey protocols were unique to 2005, 19 sites were revisited from the 2002 sample.

Lentic monitoring network

At lentic habitat monitoring sites we implemented a set of 2 standardized non-lethal multiple species detection protocols for population site occupancy monitoring: 1) bird point counts (Appendix 1-8), and 2) herpetofauna visual encounter perimeter surveys (VES) (Appendix 1-9), as well as lentic site habitat condition surveys (Appendix 1-10). Allocation of survey effort to these 148 lentic sites varied from 2002-2004 (Table I-3).

Table I-3. Survey effort and targeted species groups for protocols sampled for each year of survey at the MSIM lentic habitat network monitoring sites, Lake Tahoe basin, CA and NV, 2002-2004. Numbers in parentheses are the total number of lentic sites surveyed for the first time during the respective year; the remaining difference represents sites re-visited from previous years. Total n is the sample size of unique lentic monitoring sites surveyed across all 3 years.

		MSIM Lentic Monitoring Sites Surveyed			
Protocol	**Target Species**	**2002**	**2003**	**2004**	**Total n**
Bird Point Counts	Aquatic/riparian associated birds	-	96	81 (49)	145
Visual Encounter Surveys	Aquatic amphibians and reptiles	46	96 (50)	104 (52)	148
Lentic Habitat Condition	Aquatic vegetation structure and composition	44	96 (52)	70 (51)	147

References – Chapter 1

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CHAPTER 2: Multi Species Inventory and Monitoring Analysis and Results

Introduction/Objectives

Status and change monitoring was identified as one of several important components of an effective adaptive management strategy for national forest land management planning (USDA 2001). Status and change monitoring fills a "critical role" by indicating whether forest plan desired conditions are being achieved (USDA 2001). By monitoring whether desired elements within an ecosystem (e.g., physical, chemical, biological components and processes, etc.) are present, or above a given threshold value, we are able to evaluate current ecosystem status relative to forest plan objectives. Multi Species Inventory and Monitoring (MSIM) protocols were intended to fulfill this status and change monitoring role for biological elements of the ecosystem (e.g., wildlife and plant populations) that require presence/absence or distribution level monitoring (see Appendix E Tables E9-E12 of USDA 2001), and was originally developed as a means to meet bio-region wide (i.e., Sierra Nevada) monitoring needs through tracking site occupancy rates of species over time. MSIM protocols have also recently been developed into a USFS national technical guide (Manley et al 2006; http://www.fs.fed.us/psw/programs/snrc/featured_topics/msim) for use as a tool to meet eco-regional scale monitoring needs of national forests throughout the U.S.

The MSIM project marks the first effort to implement MSIM protocols for status and trend monitoring anywhere on national forest system lands in the U.S., and the first empirical test of each protocol's effectiveness to detect population changes over time. While intended for large bio-regional scale application, MSIM protocols were implemented in LTBMU during 2002-2005 as a pilot test of bio-regional scale application, as indicated above, and for the expanded purpose of evaluating the utility of each protocol for implementation at the Lake Tahoe basin scale. Previous modeling efforts conducted during the development of these protocols (see Appendix E of USDA 2001, Manley et al 2004) estimated that 50% of Sierra wide species would be adequately monitored (able to detect 20% decline in site occupancy with 80% confidence and power) using the MSIM approach at the bio-regional scale. A more recent analysis based on empirical data collected as part of this current MSIM project (Manely et al 2005) estimated that 47% of Sierra wide species would be adequately monitored at the bio-regionwide scale. Here we evaluate the utility and efficacy of the MSIM approach to status and change monitoring at the forestwide scale relative to that demonstrated at the bio-region wide scale.

Only a few large scale nation-wide programs aimed at monitoring status and trends in biological conditions at similarly large scales in a programmatic context have been implemented: "Vital signs" monitoring of the National Park Service (http://science.nature.nps.gov/im/monitor/), the Environmental Monitoring and Assessment Program of the Environmental Protection Agency (EMAP: http://www.epa.gov/emap/index.html), the Chesapeake Bay Monitoring Program (http://www.dnr.state.md.us/Bay/monitoring/), and the USFS Forest Health Monitoring (http://fhm.fs.fed.us/), although the latter focuses primarily on vegetation resource monitoring. Multi species Inventory and Monitoring (MSIM) protocols are a comprehensive suite of biological monitoring protocols developed by the USFS to monitor status and change of wildlife, plants and their habitats.

The MSIM project specifically contributes to long-term status and trend monitoring by establishing current baseline conditions of terrestrial and aquatic systems in the Lake Tahoe basin; as described by the existing population status (i.e., site occupancy, distribution and in some cases abundance) of species occurring in the Tahoe basin, and current habitat conditions (i.e., vegetation structure and composition) at monitoring sites.

Additional contributions of the multi-taxonomic approach of the MSIM project to long term status and trend monitoring include: 1) co-located sampling of multiple taxonomic groups which allows us to monitor the status of species groups (e.g., guilds) in relation to one another, and allows us to monitor changes in overall richness and biodiversity, measures that are likely to better indicate overall ecosystem functioning than occurrence of individual species alone, and 2) concurrent measurement of habitat conditions, likely environmental correlates to wildlife population status, which provides a foundation for interpreting observed population changes or trends. Management actions often directly affect habitat conditions (e.g., vegetation structure) which in turn are likely to be the proximate cause of changes in wildlife/plant population status.

This chapter was intended to meet all project objectives described in Chapter 1. The specific objectives of this chapter in relation to project objectives are as follows:

- **Establish baseline status of wildlife, plants and their habitats in the Lake Tahoe basin, including many species of concern**
    - Document the frequency of occurrence of vertebrate and vascular plant species and describe species distributions and relative abundances (when applicable) within the Lake Tahoe basin.

    - Describe current baseline vegetation conditions of major habitat types, watersheds and management zones sampled in the Lake Tahoe Basin in terms of vegetation structural and compositional characteristics

- **Evaluate the effectiveness of the project design for long term status and change monitoring**
    - Determine effectiveness of each MSIM protocol based on species detectability.
    - Evaluate sampling adequacy of the MSIM project for detecting a 20% decrease in population status with 80% confidence and power for each species detected.
- **Determine whether there are species or species groups that can serve as biological indicators for long-term monitoring**
    - Refine species groups identified in Pathway 2007 as indicators of biological condition based on species detectability
- **Identify wildlife habitat relationships**
    - Identify habitat variables associated with wildlife and plant species occurrence in the Tahoe basin.

Methods

Several vertebrate, plant and habitat sampling protocols were implemented at forest wide and lentic monitoring sites during 2002-2005 and were intended to form the baseline sampling period for which future monitoring efforts are compared. Vertebrate and plant survey protocols are described below in terms of the spatial and temporal design features that are important for generating the metrics of interest to the Multi Species Inventory and Monitoring Project (Table 1-1): site occupancy rates, relative abundances and probability of detection (i.e., detectability) per species. Habitat surveys are described in terms of the spatial design of sampling and the structural variables measured at each site for describing habitat conditions. More detailed protocol descriptions, including a list of all variables measured and specifics about how measurements were collected, see the descriptions in Appendices 1-1 to 1-10.

The project metrics of interest mentioned above, site occupancy, relative abundance and detection probabilities, were used to meet multiple project objectives. Site occupancy rates (or site occupancy) were the primary metric for describing population status and distributions of species in this project. Site occupancy refers to the proportion of sites that are occupied by a given species. Relative abundance, the number of individuals detected, is the second metric used to describe population status in this project. Lastly, detection probabilities (or probability of detection) were used in this project primarily for determining the effectiveness of each protocol at detecting individual and suites of species. The probability of detection is the likelihood of detecting a given species with a specified protocol at sites where the species is present; for example a detection probability of 0.80 means there is an 80% chance of detecting the species if it is present at the site. High detection probabilities indicate that the protocol is highly effective at detecting the respective species. Detection probabilities depend on the protocol being used for surveys and are unique to the individual species being detected; some species are harder to detect than others (e.g., call less frequently or are more or less trap shy, etc). Site occupancy, relative abundance and detection probabilities were originally developed as part of MSIM protocols for bio-regional scale monitoring (USDA 2001), and are evaluated here in terms of their utility for monitoring at the forestwide scale.

Lastly, analysis methods used to generate site occupancy, relative abundance and detection probability estimates are detailed, as wells as the approach for evaluating protocol effectiveness for detecting targeted species, and sampling adequacy of this project for monitoring population changes over time.

For a few protocols (e.g., Lentic bird point counts and lentic vertebrate visual encounter surveys), the results summarized in this chapter are based on a subset of all surveys conducted (Table I-3 in the Introduction), because the subset is the more appropriate for evaluating current status for these taxonomic groups.

Forest wide sampling protocols

Bird Point Counts

At each monitoring site, a total of seven stations, placed 200 m apart in a hexagonal array (Figure 1-1), were surveyed using bird point count methods (Appendix 1-1). A total of 105 monitoring sites were surveyed within the Lake Tahoe Basin Management Unit during 2002-2005. Point count methods have been identified as the recommended standard monitoring method for landbirds by the US Forest Service (Ralph et al 1993). Target species for this protocol include all diurnal songbirds associated with primarily terrestrial habitats in the basin that are known to breed in the Tahoe basin.

A minimum of 2 visits were conducted to each station at all 105 sites within the respective survey year; 56 sites had 3 visits (23 sites in 2002, 8 sites in 2004 and 25 sites in 2005). Three visits were intended to be conducted to all sites, however, human resource constraints and shorter than expected breeding seasons during 2002 and 2004 reduced our ability to conduct 3 survey visits to all sites. Counts lasted 10 minutes at each station during every survey visit to a site and data were collected in 3 or 5 distance intervals depending on the year, corresponding to 50 meter and 25 meter intervals, respectively. Point count surveys were conducted from June 13 to August 5, 2002, from June 8 to July 24, 2004 and from May 30 to July 26, 2006.

All surveys at the 105 sites were used to evaluate current forest wide bird status. Data collected during the entire 10 minute survey period to each station at each site were used in all results. Bird detections at any distance from count stations were used for general summary information regarding species detections and distributions within LTBMU, while only detections within 100 meters of count stations were used for the calculation of monitoring metrics.

Small Mammal Trapping

At each site Sherman™ live traps were deployed along 8 transects, each 200 m long, arranged in a hexagonal pattern that was bisected down the middle. Trapping transects connected point count stations at each monitoring site (Figure 1-1). Small mammal trapping surveys (Appendix 1-2) were conducted at all 105 monitoring sites. Ten traps were evenly spaced along each 200 m transect (13 traps per transect in 2002); totaling 79 traps per site (103 traps/site in 2002). Every other trap, starting with the second trap along each transect, was an extra large folding Sherman™ live trap (model XLF15), the intervening traps were extra long folding Sherman™ live traps (model XLK). Only extra long Sherman™ traps (XLK) were used in 2002.

All traps were checked twice per day for 3-3.5 consecutive days (Table 1-1), for a total of 7 visits to each site (6 in 2002). Trapping surveys were conducted from June 18 to September 12, 2002, from July 20 to September 17, 2004 and from May 14 to August 26, 2005. Target species of this protocol included all small mammal species of a maximum size that we felt would reasonably fit inside the largest of the two traps used in this protocol.

All surveys conducted to these 105 sites were used to evaluate current forest wide small mammal status. All results presented were based on detections of species during all visits to each site.

Carnivore Trackplate and Camera Surveys

Three baited track plate stations and three baited Leaf River™ digital camera stations were established in association with each of 58 monitoring sites during 2005. Track plate stations were located at the center monitoring station of each site (also a point count station) and two other stations at 500 meters from center at 90° and 270°. Additionally one camera station was located 100 meters from the central track plate station at a random azimuth and the two additional camera stations were located 500 meters from the central monitoring station at 0° and 180° (Figure 1-1). Each monitoring site was surveyed over a 10-day period, checked every other day for a total of five visits. Surveys during 2005 were conducted from May 29 to October 27.

During 2002 six trackplate stations and 4 camera stations were established per site in a pentagonal array (500 m on a side) around each of 22 monitoring sites, 18 of which were re-sampled in 2005 (Appendix 1-3). The same number of visits (5) were conducted to each site in 2002 as in 2005. Surveys during 2002 occurred from June 20 to September 20. Sampling intensity was reduced slightly in 2005 compared to 2002 due to preliminary results (USFS unpubl report: Roth et al 2004) indicating that the combination of 3 track plates and 3 camera stations per site provided for the detection of the optimal array of species per unit effort. Targeted species for this protocol included all species in the family Carnivora that are known to occur in the Tahoe basin.

Data from 2005 surveys were used to indicate "current status" of carnivores in LTBMU, whereas data from sites surveyed in 2002 (22 sites) were used only in comparison to 2005 to make preliminary inferences regarding short term changes in site occupancy for species of interest (marten, black bear and coyote).

Bat Mist-netting Surveys

Bat mist netting surveys (Appendix 1-4) were conducted at 3 stations in association with each of 22 monitoring sites (Figure 1-1). These stations were chosen by searching for the nearest suitable habitat within a 1 km radius circle from the central monitoring station at each site. Five types of habitat were considered suitable for surveys: streams, ponds, lakes, meadows, and roads/trails. Rocy outcrops and caves were not targeted. Streams and ponds were considered the best habitat for sampling bats, hence at least one station per site was a stream or pond when available.

Stations were surveyed on 2 or 4 separate occasions (i.e., visits). Repeat visits to individual stations were conducted a minimum of six days apart to spread their occurrence across the breeding season. Nets were opened at sunset and kept open for 3.5 hours. Surveys did not occur on nights with precipitation, but were rescheduled accordingly. Bat surveys were conducted from May 16 to September 1 2002. All mist-netting surveys conducted to these 22 sites were used in evaluating current status of bats in LTBMU. All bat species known to occur in the Tahoe basin were considered target species with the mist-net sampling protocol.

Additionally 58 acoustic surveys, using Pettersson ultrasound detectors (minimum model: D240), were conducted at a total of 39 stations (out of 60 total) for 1-2 visits per station. Although we had anticipated at least one simultaneous acoustic survey at each site, equipment failure prevented this from occurring. Each night, a minimum of 120 minutes (2 hours) of recording were conducted, starting at or near the time nets are open and completed before nets are closed. All acoustic surveys took place during the first hour after sunset, when bat activity is generally at its peak. Results from acoustic surveys are not reported here due to our inability to reliability identify calls to individual species for 68% of survey recordings. Therefore, acoustic data were not available consistently across sites, and hence are not reported here. Acoustic sampling of bats is still relatively new as a methodology, but has incredible potential to be a useful, efficient method of detecting bats. A library of reference calls from individual species in the local area of interest is generally required before complete analysis of an acoustic dataset can be made. Therefore, a reference collection of bat calls for the Lake Tahoe basin is needed in order for these data to be utilized to their fullest and for the use of this methodology to be best applied to future monitoring efforts. Additionally, call recognition software for use with acoustic sampling for bats and for birds is currently in development and will likely be available within the next 5 years. Despite these challenges, preliminary results from the acoustic data have been summarized in an unpublished MSIM preliminary report (Roth et al 2004).

Pitfall and Coverboard Surveys

Two pitfall trapping arrays were established at each of 9 monitoring sites only, one with the center of the array 30 m due west and the other 70 m due east of the central monitoring station. Each array consisted of 6 pitfall traps, 3 pairs of 2 traps set on opposing sides of the end of a drift fence, with drift fences arranged as three equally spaced spokes (Figure 1-1, but see Appendix 1-5 for more details). Six plywood cover boards were placed 30 m out from the central monitoring station along each of 6 azimuths at which point count stations were established (Figure 1-1).

Pitfall traps and cover boards were only surveyed in 2002 (Table 1-1) and were checked approximately twice per week depending on site accessibility for a total of 5-22 visits per site. Surveys were conducted from 21 June through August 21, and again from 23 September to 7 October. Targeted species in this protocol included a fairly broad grouping: small mammals and terrestrial reptiles and amphibians.

The use of pitfall traps and coverboards was exploratory in 2002 to determine their effectiveness in the higher elevation environment of the Lake Tahoe basin. Therefore, the surveys conducted at these 9 sites were primarily used to make preliminary inferences about the protocol effectiveness and secondarily to describe current status of terrestrial vertebrates.

Forestwide Plant Surveys

Vascular plant surveys were conducted with various levels of effort at 4 stations at each of the 105 monitoring sites (Figure 1-1), including some similar elements to the Forest Inventory and Analysis (FIA) phase 2 and phase 3 plots. Plant species composition and cover were sampled by 12 quadrats (1 m^2 /10.8 ft^2 each), 4 circular subplots (7.3 m/24 ft radius), similar to FIA, and two 25 m (82 ft) transects at the central monitoring station at all 105 sites. At 65 of the 105 monitoring sites, two 25 m transects were sampled at each of 3 additional peripheral stations 200 m (656 ft) away (Figure 1-1).

At central stations, 3 of the 12 quadrats were embedded within each of 4 subplots. Subplots were arranged in an inverted Y shape in close proximity to the central monitoring station at each site and transects radiated outward from each station and were oriented at a 90° angle from one another (Appendix 1-6).

Quadrats, subplots and transects at the central monitoring station were sampled 1-2 times (i.e., visits) at each site; 85 of all 105 sites sampled at the central station received 2 survey visits. Transects at the 3 preipheral stations were sampled only once at the respective 65 sites (Table 1-1). Percent cover was estimated for all plant species present within quadrats, in subplots and along 5 one-meter segments along each transect. Vascular plant surveys were conducted from June 11 to September 11, 2002, and from June 7 to August 30, 2005. Targeted species in plant surveys include all vascular plant species that occur in the Lake Tahoe basin.

Data collected from all methods at all 105 sites were used for some metrics of current status for plants (species richness and cover estimates), however, only data collected at the central monitoring station at each site (quadrats, subplots and transects) were used in estimating protocol effectiveness (species detectabilities), and monitoring metrics (site occupancy per species).

Forestwide Habitat Condition Surveys

Habitat surveys were conducted at four stations associated with each of the 105 forestwide monitoring sites (same 4 stations surveyed for vascular plants, Figure 1-1), including some elements of FIA phase 2 plots. A total of 3 nested circular plots with radii of 56.4 m/185 ft (i.e., hectare plot), 17.6 m/57.8 ft (i.e., ¼ acre plot), and 7.3 m/24 ft (i.e., 24 ft subplot), and two 25 m transects were centered on each station and were sampled to describe habitat conditions (Appendix 1-7). Both species composition (tree, snag and coarse woody debris species) and vegetation structure (tree/snag densities, coarse woody debris volume, canopy cover and vertical structure, etc) were measured with plots and transects at each station (see Appendix 1-7 for complete list of variables measured).

Only one survey visit was conducted to each site for habitat surveys. Surveys were conducted during the summer prior to leaf fall on deciduous species; from June 21 to September 28, 2002, from July 1 to September 30, 2004, and from June 7 to September 12, 2005.

All surveys to the 105 sites were used to describe current habitat condition in the Tahoe basin. Habitat data were additionally used to describe basic species-habitat relationships.

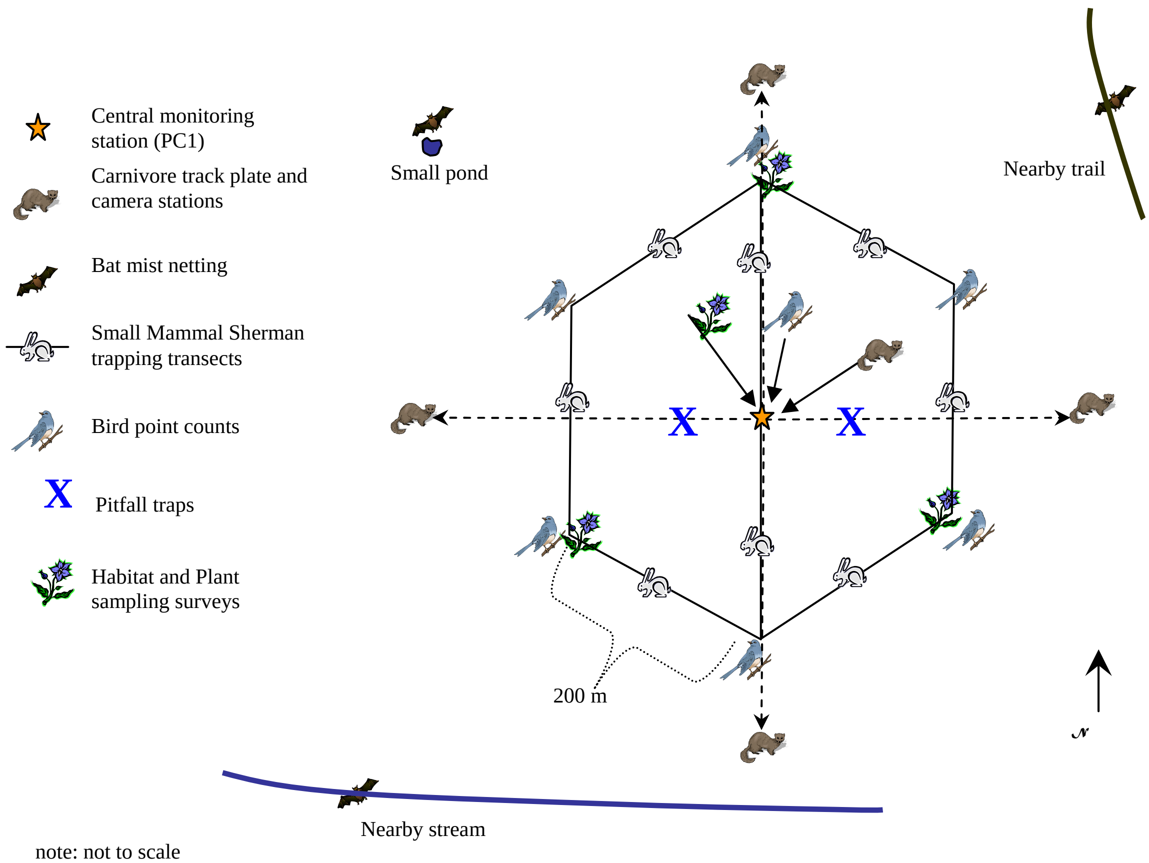

Figure 1-1. Spatial arrangement of survey protocols associated with each Forest wide monitoring site, Lake Tahoe basin, 2002 through 2005.

Lentic habitat sampling protocols

Lentic Bird Point Counts

A total of 1 to 8 stations (approximately 250-500 m apart) were established and surveyed at each of 145 unique lentic sites (Table 1-1). The number of stations per site depended on site size and visibility along the shoreline or along the edge of meadows (Figure 1-2). The primary objective was to achieve complete survey coverage of the entire lentic unit and to minimize survey overlap between stations.

One survey visit was conducted to each site in 2003 and 2 visits were conducted to sites sampled in 2004 (81 sites; Table 1-1). Survey visits in 2004 were separated by at least 1 week (i.e., 7 days). Point counts at lentic sites followed the same general protocol implemented at forestwide sites, but lasted

20 minutes at each station, as opposed to 10 minutes at forestwide sites (Appendix 1-8). Data were recorded in 3 distance intervals (5 distance intervals were recorded in 2004). Surveys were conducted between June 6 and August 2, 2003 and from July 14 to August 30, 2004. Target species for this protocol include all songbirds and waterbirds associated with aquatic and terrestrial habitats and that are known to breed in the Lake Tahoe basin.

Data collected from all 145 sites during 2003-2004 were used for determining species richness and distributions across lentic sites and for abundance information, however, only the 81 sites surveyed twice during 2004 were used for estimating site occupancy and detection probabilities.

Lentic Vertebrate Visual Encounter Surveys

Visual encounter surveys for herpetofauna status and change monitoring were conducted at each of 148 sites during 2003-2004. Surveyors either walked the entire perimeter of the site at lakes and ponds or zigzagged from side to side in a manner to cover the entire area at meadow sites (Figure 1-2, Appendix 1-9). Observers spent most of the time walking in the water near the shoreline (in suitable herpetofauna habitat), searching through emergent vegetation with a long-handled dip-net and overturning rocks, logs, and debris to reveal amphibians and reptiles (Fellers and Freel 1995).

All sites were surveyed twice in the respective year of survey (Table 1-1), and visits were separated by at least one week. Surveys occurred from May 15 to September 10, 2003 and from June 9 to September 7, 2004. Additional visual encounter surveys were conducted at lentic sites during 2002-2004 (Table I-3), however, several of these were repeated surveys and were not intended for the purpose of evaluating current population distributional status. Target species of this protocol include all amphibians and aquatic reptiles known to occur in the Tahoe basin.

Data collected from both visits to each site constituting the dataset used for evaluating current status of amphibians and reptiles at lentic sites.

Lentic Habitat Condition Surveys

Surveys of habitat condition were conducted to all 148 lentic monitoring sites during 2003 and 2004 (Table 1-1). Habitat condition was sampled based on field collected and GIS collected data (e.g., disturbance measures within a 30 m/98.4 ft buffer around the site, elevation, waterbody size, proportion of various habitat types within various buffer sizes from sites, etc.). Field collected data consisted of vegetation/substrate cover composition and structure measurements along transects extending both into the waterbody itself (i.e., lentic transects) and out from the waterbody into the upland (i.e, upland transects) (Appendix 1-10).

A total of 30 (during 2003) to 50 (during 2004) 3 m/9.8 ft long lentic transects were established (Figure 1-2) at each site. At lakes and ponds, lentic transects were placed along the perimeter of the waterbody, were oriented perpendicular to the shoreline and extended into the water. At wet meadows and fens, a randomly determined starting point was selected for a straight line across the longest dimension of the meadow and transects were placed perpendicular to and centered on this imaginary line. Transects were evenly spaced along the length of the meadow or perimeter of the shoreline in order to fit the 30 or 50 transects. Water depth, substrate composition, frequency of emergent vegetation (as well as submergent, floating and hanging vegetation in 2004) and occurrence of logs were recorded on each transect.

At sites sampled in 2004 (52 sites), an additional 50 upland transects were sampled at lakes and ponds that extended upland from the shoreline to describe adjacent terrestrial habitat features. Data collected along upland transects included: substrate composition, occurrence of logs, and presence of plants by life form group for herbs and shrubs (e.g. rushes, grasses, pond lily, shrubs), and by species for trees (e.g., willow, alder, lodgepole pine, etc.). Also collected only during 2004 was the number of inlets/outlets > 10 cm/4 in wide that occurred at the lentic site to describe its connectivity to nearby aquatic sites.

Habitat measurements were taken once at each site; during one of the two vertebrate perimeter survey visits or within two days of the vertebrate survey. Lentic habitat surveys were conducted from May 15 to September 10, 2003 and from June 22 to September 11, 2004. Similar to visual encounter surveys, multiple lentic habitat surveys were conducted at individual lentic sites during 2002-2004 (Table I-3), however, repeated surveys were not intended for the purpose of evaluating current habitat condition; hence results for only one survey per site are reported here.

Similar to forestwide habitat condition surveys, data from these surveys were used to describe current habitat condition at lentic sites and to describe species-habitat relationships. Current habitat conditions at lentic sites were summarized in 2 ways: one including variables collected at all 148 sites in both 2003 and 2004 (e.g., lentic transect substrate, emergent vegetation and coarse woody debris frequency; shoreline disturbance, site size, site elevation and proportion of various terrestrial habitat types in the vicinity of each lentic unit); and the second including only those additional variables sampled at the 52 sites sampled in 2004 (e.g., upland transect substrate, vegetation characteristics and coarse woody debris frequency; and frequency of inlets and outlets).

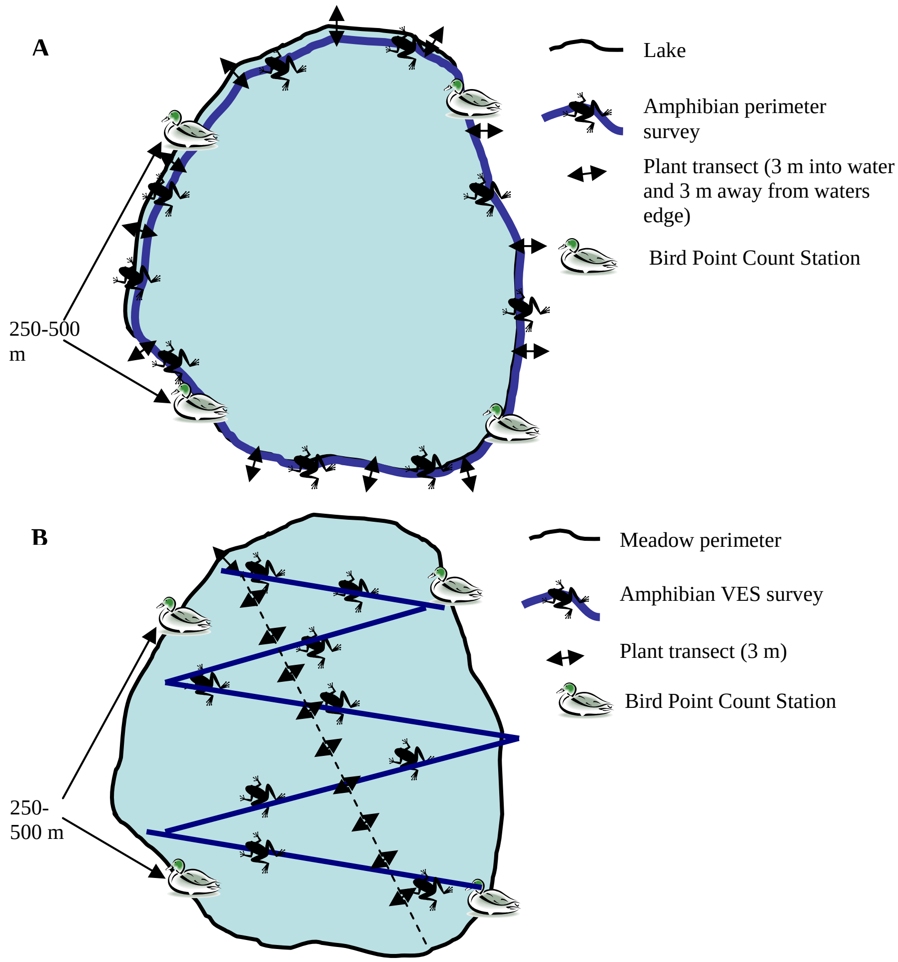

Figure 1-2. Spatial arrangement of aquatic survey protocols associated with each A) pond/lake or B) meadow monitoring site, MSIM, Lake Tahoe basin, CA and NV, 2003, and 2004

Table 1-1. Survey effort of each protocol implemented each year of survey, MSIM, Lake Tahoe basin, CA and NV, 2002, 2003, 2004 and 2005.

	2002			**2003**			**2004**			**2005**		
Protocol	**Sites**	**Stations per site**	**Visits**	**Sites**	**Stations per site**	**Visits**	**Sites**	**Stations per site**	**Visits**	**Sites**	**Stations per site**	**Visits**
Forest wide Monitoring Protocols												
Bird Point Counts	40	7	2-3	-	-	-	40	7	2-3	25	7	3
Small Mammal Trapping	40	n/a	6	-	-	-	40	n/a	7	25	n/a	7
Carnivore Track Plate and Camera Surveys	22	10	5	-	-	-	-	-	-	58	6	5
Pitfall and Cover boards	9	2	5-22	-	-	-	-	-	-	-	-	-
Bat Mist-netting	22	3	2-4	-	-	-	-	-	-	-	-	-
Plant Surveys (quadrats, subplots, transects)	40	1	1-2	-	-	-	-	-	-	65	1	2
Terrestrial Habitat Condition	40	4	1	-	-	-	28	4	1	37	4	1
Lentic Monitoring Protocols												
Lentic Bird Point Counts	n/a	-	-	96[a]	1-8 (site dependent)	1	81	2-8 (site dependent)	2	-	-	-
Vertebrate Encounter Surveys	n/a	-	-	79	n/a	2	69	n/a	2	-	-	-
Lentic Habitat Condition	n/a	-	-	79	n/a	1	69	n/a	1	-	-	-

a 32 of the 96 sites sampled in 2003 were re-sampled in 2004.

Data quality control

Surveyor Training

All surveyors were hired based on level of experience necessary for conducting each respective protocol; some protocols required more extensive prior experience (bat mist netting, bird point counts, small mammal trapping and plant surveys) than others. Additionally, a training period occurred at the start of each field season for surveyors of all protocols and a species identification test was given to surveyors of the following protocols: bird point counts, small mammal trapping and plant surveys (2005 only) to ensure only qualified surveyors were collecting data.

Bat mist-netting surveyors required the most specific prior experience. Surveyors hired for bat mist-netting surveys were required to hold a current

California bat handler memorandum of Understanding (MOU). Bird point count surveyors were required to have a minimum of one year prior experience conducting bird point count surveys in western coniferous forest ecosystems, or many years of experience detecting birds by sight and sound in a variety of habitat types and demonstrated high potential for learning species of the Tahoe basin rapidly. Small mammal trapping surveyors were not necessarily required to have prior experience handling and identifying small mammals, however such experience was preferred, and experience with small mammal communities similar to those in the Lake Tahoe basin was preferred. Prior experience identifying plants to species in the Sierra Nevada was required for surveyors conducting plant surveys. Conversely, prior experience was not required for surveyors conducting carnivore surveys, amphibian and reptile surveys or for habitat surveys, due to protocols being fairly simple to learn within a few weeks time. Only individuals with greater than 3 seasons experience identifying carnivore species tracks were employed to identify species by track prints and photos.

For all protocols, surveyors spent 1-3 weeks becoming oriented to the protocols and refreshing on species identification for the respective species group. For bird point counts, and small mammal trapping, surveyors were given a species identification test prior to data collection to indicate their level of expertise; only surveyors meeting a minimum standard were allowed to implement protocols.

Data Collection and Database Creation

During each year of data collection, data sheets were checked weekly or bi-weekly for completeness, legibility and obvious species detection errors (e.g., mis-recorded species name, etc) by crew leaders or by another person with appropriate experience with the respective species group. After data collection was complete in each year, all data were entered from data forms into a Microsoft Access relational database and each data sheet checked once for correct data entry into the database.

Occasional double observer approaches were conducted between crew leaders (with the greatest experience level) and crew members to calibrate observer biases, however these were conducted on a limited basis and were primarily completed qualitatively.

Database Integrity

Once the database was populated with data, a series of database queries were performed to additionally check for data entry errors for each variable collected in each protocol. Queries were generated to show the range of values input for each variable collected in each protocol in order to detect any aberrant values that needed to be checked. Any obvious outliers were checked for integrity with the original datasheet. For example, for each protocol dataset, we conducted queries to show the list of species recorded in the database, in order to see if all species codes entered matched species that occurred in the Tahoe basin, and to ensure that all codes or names for each species were consistent across the dataset. Any errors were investigated on the original datasheet and corrected as necessary. Additionally, the list of site and station codes recorded with all species detections were checked for the correct range of values, and again any errors resolved using the original datasheets. This process was repeated for all variables summarized in this report.

Data analysis methods

Species population status and monitoring metrics

Species population status can be defined in many ways, but for this study was defined by two population metrics, site occupancy (or proportion of sites occupied) and relative abundance.

Multi Species Inventory and Monitoring protocols were developed primarily to address the monitoring needs of species requiring presence/absence (i.e., site occupancy or distribution) and to a lesser extent species requiring relative abundance population status/trend data (USDA 2001). Sampling for presence/absence (e.g., site occupancy rates) is generally less intensive than sampling for population abundances; and changes in site occupancy (i.e., proportion of sites occupied) across a landscape ultimately reflect underlying changes in population abundances. Therefore, site occupancy was the primary monitoring metric of interest for indicating basinwide population status of species in the MSIM project.

Observed site occupancy rates (based on the number of sites with detections of a species), are likely to underestimate true occupancy by a species due to the fact that species are almost never detected perfectly with most sampling protocols (less than 100% chance of detecting a species during a survey when the species occurs at the site; Geissler and Fuller 1987). Recent advancements in statistical methodologies now allow for estimation of species' site occupancy rates as a metric for long-term monitoring programs, by accounting for imperfect detection probabilities (MacKenzie et al 2002, 2006). Essentially, detection probabilities are used to correct observed site occupancy values to better reflect the true site occupancy status of a species. By conducting multiple survey visits to a monitoring site during the same sampling season, as was completed in the MSIM project, these statistical procedures can be applied to estimate detection probabilities (probability of detecting a species at a site when it occurs there) and site occupancy rates simulataneously. Wildlife researchers and managers are beginning to recognize the importance of accounting for imperfect detection probabilities when designing monitoring programs and for better understanding habitat suitability (Pollock et al, 2002, Bailey et al 2004, Pellet and Schmidt 2005, Schmidt 2005, Vojta 2005). Therefore "estimated site occupancy", as calculated through maximum likelihood methodologies detailed in MacKenzie et al (2002), was estimated for each species detected in all protocols (with the exception of pitfall trapping as sample sizes were not suitable) to indicate current population status.

Site occupancy estimates were considered reliable metrics of population status only if the detection probabilities upon which they were based were both reliable (based on 20 or more sites with detections; 15 for species detected with the bat mist-netting protocol) and sufficiently high to allow for accurate, unbiased estimation of "true" site occupancy rates. MacKenzie et al (2002) conducted a simulation exercise to evaluate the influence of various parameters relating to protocol design and detection probability values on the accuracy/reliability of site occupancy estimates, and provided some general guidelines to indicate when occupancy estimates are reliable.

In general, protocols with very few visits (2-3) and species with very low detection probabilities per sampling visit yield less reliable site occupancy estimates than species surveyed via protocols with many sampling visits ($\geq$ 5), and with high detection probabilities per sampling visit. Since MSIM protocols varied in the number of sampling visits conducted to each site and each species varied in their detectability, we applied the results of the simulation study by MacKenzie et al (2002) to establish a minimum overall protocol probability of detection[1] (resulting from all completed survey visits) of 0.80, which was likely to indicate reliable site occupancy estimates.

Species that met this minimum protocol detection probability standard were assumed to have reliable and unbiased site occupancy estimates that accurately reflected their current status across LTBMU. Site occupancy status was summarized for species with reliable estimates in terms of the average estimated site occupancy (% of sites occupied) by those species and the degree to which estimated occupancy rates were greater than observed occupancy rates.

A secondary metric of population status, relative abundance, while not identified as the primary monitoring metric for most MIS and species at risk at the bio-regional scale (USDA 2001), was identified as a potential metric for special status species monitoring and for incorporation into various indices of biological integrity (IBIs) for monitoring ecosystem integrity in the Tahoe basin. Hence, for species detected with MSIM protocols in which abundance measures were taken (e.g., bird point counts, small mammal trapping and botany surveys), we also summarized observed relative abundance values (e.g., average number of individuals observed/detected per site, or average % cover per site) to indicate population status on a per site basis.

[1] See Protocol Effectiveness/species detectability section for a more complete description of detection probabilities and for calculations of protocol probability of detection.

Protocol effectiveness/species detectability

While detection probabilities were used to correct site occupancy rates to better indicate "true" site occupancy status for individual species (see above section), they are also important for indicating the overall effectiveness of a given protocol at detecting the targeted suite of species; for example the effectiveness of the bird point count protocol at detecting songbirds, or of the small mammal trapping protocol at detecting small mammal communities. By evaluating each protocol for the species it detects with high probability, we can determine how many and which species a particular protocol is most effective at sampling, and we can evaluate whether those species are a representative subset of the targeted species group. In particular we evaluated the effectiveness of each MSIM protocol at detecting each targeted species group (e.g., songbirds for bird point counts, carnivores for trackplate and camera surveys) in 3 ways.

We first evaluated protocols by the proportion of species expected to be detected with each protocol that were in fact detected at least once within the Tahoe basin. Expected species were defined as species within the targeted taxonomic group that are listed as currently occurring in the Lake Tahoe Watershed Assessment (Murphy and Knopp 2000). Target species for each protocol were defined within each individually described protocol section above. This indicated at a coarse scale the capability of the protocol for detecting the targeted species group.

The second way each protocol was evaluated was by the proportion of all species detected and the proportion of only special status species detected that had estimated detection probabilities (Pd) of at least 0.80 (meaning that the species had an estimated 80% or higher chance of being detected by the protocol when it occured at a given site). Procedures for calculating detection probabilities are described below. Special status species were defined as: USFS Management Indicator Species (MIS) or sensitive species (FSS), Pathway 2007 proposed species of concern (SOC), species of interest (SOI) and species groups (FSH 1909.12 sections 43.22b, c and 43.24), and totalled 74 species in all. These "special interest" species were intended to represent the suite of species for which focused individual monitoring efforts are either currently desired (MIS, FSS, USDA 2001) or may be desired in the future (SOC, SOI, species groups) and include species with either a high degree of rarity, decline or potential negative impacts to native species (e.g., invasives or exotics), or are of general public interest (e.g., bear, beaver).

The third way protocol effectiveness was evaluated was in terms of the representation of various life history characteristics among those species with high ($\geq$ 0.8) and moderate (0.5-0.8) detection probabilities. Ecological sub-groups were defined based upon life history traits of species within 3 selected species groups (terrestrial songbirds detected with forestwide point counts, small mammals detected with Sherman trapping and carnivores) and are described in

Manley and McIntyre (2006). Ecological sub-groups consisted of groups based on similar functional characteristics (e.g., foraging strategies), similar structural associations (e.g., nesting strategy) or intrinsic compositional similarities of species (e.g., migratory status, family or genus group, etc). We compared the proportion of species within each ecological sub-group with high and moderate detection probabilities to determine whether each protocol was equally effective at detecting species within all sub-groups or if there were any apparent biases with regard to life history characteristics.

Detection probability (Pd or probability of detection) is a measure of the chance of detecting a particular species at least once during all survey visits to a site within a given year with the respective protocol. Estimating detection probabilities requires that 2 or more sampling visits occur to a given site within the respective sampling season and that occupancy of a given site by a species does not change between sampling visits (MacKenzie et al 2002); assumptions that we believe to have met with the protocols evaluated. Detection probabilities (Pd) were estimated for each species detected by each protocol, with the exception of the pitfall and coverboard protocol (due to sample size and design constraints), and were estimated based on empirical data collected in this project. We first estimated the probability of detection for each species per sampling visit (p = probability of detecting a species during a single survey visit to a site) using a maximum likelihood statistical approach (MacKenzie et al 2002). We then calculated detection probabilities per protocol (Pd = probability of detecting a species at least once during any survey visit conducted to a site) based on these estimated per-visit detectabilities (p). Detection probability per protocol (Pd) was the metric of interest for our evaluation of protocol effectiveness and represented the chance of detecting a particular species at an occupied site with the respective protocol. The formula used for this calculation is as follows:

$$Pd = 1-(1-p)^t$$

Where:
Pd = the protocol detection probability for a particular species
p = the estimated detection probability per visit for a particular species
t = the number of sampling visits occurring to each site with the respective protocol (Table 1.2).

Detection probability values (Pd) were only considered to be reliable for those species for which probability estimates were based upon a sufficient number of detections to give us confidence in their accuracy. We arbitrarily defined the sufficient number of detections as a minimum of 20 sites with detections for each species; with the exception of bats for which only 22 sites were sampled and we assumed species with detections at a minimum of 15 sites would have reliable detection probability estimates. Therefore, in the context of evaluating protocol effectiveness based on species detectabilities, species with unreliable detection probability estimates did not contribute to protocol effectiveness evaluation. Such species either 1) have high detectability with the respective protocol but are too rare in the Tahoe basin to accurately measure detectability, 2) have low detectability with the respective protocol, explaining the low number of detections in the dataset, or 3) a combination of the two, where the species is rare or has low detectability only within the habitats sampled with the respective protocol.

Population change and sampling adequacy

We evaluated the ability of current MSIM sampling design to detect changes in species' population status over time. Sampling adequacy was defined as the ability of a given MSIM protocol to detect either a 20% change or 20% decline in population status (estimated site occupancy or relative abundance) with 80% confidence and power based on sample sizes realized in this survey effort for each respective protocol; for site occupancy, sample sizes were 22-105 for forestwide network sites and 145-148 for lentic network sites, and for abundances, sample sizes were equal to the number of sites with detections of the respective species. We used a sample size analysis approach in which we calculated the minimum sample size necessary to detect the desired population change (as mentioned above) for each species and compared that value to the actual number of monitoring sites sampled from 2002-2005, and defined above. Species with sample size requirements less than what was actually sampled in this project were sampled adequately to detect a 20% change or decline in population status assuming monitoring continues at the existing monitoring sites. The remaining species were not sampled adequately.

Species that were sampled adequately to detect change or decline in site occupancy were compared to those species sampled adequately for relative abundances (for birds and small mammals only) in order to compare the relative strengths/weaknesses of these 2 monitoring metrics for inclusion in a long-term monitoring program.

Sampling adequacy was conducted separately for species detected at forestwide monitoring sites and at lentic monitoring sites.

<u>Site occupancy analysis</u>

Sampling adequacy was assessed for each species detected in each protocol that was identified as having reliable site occupancy estimates based on Table 1-2. Minimum sample size requirements for detecting a change or decline in site occupancy were calculated based on an application developed by PSW (fsweb.psw.fs.fed.us/stat- web enabled computing-Point and Click Sample size estimation application) which was appropriate for analysis of changes in proportions (i.e., site occupancy rates) over time. In this analysis the following parameters are input for a given species: P1 = estimated site occupancy in the first sample period (i.e., estimates generated from MSIM field surveys 2002-

2005), P2 = estimated site occupancy during the second sample period (i.e., value was calculated based on the desired change to be detected for 20% change, P2 = P1 * 0.80 or P1*1.2), alpha level and desired power (we selected alpha = 0.2, and power = 0.8 in all sample size estimates which corresponds to 80% confidence and power).

Minimum sample size requirements generated based on above methods are conservative and are based on the assumption that site occupancy from year to year at any given site is independent of occupancy status the previous year (i.e., site persistence = 0). It is likely that this is not a correct assumption and that site persistence is positive, but by how much is uncertain. As persistence increases from 0 (independence) to 1 (complete dependence of one year to the next), minimum sample size requirements for detecting population change are reduced.

Abundance analysis

Minimum sample size requirements for detecting changes in abundance were calculated based on the sample size statistics tool for a paired t-test from the program SigmaStat (v3.5). In this analysis the following parameters were input for each species: alpha level and desired power (we selected alpha = 0.2, and power = 0.8 in all sample size estimates which corresponds to 80% confidence and power), estimated standard deviation of the difference in abundances between the 2 samping periods being compared, and the desired change to be detected or effect size. Because we only have abundance estimates for a single sampling period, 2002-2005 and have not yet repeated sampling at monitoring sites, we used the following equation to estimate the standard deviation of the difference between 2 sample periods:

$$s_{diff} = s_1 * [\text{sqrt}(2 * (1 - \text{corr}))]$$

Where:

s_{diff} = Estimated standard deviation of the differences between paired samples

s_1 = Sample standard deviation among sites during the first sampling period

corr = Correlation coefficient between abundance values at sites in the first sampling period and in the second sampling period. Due to the lack of available pilot data for estimating this value, we used a correlation coefficient = 0.5.

Additionally, we selected a 20% change as our desired effect size, hence the effect size depended on the relative abundance value measured per species and was unique to each species.

Sample size estimates generated in the above analysis for each species were compared to the number of sites with detections for each species to determine if we adequately sampled each species in order to detect a 20% change in abundance over time with 80% confidence and power. Species with sample size estimates less than the number of sites with detections were considered adequately sampled; all other species were not adequately sampled given the implemented sampling design.

Species sampled adequately to detect changes in site occupancy and abundance were compared to one another to see which metric allowed for the greatest number of and most desired species to be adequately sampled.

Results and Discussion

Status of Wildlife in the Tahoe Basin

Wildlife data were collected at monitoring sites in order to determine species occurrences, distributions, abundances (when applicable) and monitoring metrics for the purpose of establishing current status, and evaluating our ability to monitor status over time.

A. Forestwide and Lentic Bird Point Counts

Species detections, site occupancy and abundance

Detections

Observers detected 134 bird and 3 small mammal species across all monitoring sites; 117 at forestwide sites and 116 at lentic aquatic sites (i.e., ponds, lakes, wet meadows etc.) from 2002-2005 (Appendix A-1). Ninety-nine species were detected at both networks of sites (Appendix A-1). Species detected were primarily conifer forest associated species. To a lesser extent riparian associated species followed by small lake and pond associated species were detected due to sampling of lentic aquatic monitoring sites. The majority of lentic monitoring sites, however, were relatively small in size compared to the surrounding forested landscape, resulting in the strong representation of forest associated species at even lentic monitoring sites.

A total of 7 species were detected that were not recognized as currently occurring in the Tahoe basin; 2 of which were presumed to be extinct in the Tahoe basin (Canyon Wren and Savannah Sparrow), but were detected on several occasions during the breeding season and should be added to the list of species currently occurring in the Tahoe basin, and 5 which were detected infrequently and were considered accidental or transient summertime visitors:

Black Phoebe, Clark's Grebe, Ovenbird, Swainson's Hawk and Wrentit. The latter 5 species do not regularly occur in the Tahoe basin.

The Golden Eagle was additionally detected at a baited camera station in the Shower's Lake area of the Upper Truckee drainage (see Carnivore trackplate and camera survey results below). This detection represents one of very few detections of this species in the Lake Tahoe basin. The Golden Eagle was not detected in point count surveys.

Site Occupancy

A total of 19 bird species (14%) were detected at high frequencies, $\geq$ 50% of all sites surveyed (forestwide and lentic), and these species were primarily coniferous forest dwelling species, as was expected based on the dominance of conifer forest habitat sampled in this effort and existing throughout the Tahoe basin. Mountain Chickadee, American Robin, and Dark-eyed Junco were detected at all 105 forestwide sites, with the Steller's Jay and Yellow-rumped Warbler at 104 forestwide sites. The next 5 most frequently detected species included Red-breasted Nuthatch, Dusky Flycatcher, Northern Flicker, Fox Sparrow and Western Tanager (Appendix A-1). No species were detected at all 145 lentic aquatic sites, however the same species were among the most frequently detected at lentic sites as at forestwide sites (Appendix A-1): Mountain Chickadee was detected at 141 lentic sites, Steller's Jay at 132, Dark-eyed Junco at 129, and American Robin at 120 of 145 sites. This is likely due to the fact that > 50% of the area around most lentic aquatic sites consisted of forested habitats (see Lentic Habitat Condition section below), and bird surveys at lentic sites included sampling within the transition zone to the surrounding landscape. The most frequently encountered aquatic/riparian associated species at lentic sites were the Mallard (39% of lentic sites), Wilson's Warbler (38% of sites), and the Warbling Vireo and MacGillivray's Warbler (37% of sites each), followed next by the following 5 species detected at between 20 and 30% of lentic monitoring sites: Rufous Hummingbird, Brewer's Blackbird, Song Sparrow, Lincoln's Sparrow and Red-winged blackbird.

The majority of species detected at forestwide and lentic sites, however, were detected at low frequency; 89 avian species (67%) were detected at fewer than 20% of sites surveyed, including most special status species[1] (Appendix A-1).

Despite their low frequencies of detection, a total of 37 of 42 special status bird species[1] were detected with MSIM surveys at lentic and forestwide sites; 33 at lentic sites and 26 at forestwide sites (Appendix A-1). The Brown-headed Cowbird (an invasive species of interest) was the most frequently encountered

[1] Management Indicator Species, Forest Service Sensitive species, Federal ESA Threatened or Endangered species, Pathway proposed species on concern (FSH 1909.12 43.22b), species of interest (FSH 1909.12 43.22c) and species groups (FSH 1909.12 43.24).

special status species, detected at 42% (106 sites) of all lentic and forestwide sites combined, followed by the White-headed Woodpecker (32%), Mallard (27%), Lincoln's sparrow (19%), and Blue Grouse (17%).

Most special status species[1] are aquatic or riparian associates, and were detected more frequently at lentic than forestwide sites (Appendix A-1), albeit at generally low frequencies relative to conifer forest associates. Therefore, lentic and riparian habitats in the Lake Tahoe basin are disproportionately more important for current special status species, and may warrant greater sampling effort in future monitoring efforts. A previous study in which bird surveys were conducted along 80 riparian reaches throughout the Tahoe basin (Manley and Schlesinger 2001), demonstrated very similar results to our lentic aquatic site surveys. At both lentic and riparian sites surveyed, bird communities were dominated by conifer forest species (detected most frequently across sites) demonstrating the influence of the surrounding forest landscape on bird communities in these aquatic/riparian habitat types in the Tahoe basin. Additionally, aquatic and riparian associated birds that were most frequently detected at lentic sites, were generally also the most frequently detected species at riparian sites, with the exception of some open water and marsh species (e.g., Bufflehead, Gadwall, Mallard, Red-winged Blackbird) detected more frequently at lentic sites than riparian sites, and a few characteristic riparian aquatic associated species (e.g., Nashville Warbler, Yellow Warbler and American Dipper) detected more frequently at riparian sites. This suggests the importance of a stratified sampling design in future monitoring efforts that targets habitats (or other appropriate strata) of interest, and highlights the potential challenge of identifying a distincting aquatic/riparian community separate from the surrounding forested landscape.

When compared to historical records for forest dwelling bird species in the Tahoe region (Orr and Moffitt 1971), we found that several species demonstrated marked or potential changes in their frequency of occurrence relative to the early/mid 1900s. In particular 3 species recorded as common in the Tahoe basin by Orr and Moffitt (1971) showed marked declines in recent MSIM surveys: White-crowned Sparrow, Ruby-crowned Kinglet and House Finch were detected at 12% or fewer forestwide sites; and 4 species showed possible moderate declines: Hermit Warbler, Red-breasted Sapsucker, Blue Grouse and House Wren, detected at ~30% of contemporary sites. While the low frequency of detection of the House Finch in our surveys may have been due to the predominance of dense forest in our sample and general lack of representation of highly developed sites where this species thrives, similar recent surveys conducted within the urban-wildland interface (Manley et al. 2007) detected this species very infrequently as well.

Conversely, 7 species showed likely or potential increases in frequency from historic conditions. The White-Breasted Nuthatch displayed the most dramatic apparent increase, from being recorded as rare (Orr and Moffitt 1971), to being detected at over 80% of forested locations surveyed in this project. The Brown-headed Cowbird, similarly reported as rare historically, was detected recently at 28 and 62% of lentic aquatic and terrestrial sites, respectively. Additionally, Cassin's Vireo, Mourning Dove, Band-tailed pigeon, Pine grosbeak and Red Crossbill, recorded as rare historically, were fairly common in recent surveys (detected at>30-50% of sites).

In addition to birds, 3 small mammal species were detected with vocal calls recorded during point counts rather than with trapping: Douglas' squirrel was detected at 209 of lentic and forestwide sites surveyed (82%), American pika at 30 (12%) sites and yellow-bellied marmot at four forestwide sites (2% of sites); these very vocal small mammals were detected more frequently with bird point counts (Appendix A-1) than with small mammal traps (Appendix B-1) at forestwide sites. Additionally, these 3 small mammals were consistently detected with greater frequencies at forestwide sites than at lentic monitoring sites, however differences were fairly small (Appendix A-1). While small mammal trapping is generally considered the primary detection protocol for these species, we recommend using point count auditory/visual survey methods as the primary detection method for these 3 small mammal species if their detection is desired. Time of day may need to be considered, however, when using this typical bird survey method for detecting auditory small mammals.

Abundance

Forestwide sites: Species abundances per count station among sites with detections of the respective species varied from an average of 0.05 individuals per count station to 1.6. The top 15 most abundant species at forestwide monitoring sites included several species detected at the greatest frequency of sites: Mountain Chickadee Dark-eyed Junco, Steller's Jay and American Robin, but also included species one might expect to be detected in high numbers when encountered; Barn Swallow, Cliff Swallow, White-crowned Sparrow and Red-winged Blackbird (Table A-2). While the latter species are not generally characteristic of the coniferous forest bird communities, they were detected primarily at the few riparian/meadow sites included within the forestwide monitoring network of sites.

Lentic sites: Species abundances per count station at lentic sites among only sites with detections of the respective species averaged > 1.25 individuals per count station (Table A-2). Species with the greatest abundances recorded per count station were primarily aquatic/riparian associated species (Table A-3), but also included the Mountain Chickadee, Dark-eyed Junco and European Starling (an exotic species).

Table A-2. Most abundant bird species at forest wide and lentic monitoring sites in the Lake Tahoe Basin Management Unit (LTBMU), sampled in 2002-2005. Abundances are mean values per point count per site at sites with detections of the respective species. Values are based on detections within 100 meters of count stations and based on 10 minute (forestwide sites) or 20 minute counts (lentic sites).

Forestwide Sites			**Lentic Sites**		
Common Name	**Abundance**	**s.e.**	**Common Name**	**Abundance**	**s.e.**
Mountain Chickadee	1.59	0.06	Canada Goose	6.31	3.44
Dark-eyed Junco	1.54	0.07	Brewer's Blackbird	3.45	0.85
Steller's Jay	0.99	0.07	Mallard	2.68	0.95
Fox Sparrow	0.97	0.09	Bufflehead	2.54	1.39
Yellow-rumped Warbler	0.9	0.05	Northern Rough-winged Swallow	2.5	2
Red-breasted Nuthatch	0.78	0.05	Red-winged Blackbird	2.46	0.39
Barn Swallow	0.76	n/a	Mountain Chickadee	2.08	0.11
American Robin	0.67	0.04	European Starling	2.03	1.26
White-crowned Sparrow	0.66	0.3	Dark-eyed Junco	1.85	0.14
Red-winged Blackbird	0.65	0.29	Barn Swallow	1.72	0.58
Dusky Flycatcher	0.63	0.05	Common Merganser	1.67	0.49
Western Tanager	0.61	0.05	Cliff Swallow	1.57	0.45
Cliff Swallow	0.52	0.24	American Coot	1.44	0.71
Brown-headed Cowbird	0.5	0.07	Green-winged Teal	1.33	1.17
Gray-crowned Rosy Finch	0.46	0.18	Brewer's Sparrow	1.25	n/a

We compared average abundance estimates based on this MSIM survey effort to recommended abundance targets established by the Point Reyes Bird Observatory (PRBO) for conifer focal species in the Sierra bio-region (Table A-3; CalPIF 2002,) in order to have some understanding of existing conditions in the Lake Tahoe basin relative to that expected for bird communities throughout the Sierra.

Average abundances of conifer focal species from the MSIM project were consistently greater than recommended PRBO targets for the Sierra bio-region by approximately 2-7 times (Table A-3). However, data used for generating abundance targets for coniferous focal species were based on point counts in riparian dominated habitat mixed with conifer habitat along the east side of the Sierra Nevada range (Inyo and Mono counties), a habitat type that is likely not representative of desired conditions for conifer forest throughout most of the Sierra Nevada. Therefore, we believe that abundance estimates generated from the MSIM survey effort are likely more appropriate as targets for the coniferous forest species since they were generated from coniferous dominated habitat closer to the Sierra Nevada Crest. Hence we recommend using average abundance values generated from MSIM data as reference targets for future long term monitoring of conifer forest focal species in the Lake Tahoe Basin Mangement Unit.

PRBO additionally established targets for riparian focal species (RHJV 2004), however comparisons to MSIM data were not appropriate due to the fact that riparian habitats were sampled very infrequently in the MSIM project (Table A-3); only 8 sites were dominated by riparian habitat. Therefore abundance estimates for riparian bird species in this project are not likely to reflect expected abundances for these species in riparian dominated habitats. Previously however, extensive bird surveys were conducted in riparian dominated habitat in the Lake Tahoe basin; Manley and Schlesinger (2001) conducted bird point counts along 80 riparian reaches in the Lake Tahoe basin. Comparing abundances from this previous study to PRBO targets would provide valuable information regarding the existing condition of riparian bird communities relative to elsewhere in the Sierra Nevada. This demonstrates the importance of and need for establishing a portion of these riparian sampling locations into a future long-term monitoring program if monitoring riparian bird communities is of interest.

Table A-3. Comparison of average bird abundances per site between recommended targets for pine or lodgepole and riparian habitats in the Sierra bio-region (CalPIF 2002, RHJV 2004), and those generated from bird point count surveys associated with the Multi Species Inventory and Monitoring (MSIM) project, 2002-2005. Bolded values represent the greater abundance value of the two, either the target or estimates from MSIM surveys.

Species Name	Focal Species Type[1]	Abundance target[2]	MSIM Ave. Abundance
Brown Creeper	Conifer Forest	0.1	**0.54**
Dark-eyed Junco	Conifer Forest	0.33	**0.91**
Fox Sparrow	Conifer Forest	0.13	**0.69**
MacGillivray's Warbler	Conifer Forest	0.08	**0.57**
Western Tanager	Conifer Forest	0.24	**0.54**
Warbling Vireo	Riparian	**1.2**	n/a
Tree Swallow	Riparian	0.2	n/a
Swainson's Thrush	Riparian	0.04	n/a
Yellow Warbler	Riparian	**2.5**	n/a
Black-headed Grosbeak	Riparian	0.17	n/a
Song Sparrow	Riparian	**1.2**	n/a

[1] Focal species as determined by the Draft Coniferous Forest Bird Conservation Plan (CalPIF 2002), and the Riparian Bird Conservation Plan (RHJV 2004).

[2] Bird abundance targets are reproduced here from Table 5-1 in CalPIF (2002), and Table 6-1 in RHJV (2004), and represent maximum values observed from point count sampling in the Sierra bio-region within creekside coniferous-riparian habitat types (primarily based on Jeffrey pine and lodgepole pine inclusions).

Bird distributions in the Lake Tahoe basin

Distribution by watershed

Total avian richness per sub-watershed (i.e., Hydologic Unit Category 6 watersheds) ranged from 58-91 species at forestwide sites and from 41-93 at lentic sites. Total richness was highest in the southernmost Upper Truckee River sub-watershed at both forestwide and lentic sites (Appendix A-2), although this watershed also had the greatest number of sampling locations. Total richness per site (total richness/# sites sampled) was greatest at both lentic and forestwide monitoring sites in the Lake Tahoe East Shore-North and Stateline Point-Third Creek-Incline Creek subwatershed (Appendix A-2).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was higher overall for birds sampled at lentic aquatic sites (2.4-5.0) than at forestwide terrestrial sites (1.8-3.2) (Appendix A-2). For both lentic and terrestrial bird sampling, the Upper Truckee subwatershed had the greatest beta diversity for birds.

Mean bird species richness per site varied throughout the Lake Tahoe basin (Appendix A-2, Figure A-1). On average 32 (s.d. = 6.2) species were detected per site at forest wide monitoring sites, and 19 (s.d. = 8.2) species per site at lentic monitoring sites. For both forestwide and lentic sites, mean avian richness per site was highest in the Lake Tahoe East Shore-North and the Ward Creek-Blackwood Creek-Eagle Rock Frontal sub-watersheds, and lowest in Upper Truckee River- Trout Creek sub-watershed (Appendix A-2, Figure A-1).

Individual species varied greatly, however, with regard to their distributions throughout the sub-watersheds of LTBMU according to point count surveys. Sixty-three (47%) birds were broadly distributed across 7 or more sub-watersheds in the Tahoe basin, 37 (28%) were moderately distributed (3-6 sub-watersheds), and 34 (25%) had the most restricted distributions in 2 or fewer sub-watersheds.

Of species broadly distributed throughout the Tahoe basin, 47 bird and one mammal (Douglas' squirrel) species were observed in all nine sub-watersheds of the Lake Tahoe basin (Appendix A-2). Notable among those species distributed across all watersheds were the Brown-headed Cowbird (invasive species, proposed species of interest) and the Blue Grouse (MIS species). Additional distributional patterns for individual species are shown in Appendix A-2.

Thirty-three species were restricted to only a single sub-watershed and were primarily open water species primarily associated with Lake Tahoe itself (e.g., dabbling ducks, grebes, gulls and a few others; Appendix A-2) which was primarily outside the scope of this sampling effort.

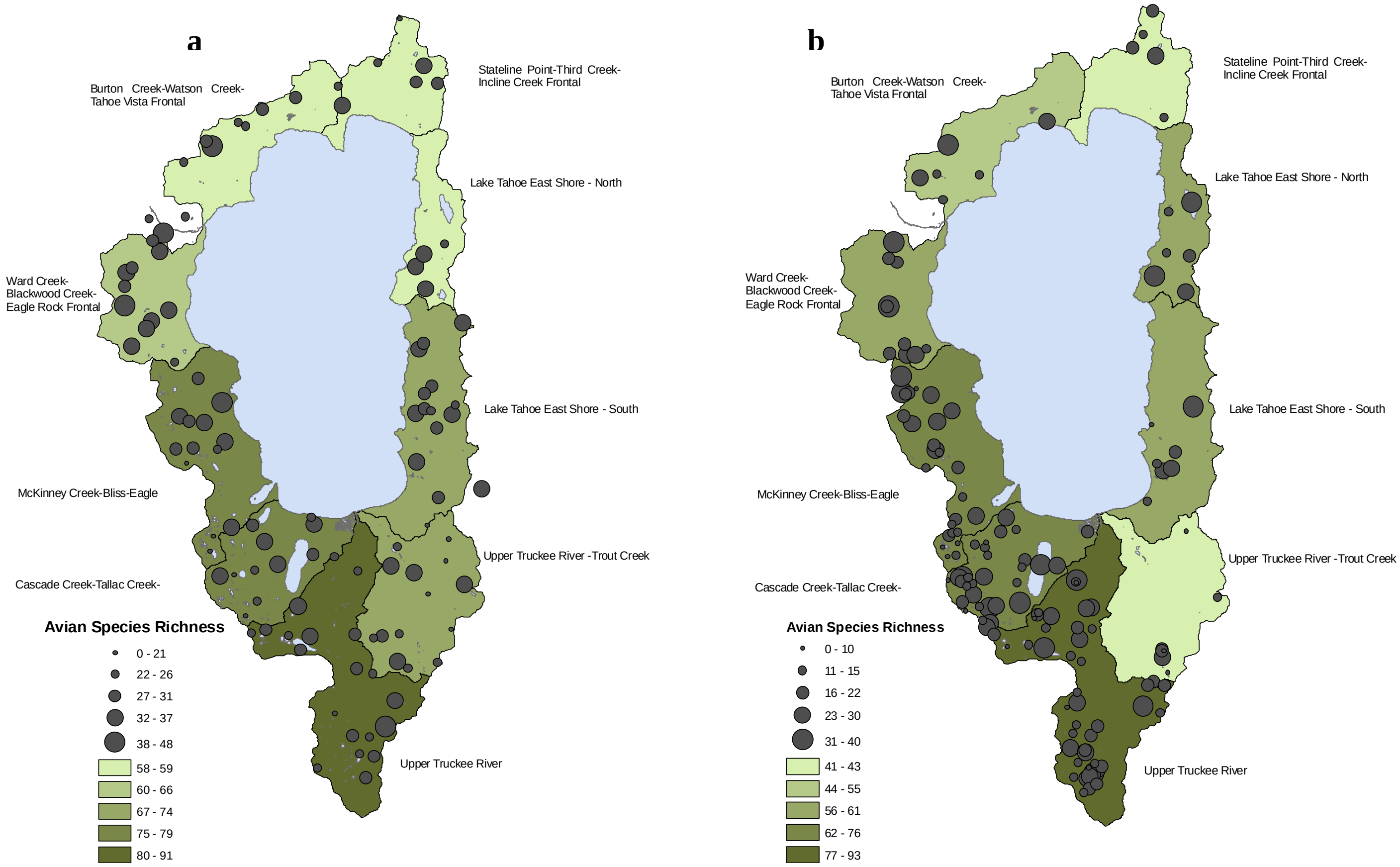

Figure A-1. Mean avian richness per forestwide monitoring site (a) and per lentic monitoring site (b) within each of 9 sub-watersheds (HUC level 6) within the Lake Tahoe basin. Dot size reflects relative avian richness values per site. Shade of green indicates total species richness values across sites within each sub-watershed.

Point count protocol effectiveness

The 134 bird species detected in point count surveys constituted 62% of the 217 avian species listed as currently occurring in the Lake Tahoe basin according to a recent watershed wide assessment (Murphy and Knopp 2000). Most species that were missed in this survey effort were not expected to be detected with MSIM surveys, however, because they are either associated with specialized habitats that were not surveyed, require specific survey methodologies not employed in this survey effort, or their primary or core elevational/geographical range does not include the Lake Tahoe basin. For example, 48 missed species were open-water, marsh associated or shorebird species that are likely restricted in distribution to Lake Tahoe and it's shoreline or the very few marshes within Lake Tahoe's shorezone, habitats that were not well represented in the MSIM sampling effort and hence not expected. Seven species were owls which are best detected with nocturnal broadcast calling techniques, not point counts. For an additional 11-25 species, the Tahoe basin is largely outside either the year round or summer elevational/geographical range of the species (e.g, Pinyon Jay, American Crow, Tri-colored Blackbird, California Quail, etc). When adjusted for the above mentioned sampling biases, the MSIM bird survey protocol was in fact highly effective at detecting the 137-151 songbird species expected within the habitats sampled; 89-98% of expected species were detected.

In order for a future basin-wide monitoring program to represent the entire bird community occurring in the Tahoe basin, we recommend allocating additional monitoring sites to underrepresented habitat types of interest (e.g., marshes, riparian habitats, etc) as well as the addition of diurnal and nocturnal broadcast calling methods for the increased detection of accipiters and owls, representing key top predators in the bird community.

Detectability

Of all 134 bird species detected at lentic and forestwide sites, 48 were detected frequently enough to calculate reliable detection probability estimates (see Data Analysis section). Our dataset was not sufficient for evaluating detectability of the remaining 86 species. Of the 48 species with reliable estimates, 35 had high detection probabilities ($Pd \geq 0.8$; 80% chance of detecting the species when present at a given site) and 9 had moderate detection probabilities ($0.5 < Pd < 0.8$; 50-80% chance of being detected when present). Three of the species with high detection probabilities (Lincoln's Sparrow, Mallard and Brewer's Blackbird) had high detectability at lentic sites only, the remaining species had high detectability at forestwide sites only. An additional 4 species also had high detection probability estimates, however, estimates were based on 10-20 sites with detections; these species are likely to also have high detectability with point counts (Red-winged Blackbird, Rock Wren, Song Sparrow and Winter Wren).

In total, 39 species (29%) were sampled with high detectability using point count survey methods (Table A-4). These 39 species represent the suite of birds for which point count protocols will be most effective at monitoring in conifer and small wetland habitats of the Tahoe basin.

These 39 species with high detectability additionally represented a variety of ecological niches (i.e., subgroups) based on different life history traits and functional characteristics (Table A-4), and would be appropriate to include as focal species in a monitoring program aimed at indicating ecosystem biodiversity and health of forest ecosystems in the Tahoe basin.

Within the nesting substrate subgroups, cavity nesters were most often detected effectively (~50% of species with high detection probabilities) and shrub nesters least often effectively (~30%) (Table A-4). Of the foraging substrate subgroups, bark and ground foragers were most often detected effectively (~50%) and air foragers least often (21%). Within the diet subgroups, omnivores and insectivores contained the greatest proportion of species with high detection probabilities (~45%) whereas granivores and nectivores contained the least (~30%). Habitat specialists, moderate specialists and habitat generalists were each detected with similar effectiveness (~40% of species with high detectability), and of remaining subgroups, development tolerant and intolerant species were most often detected effectively (~70-80%), and exotic and rare species least often (0-12%).

Additionally, nearly all 39 species have been identified as important "focal" species associated with habitats determined to be the most threatened and highest priority for conservation of bird communities in California (Table A-4): riparian, conifer forest, Sierra Nevada meadows and Sierra Nevada old growth habitats (CalPIF 2002, RHJV 2004, Siegel and DeSante 1999).

Table A-4. Ecological subgroup representation and California Partners in Flight (CalPIF) focal species habitat associations of bird species with high detection probabilities (Pd= 0.8; 80% chance of being detected when present at a site) based on the MSIM point count sampling protocol, with the exception of the Mallard which was not evaluated here.

		Ecological Subgroup[1]																					
		Nest substrate					Foraging substrate				Diet				Habitat specialization			Other					
Species Name	CalPIF Focal Species Habitat[6]	Ground nester[3]	Shrub nester[3]	Canopy nester	Primary Cavity nester	Secondary cavity nester	Ground forager	Bark forager	Foliage forager[3]	Air forager	Granivore	Nectarivore	Omnivore	Invertivore[3]	Habitat specialist[3]	Moderate specialist	Generalist	Development Intolerant[3]	Development Tolerant[4]	Corvids	Malentity[2]	Exotic	Rare[3]
American robin	M			√			√									√							
Brewer's blackbird				√			√						√			√			√				
Brown creeper	C, OG					√		√						√	√			√					
Brown-headed cowbird							√						√			√			√		√		
Cassin's finch	C, M, OG			√			√				√				√			√					
Clark's nutcracker	C			√					√				√		√					√	√		√
Dark-eyed junco	C, M	√					√			√			√				√	√					
Dusky flycatcher	M		√											√		√		√					
Evening grosbeak	OG			√			√				√					√							
Fox sparrow	C	√					√						√			√							
Golden-crowned kinglet	C, OG	√		√					√					√	√			√					
Green-tailed towhee			√				√						√		√			√					
Hairy woodpecker	OG				√			√						√		√		√					
Hermit thrush	OG	√					√							√		√		√					
MacGillivray's warbler	C, M		√						√					√	√			√					
Mountain chickadee						√			√					√		√			√				
Mourning dove				√			√				√					√			√				
Nashville warbler	M	√							√					√		√		√					
Northern flicker					√		√							√			√		√				
Olive-sided flycatcher	C, OG			√						√				√	√			√					
Pygmy nuthatch	OG					√		√						√	√				√				
Red-breasted nuthatch	C, OG					√		√						√	√								
Rufous hummingbird				√					√			√				√							

Species Name	CalPIF Focal Species Habitat[6]	Ecological Subgroup[1]: Nest substrate: Ground nester[3]	Shrub nester[3]	Canopy nester	Primary Cavity nester	Secondary cavity nester	Foraging substrate: Ground forager	Bark forager	Foliage forager[3]	Air forager	Diet: Granivore	Nectarivore	Omnivore	Invertivore[3]	Habitat specialization: Habitat specialist[3]	Moderate specialist	Generalist	Other: Development Intolerant[3]	Development Tolerant[4]	Corvids	Malentity[2]	Exotic	Rare[3]
Steller's jay	C, OG			√			√						√			√			√	√	√		
Townsend's solitaire		√								√				√	√			√					
Warbling vireo	R, M			√					√					√		√		√					
Western tanager	C			√					√					√		√		√					
Western wood-pewee				√						√				√		√							
White-breasted nuthatch	OG					√		√						√		√		√					
White-headed woodpecker	OG				√			√					√		√				√				
Williamson's sapsucker	OG				√			√						√	√								
Wilson's warbler	R, M	√							√					√		√		√					
Yellow-rumped warbler	C			√					√					√			√	√					
Lincoln's sparrow	M	√					√						√		√			√					√
Red-winged blackbird[5]	M	√					√						√		√								
Rock wren[5]		√					√							√	√								√
Song sparrow[5]	R, M	√					√						√		√								
Winter wren[5]	OG					√	√							√	√								√
Total # species in subgroup		25	9	39	7	11	40	11	28	19	10	3	24	56	49	43	8	27	10	5	6	3	33
Species with high detectability (#)		11	3	14	4	6	17	7	10	4	3	1	11	22	17	18	3	18	8	2	3	0	4
Species with high detectability (%)		44	33	36	57	55	43	64	36	21	30	33	46	39	35	42	38	67	80	40	50	0	12

[1] Ecological subgroups are defined in Manley and McIntyre (2006)

[2] Malentity species include species that cause harm to other breeding birds, such as by robbing other birds' nests, brood parasitism, etc.

[3] Ecological subgroups proposed for inclusion in index of biological integrity for terrestrial ecosystems as a species richness metric (Manley and McIntyre 2006).

[4] Ecological subgroups proposed for inclusion in index of biological integrity for terrestrial ecosystems as a relative abundance metric (Manley and McIntyre 2006).

[5] Species likely to have high detection probabilities, despite estimates being based on less than 20 sites, minimum we felt indicated reliable estimates.

[6] Focal species for the following habitat types: C = conifer forest, M = Sierra Nevada meadows, OG = Sierra Nevada old growth and R = riparian, as defined by California Partners in Flight and the Point Reyes Bird Observatory (CalPIF 2002, RHJV 2004, Siegel and DeSante 1999).

Only 4 (10%) special status species were detected with high detection probabilities: Mallard (MIS), Brown-headed Cowbird (SOI), Lincoln's Sparrow (SOI) and White-headed Woodpecker (SOI). No species of concern or Federally Threatened and Endangered species were detected with high probability by point counts in this project. Point counts may be a suitable and effective protocol for many of the remaining special status species, but due to the dominance of conifer forest and small lentic habitats sampled in this project, most of these additional species were not sampled effectively because of their association with rare or undersampled habitats. Sampling more intensively in other habitat types (e.g., larger lakes, wetlands, and riparian habitats) will allow us to determine the utility of the bird point count protocol for detecting special status species associated with these other habitat types.

Manley and Schlesinger (2001) used bird point count protocols to sample birds along 80 riparian reaches in the Lake Tahoe basin. Data from their survey efforts should be utilized to identify riparian associated birds with high detection probabilities and that could serve as potential indicators of biological integrity. For example, they detected Yellow Warbler (proposed species of concern) at 21 of 80 riparian reaches, whereas we only detected this species at 7 of 105 forest wide monitoring sites. Hence it is likely that data collected along riparian reaches would have sufficient sample sizes for evaluating species detectability for yellow warbler and a number of additional riparian associated species detected infrequently in MSIM surveys. Similarly, the Tahoe Regional Planning Agency (TRPA) has been conducting waterbird surveys at several marshes along the shores of Lake Tahoe in recent years and a recent inventory of 11 aspen stands in the Lake Tahoe basin has been conducted (Borgmann et al. 2006). We recommend evaluating these 3 additional datasets with regard to species detectability and life history/niche representation in order to identify a list of potential focal species for each habitat type (conifer forest, small wetlands, riparian habitat, marshes and aspen) for a long-term monitoring program. Key features of focal species should include: high detectability with standardized protocol and representation of key structural and functional elements for each habitat type.

Additionally, detection probability estimates for small mammals based on point count sampling indicated that point counts were more reliable for detecting Douglas' squirrel, American pika and yellow-bellied marmots than Sherman live trapping methods. Douglas' squirrel had a higher detection probability with point counts than trapping (0.99 versus 0.75). Detection probabilities for pika, while lower with point counts than Sherman trapping, were much more reliable with point counts (Pd = 0.66, based on sample size of 21) than with Sherman live trapping (Pd= 0.92, based on sample size of 2). Finally, yellow-bellied marmots were only detected with point counts, and not in trapping surveys (small trap size precluded their capture), but were detected too infrequently to estimate detection probability. This additionally supports our earlier recommendation that point counts be used as the primary sampling protocol for this species when their site occupancy is a metric of interest.

Population Status

Estimated site occupancy is the proportion of sites estimated to be occupied by a given species. It is based on the number of sites at which the species was detected and the estimated detection probability of the respective species. By estimating site occupancy, we are accounting for the fact that species are occasionally not detected at a site even when they are present due to factors such as weather, species characteristics (sing/call frequently or intensity), surveyor experience, habitat complexity, etc. Therefore, estimating site occupancy improves accuracy and is a less biased measure of an individual species status as compared to the observed site occupancy alone. However, site occupancy estimates are only reliable indicators of population status when based upon detection probabilities that are both reliable (based on ~ 20 or more sites with detections) and sufficiently high (Pd $\geq$ ~ 0.80). Consequently, of the 134 bird species detected in this effort, we found 39 bird species and the Douglas' squirrel had site occupancy estimates that reliably reflected their current "true" occupancy status. For the 39 bird species, estimated site occupancy rates were on average 8% (s.d. = 6.2%, range = 0-24%) greater than observed values. Estimated occupancy rates for these species ranged from 13 – 100% (Appendix A-3).

It is recommended that the occupancy rates estimated in this sampling effort be used as a baseline reference for future monitoring of the 39 above mentioned species. Additionally, these estimates only apply to the habitat types for which the estimates were based; for the 35 forest associated species (and the Douglas' squirrel) estimates apply to status of these species in forested habitats of the Tahoe basin, where as for the 4 lentic aquatic associated species, occupancy estimates only apply to their population status at lentic sites in the Tahoe basin.

For the remaining species for which we were unable to make reliable estimates for site occupancy, we suggest either not including them as focal species or indicators of ecosystem health in a long-term monitoring program, or evaluating whether these species are likely to be effectively sampled in habitats not well represented in this survey effort (e.g., aspen, riparian habitats, marshes, etc).

Population change and sampling adequacy

Site Occupancy

For this dataset, sampling adequacy was defined as the ability to detect a decrease in site occupancy by 20% with a specified level (80%) of confidence and power (confidence = the level of certainty a decline actually occurred; power = level of certainty that a decrease wasn't missed). Based on our sampling adequacy analysis we found that at forestwide monitoring sites site occupancy rates of $\geq$ 65% were required to adequately detect a 20% decrease in site occupancy with 80% certainty. Alternatively, at lentic monitoring sites, we found that slightly lower initial site occupancy rates of $\geq$ 55% were necessary to adequately detect the same decrease with 80% certainty, due primarily to the greater number of lentic monitoring sites sampled (148 sites) compared to forestwide sites (105 sites).

In total, 25 bird species and the Douglas' squirrel were sampled adequately to a 20% decrease in estimated site occupancy over time (Table A-5). This included only 2 special status species (Brown-headed Cowbird and White-headed Woodpecker), but did include several focal species identified for the Sierra Nevada bio-region (Siegel and DeSante 1999), and a variety ecological subgroups recently proposed for inclusion as metrics in a terrestrial bird index of biological integrity for the Tahoe basin (Manley and McIntyre 2006).

Table A-5. Sampling adequacy of the MSIM project for detecting decreases in site occupancy of bird and mammal species detected with point counts in Lake Tahoe, 2002 to 2005. Minimum sample size requirements for detecting a 20% decrease (N_{min} dec) in estimated site occupancy (Psi) with 80% certainty (i.e., confidence and power) are shown. Species sampled adequately were those for which minimum sample size requirements for detecting a decrease (N_{min} dec) were less than the number of sites sampled in the MSIM project (105 and 148 sites for forestwide and lentic datasets respectively). Shaded cells indicate species evaluated based upon the lentic monitoring dataset. All other results are based on forestwide monitoring dataset.

					Ecological Sub-group[3]							
Common Name	**Status[1]**	**Cal PIF Focal Species[2]**	**Psi (%)**	**Nmin dec**	**Development Tolerant**	**Development Intolerant**	**Shrub nester**	**Foliage forager**	**Habitat specialist**	**Ground nester**	**Invertivore**	**Rare**
Sampled adequately												
American Robin		M*	97.6	24								
Brown Creeper		OG*	86.2	46		√			√		√	
Brown-headed Cowbird	SOI		66.1	96	√							
Cassin's Finch		OG*	91.8	37		√			√			
Clark's Nutcracker			73.1	68				√	√			√
Dark-eyed Junco		M	100.0	24		√				√		
Douglas' squirrel			96.1	29								
Dusky Flycatcher		M	91.3	37		√	√				√	
Fox Sparrow			86.3	46						√		
Golden-crowned Kinglet		OG	71.7	81		√		√	√	√	√	
Hairy Woodpecker		OG	93.7	29		√					√	
Macgillivray's Warbler		M*, R*	71.7	81		√	√	√	√		√	
Mountain Chickadee			100.0	24	√			√			√	

Common Name	Status[1]	Cal PIF Focal Species[2]	Psi (%)	Nmin dec	Ecological Sub-group[3] Development Tolerant	Development Intolerant	Shrub nester	Foliage forager	Habitat specialist	Ground nester	Invertivore	Rare
Nashville Warbler		M*	70.6	81		√		√		√	√	
Northern Flicker			97.7	24	√						√	
Olive-sided Flycatcher		OG	78.1	56		√			√		√	
Red-breasted Nuthatch		OG*	94.9	29					√		√	
Steller's Jay		OG	96.5	29	√							
Townsend's Solitaire			82.3	56		√			√	√	√	
Warbling Vireo		M, R*	76.5	68		√		√			√	
Western Tanager			84.4	46		√		√			√	
Western Wood-pewee			76.0	68							√	
White-breasted Nuthatch		OG	91.1	37		√					√	
White-headed Woodpecker	SOI	OG*	62.6	96	√				√			
Williamson's Sapsucker		OG	69.6	81					√		√	
Yellow-rumped Warbler			99.1	24		√		√			√	
Not sampled adequately												
Brewer's Blackbird			32.4	380	√							
Evening Grosbeak		OG*	52.4	159								
Green-tailed Towhee			57.3	134		√	√		√			
Hermit Thrush		OG	60.4	114		√				√	√	
Lincoln's Sparrow[4]	SOI	M*	37.3	301		√			√	√		√
Mallard	MIS		46.3	196								
Mourning Dove			45.6	196	√							
Pygmy Nuthatch		OG*	52.3	159	√				√		√	
Red-winged Blackbird[4]		M	12.7	933					√	√		
Rock Wren[4]			12.7	933					√	√	√	√
Rufous Hummingbird			39.5	242				√				
Song Sparrow[4]		M*, R*	22.7	491					√	√		
Wilson's Warbler		M*, R*	61.7	114		√		√		√	√	
Winter Wren[4]		R*	16.6	933					√		√	√

1 Status includes species that are currently listed as MIS (Management Indicator Species), FSS (Forest Service Sensitive species), or proposed for consideration as species of concern (SOC) or species of public interest (SOI) for forest plan revision.

2 Focal species assigned according to the Sierra Nevada Avian Conservation Plan (Siegel and DeSante 1999). Species have at least part of their life cycle dependent upon the respective habitat type; OG = old growth, M = meadow and R = riparian.

3 Ecological subgroups proposed for inclusion in index of biological integrity for terrestrial ecosystems (Manley and McIntyre 2006).

4 Species considered to have high detection probability and reliable estimates of site occupancy (Psi), despite sample size (N) and/or detection probabilities (Pd) being less than arbitrarily defined minimums; N > 20 and Pd > 0.80. Values for these species nearly met minimum values.

* Focal species that criticaly depend on respective habitat type for a portion of their life cycle according to Siegel and DeSante (1999)

Abundance

Of all 134 birds detected, 32 species were detected at ≥ 20 sites and were sufficient to detect 20% decrease in abundance per site with 80% certainty, 5 of which were unique to lentic survey sites and 13 unique to forestwide sites. Only 2 special status species were sufficiently sampled in order to detect a 20% decrease in abundance: Blue Grouse and Brown-headed Cowbird (Table A-6). However, point count surveys conducted at forestwide and lentic sites throughout LTBMU are only effective at detecting approximately 27 of the 42 special status bird species, excluding species such as birds of prey (e.g., Peregrine Falcon, California Spotted Owl, Northern Goshawk, etc) and waterbirds highly associated with marshes or Lake Tahoe itself (e.g., terns, grebes, herons, etc).

Table A-6. Bird species determined to be adequately sampled to detect a 20% decrease in relative abundance with 80% certainty (i.e., confidence and power) at lentic and forestwide monitoring sites.

	Status[1]	Cal PIF Focal Species[2]	Mean Abundance	Abundance s.d.	Nmin dec	Sites with detections (#)
Lentic Network						
American Robin		M*	1.89	1.73	61	117
Brown Creeper		OG*	1.02	0.98	71	75
Brown-headed Cowbird	SOI		1.36	0.97	39	40
Clark's Nutcracker			2.19	1.97	59	74
Dark-eyed Junco		M	2.80	2.60	64	126
Hairy Woodpecker		OG	0.66	0.47	40	45
House Wren		M*, R*	0.65	0.45	36	44
Macgillivray's Warbler		M*, R*	0.92	0.75	52	52
Mountain Chickadee			3.46	3.15	62	138
Northern Flicker			1.13	0.99	55	82
Olive-sided Flycatcher		OG	1.25	0.95	43	75
Pine Siskin			1.09	0.85	45	53
Red-breasted Nuthatch		OG*	1.97	1.28	33	104
Song Sparrow		M*, R*	1.60	1.05	33	35
Steller's Jay		OG	2.51	2.42	69	129
Townsend's Solitaire			0.83	0.61	39	50
Warbling Vireo		M, R*	1.27	0.95	43	53
Western Wood-pewee			2.10	1.58	43	104
White-breasted Nuthatch		OG	1.19	1.02	54	62
Wilson's Warbler		M*, R*	0.80	0.50	30	53
Yellow-rumped Warbler			1.69	1.60	65	92
Forestwide Network						
American Robin		M*	4.67	3.06	34	105
Band-tailed Pigeon		OG	0.77	0.47	34	42
Blue Grouse	MIS	OG	0.78	0.52	30	32
Brown Creeper		OG*	2.68	1.93	39	88
Common Raven			0.59	0.38	34	37

	Status[1]	Cal PIF Focal Species[2]	Mean Abundance	Abundance s.d.	Nmin dec	Sites with detections (#)
Dark-eyed Junco		M	10.80	5.34	20	105
Downy Woodpecker		R*	0.69	0.29	16	21
Dusky Flycatcher		M	4.38	3.64	51	94
Fox Sparrow			6.80	5.72	53	91
Golden-crowned Kinglet		OG	2.78	2.72	68	70
Hairy Woodpecker		OG	1.09	0.92	50	75
Hermit Thrush		OG	2.07	1.82	57	68
Macgillivray's Warbler		M*, R*	2.08	2.03	67	67
Mountain Chickadee			11.14	3.99	12	105
Nashville Warbler		M*	2.41	2.21	62	63
Northern Flicker			1.41	1.20	53	92
Olive-sided Flycatcher		OG	2.16	1.90	58	87
Pine Siskin			1.68	1.42	53	88
Red-breasted Nuthatch		OG*	5.48	3.67	34	100
Red-breasted Sapsucker		M*, OG	0.88	0.58	32	32
Steller's Jay		OG	6.90	4.64	34	104
Townsend's Solitaire			1.69	1.15	35	85
Western Tanager			4.24	3.07	40	90
Western Wood-pewee			3.18	2.85	59	83
White-breasted Nuthatch		OG	2.26	1.83	49	87
Wilson's Warbler		M*, R*	1.66	1.30	46	51
Yellow-rumped Warbler			6.32	3.67	27	104

1 Special interest species are species that are currently listed as MIS (Management Indicator Species), FSS (Forest Service Sensitive species), or proposed for consideration as species of concern (SOC) or species of public interest (SOI) in the forest plan revision process.

2 Focal species assigned according to the Sierra Nevada Avian Conservation Plan (Siegel and DeSante 1999). Species have at least part of their life cycle dependent upon the respective habitat type; OG = old growth, M = meadow and R = riparian.

* Focal species that criticaly depend on respective habitat type for a portion of their life cycle according to Siegel and DeSante (1999).

In summary, a greater number of species were sampled adequately to detect decreases in abundance than in site occupancy. A total of 22 birds were sampled adequately to detect at least a 20% decrease in both site occupancy and relative abundance over time. An additional 3 species were sampled adequately to detect a 20% decrease in site occupancy but not abundance: Cassin's Finch, White-headed Woodpecker and Williamson's sapsucker, whereas an additional 12 species were sampled adequately to detect a 20% decrease in relative abundance but not site occupancy: Band-tailed Pigeon, Blue Grouse, Common Raven, Downey Woodpecker, Hermit Thrush, House Wren, Pine Siskin, Red-breasted Sapsucker, Song Sparrow and Wilson's Warbler.

Species sampled adequately to detect significant changes in both site occupancy and abundance should be considered for inclusion as focal species for a long-term monitoring program aimed at monitoring biological diversity within the Tahoe basin.

B. Small mammal trapping

During the three years of trapping surveys at the 105 monitoring sites there were a total of 60,665 trap opportunities with 17,264 captures. However, 3,547 (5.8%) trap opportunities were unavailable for animal captures due to trap disfunctions. Adjusting for this, average trap success over all three years was 31%.

Species detections, site occupancy and abundance

Detections

Twenty-six small mammal species were captured during Sherman live trapping surveys, with an average of 6 species (s.d. = 1.6) detected per site (Appendix B-1).

One additional species not previously documented as occurring in the Tahoe basin (Murphy and Knopp 2000), the Great Basin pocket mouse, was captured at two different locations (1 individual per site) during MSIM surveys; one in the upper reaches of the Upper Truckee river watershed and the other in Blackwood canyon. While the Lake Tahoe basin is outside of the previously recognized geographic range for the Great Basin pocket mouse, suitable habitat does exist for this species, and more extensive populations exist to the southeast of the Tahoe basin. Detections of this species with MSIM surveys mark the first documented occurrence for the Tahoe basin. Based on these 2 detections and an additional detection of this species during a similar trapping effort in 2001 (also in the Upper Truckee river watershed), we conclude that the Great basin pocket mouse currently occurs in the Lake Tahoe basin.

No small mammals are currently listed as management indicator species (MIS) or Forest Service sensitive species (FSS). However the Trowbridge's shrew, a proposed species of concern (SOC) in the current land management plan revision process (Pathway 2007), was detected with Sherman trapping surveys at 12 of 105 sites. It is likely this species exists at a greater number of sites in the Tahoe basin given that the detection probabilitiy for this species with this method was low (Pd = 0.42). Shrews are generally detected with greater success using pitfall trapping methods (see results under Pitfall traps and coverboards below), in which we detected this species at 44% of sites, however these alternative methods often result in high rates of mortality and were not implemented at all 105 sites (Karraker 2001).

An additionally proposed species of concern, the mountain beaver, was not detected in the current survey effort. This species was, however, detected with Tomahawk live-traps in the Showers lake area as part of a similar inventory and monitoring effort during 2001 (Manley et al. 2002). No other small mammals (excluding bats) are currently being considered as special status species.

Site Occupancy

Deer mouse was the only small mammal to be captured at all 105 forestwide sites (Appendix B-1). The Douglas' squirrel however, while only captured at 26% of sites with Sherman traps, is a highly vocal species and was detected at 100 sites (95%) with forestwide bird point counts (see forestwide and lentic bird point count results above), making this species the second most frequently occurring species. Deer mice are important prey of the California Spotted Owl, a FSS and proposed Pathway 2007 species of concern. Douglas' squirrels are important prey for the Northern goshawk, which is currently a MIS, FSS species and a proposed Pathway 2007 species of concern.

Five additional small mammals were detected at over 50% of all sites: golden-mantled ground squirrel, yellow-pine chipmunk, lodgepole chipmunk, shadow chipmunk and the long-eared chipmunk. These 5 species are also important food sources to birds of prey and chipmunks are important pine seed dispersers. Three additional species were detected at between 20 and 50% of sites: California ground squirrel, long-tailed vole, and American pika. American pika is also a very vocal species, detected at only 2 sites with with Sherman trapping and much more frequently, at 21 sites (20%), with bird point counts.

The remaining 17 species were detected at fewer than 20% of the 105 sites. Notable detections among these species include those of the bushy tailed woodrat and the northern flying squirrel, detected at 13 and 17 sites, respectively. Both species are important prey of California Spotted Owls in the Sierra Nevada.

When compared to historical records for small mammal species in the Tahoe region (Orr 1949), we found that 3 species demonstrated decreased frequency of occurrence in recent MSIM surveys: long-tailed weasel, bushy-tailed woodrat and yellow-bellied marmot. The yellow-bellied marmot, however, may not have been sampled effectively in MSIM surveys for this to be a valid comparison. Small mammal surveys used traps that were too small to capture adult marmots; and while bird point count surveys detected this species most frequently, bird surveys were conducted during the early morning hours, when marmots are likely not as active. Only the occurrence of Trowbridge's shrew (based on pitfall trap sampling) appeared to increase since the mid 1900s; recorded as rare historically (Orr 1949) and detected at >40% of sites sampled with pitfall traps. Recent surveys in riparian habitats of the Tahoe basin (Manley and Schlesinger 2001) also demonstrated a high occurrence of Trowbridge's shrew in the Tahoe basin; ~52% of riparian reaches were occupied by this species. This apparent increase, however, may be an artifact of the elusive nature of most shrews, species which often require intensive pitfall trap sampling in order to detect effectively.

Abundance

Overall, total small mammal capture rates (including recaptures) averaged 30 (s.d. = 14.4) captures per site per 100 trap nights (equivalent to 100 traps set for one night or 50 traps set for 2 nights, etc). When only considering unique individuals, capture rates were 19 (s.d. = 9.3) captures per site per 100 trap nights.

The most abundant small mammals were the same species detected at the greatest proportion of sites, the deer mouse, the four dominant species of chipmunk and ground squirrels. These species averaged 4-43 individuals per site, the most abundant being the deer mouse, followed by the yellow-pine chipmunk (24 individuals per site), lodgepole chipmunk (20 individuals per site), the golden-mantled ground squirrel (12 individuals per site) and the other species at 11 individuals or less per site (Appendix B-1).

Both woodrat species (bushy-tailed and desert woodrats), both vole species (montane vole and long-tailed vole), the western jumping mouse and American pika had a mean of 2-4 individuals detected at sites with each respective species. The remaining species were detected with fewer than 2 individuals per site on average.

Small mammal distributions in the Lake Tahoe basin

Total small mammal species richness varied from 14-20 species per sub-watershed in the Tahoe basin (Appendix B-2). Species richness was generally greater in sub-watersheds with largest area and greater sampling intensity, with sub-watersheds in the southern half of the Tahoe basin having the greatest total species richness; Cascade Creek-Tallac Creek-Taylor Creek Frontal and the Upper Truckee River sub-watersheds. However, the Cascade Creek-Tallac Creek-Taylor Creek Frontal sub-watershed had the highest richness with moderate sampling intensity (12 sites), and the McKinney Creek-Bliss-Eagle Creek Frontal sub-watershed had a similarly moderate sample size (13 sites), albeit 5 fewer small mammal species detected. Total species richness per site (total richness/# sites sampled) was greatest in the Lake Tahoe-East Shore Frontal/North Half subwatershed (Appendix B-2).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was highest for small mammals in the Upper Truckee-Trout subwatershed (Appendix B-2).

Mean species richness per site varied from 6.0 to 8.3 across all sub-watersheds (Appendix B-2; and also see Figure B-1). Mean site richness was highest in Cascade Creek-Tallac Creek-Taylor Creek Frontal and Stateline Point-Third Creek-Incline Creek Frontal sub-watersheds, and lowest in Upper Truckee River - Trout Creek and Ward Creek-Blackwood Creek-Eagle Rock Frontal.

Similarly mean small mammal abundances per site (all species combined) were highest in the Cascade Creek and Burton Creek sub-watersheds, with an average of 21 (s.d. = 9.8) and 24 (s.d. = 8.5) individuals captured per site, respectively (Appendix B-2).

Individual species varied with regard to their distributions throughout the sub-watersheds of LTBMU according to Sherman trapping surveys. Nine (33%) small mammals were broadly distributed across 7 or more sub-watersheds in the Tahoe basin, all of which were captured in all 9 sub-watersheds. Species captured in all sub-watersheds included: the deer mouse, Douglas' squirrel (based on bird point count surveys), California and golden-mantled ground squirrels, all chipmunk species, except the least chipmunk, and the long-tailed vole (Appendix B-2). Thirteen (48%) were moderately distributed throughout the basin (in 3-6 sub-watersheds), and 5 (19%) had the most restricted distributions in 2 or fewer sub-watersheds.

Species with moderate distributions (3-6 sub-watersheds) included the most diverse array of life history traits, including shrews, woodrats, long-tailed and short-tailed weasels, northern flying squirrel, western jumping mouse, the America pika and yellow-bellied marmot (based on bird point counts) and others (Appendix B-2). The northern flying squirrel (a food source for the California Spotted Owl) was fairly well distributed throughout all regions of the Tahoe basin, including all 3 watersheds in the southern portion of the basin. Woodrats (another food source for the spotted owl) were present throughout much of the Tahoe basin, with the exception of the western and northern-western 3 sub-watersheds. Despite Sherman trapping not being the most effective means of capture for the Trowbridge's shrew, this species was fairly well distributed throughout most regions of the Tahoe basin with the exception of the 2 eastern sub-watersheds. Additionally, based on detections from bird point counts, pikas were detected in all sub-watersheds except the eastern most 3 at elevations near lake level and above (> 6,700 ft) and yellow-bellied marmots were detected only above 8,000 ft in southern and southwestern sub-watersheds.

The 5 species with restricted distributions (in $\leq$ 2 sub-watersheds) were species either at the edge of their range in the Tahoe basin (Great Basin pocket mouse and least chipmunk) or are not well detected with Sherman traps used in this effort (Nuttall's cottontail, mountain pocket gopher and western gray squirrel).

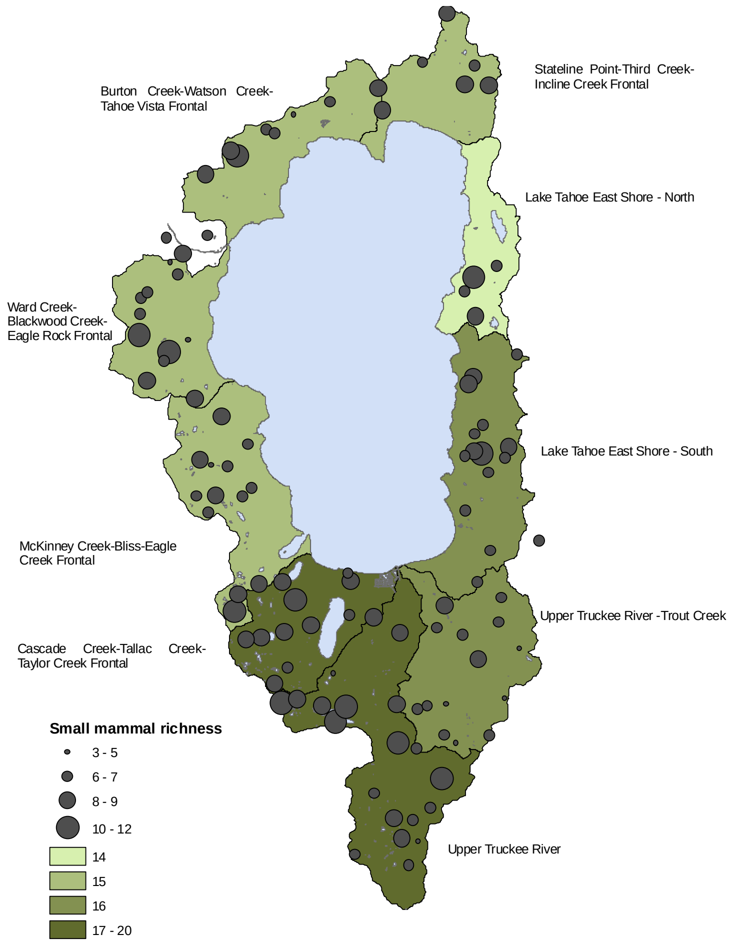

Figure B-1. Mean small mammal richness per site within each of 9 sub-watersheds (HUC 6) within the Lake Tahoe basin. Dot size reflects relative species richness values per site. Shade of green indicates total species richness values across sites within each sub-watershed.

Sherman trapping protocol effectiveness

The 26 species detected with Sherman traps constituted 90% of the 29 small mammals (excluding bats) previously identified as occurring in the basin (Murphy and Knopp 2002). Missed species were the pinyon mouse, broad-footed mole and the water shrew.

Pinyon mice are known to exist at high elevations in the Sierra Nevada and are most abundant in open woodland, rocky areas with brushy thickets (CDFG 2005a). Historic (Orr 1949) and contemporary (Manley and Schlesinger 2001) records exist for this species in the Tahoe basin, primarily in the northern and eastern portions of the Tahoe basin, areas with the least coverage of national forest lands and hence the fewest MSIM sampling locations. The lack of detection of this species with MSIM surveys may be a result of the limited total area of habitat and limited sampling in arid habitats of the northern and eastern portions of the Tahoe basin.

Both the broad-footed mole and water shrew were also recently detected in trapping efforts targeting riparian stream reaches (Manley and Schlesinger 2001); hence they do exist in the Tahoe basin and should have been captured if occupied sites were sampled. Both species are associated with aquatic, riparian and meadow areas. Therefore, their lack of detection in the MSIM sampling effort likely reflects the limited sampling of water associated habitats in this effort; only forestwide monitoring sites were sampled for small mammals and <10 forestwide sites contained portions of riparian/meadow habitat. Small mammal trapping may have been successful at detecting these species if conducted at lentic and riparian sites, although moles are primarily active beneath the surface of the ground (Verts and Carraway 2001), similar to pocket gophers and may be best detected with traps place along sub-surface runways or with pitfall traps. Therefore we recommend sampling small mammals in aquatic associated habitats in addition to conifer forest if the full community of small mammals within the Tahoe basin is to be monitored effectively.

Of thse 26 small mammals detected, 8 (35%) had high detection probabilities (Pd $\geq$ 0.8; species has 80% chance of being detected when present at a given site). These species included the deer mouse, the 4 most common chipmunk species, golden-mantled and California ground squirrels, the long-tailed vole, and the Douglas' squirrel based on detections with point counts (Appendix B-1). It is likely that the bushy-tailed woodrat also has high detectability with MSIM trapping methods, although the species was only detected at 13 sites, below the minimum number of sites (20) arbitrarily set to indicate reliable detectability estimates; the estimated probability of detection for this species was 0.94.

Only one species, the Douglas' squirrel, was estimated to have moderate detection probability with Sherman trapping, however, this species was detected with high detectability with bird point count surveys. The remaining 17 species were detected at fewer than 20 sites and hence detection probabilities considered unreliable and unknown. The northern flying squirrel, however, was likely to have moderate detection probability with Sherman trapping, but was detected at fewer than the minimum of 20 sites that we believe indicates a reliable estimate of detectability (Pd). Since northern flying squirrels were detected at nearly 20 sites (17), it is likely that the detectability estimates were reliable (Pd = 0.58).

Improved detectability of both the bushy-tailed woodrat and northern flying squirrel (important prey for Northern Goshawk and Spotted Owl) may be possible, if desired, based on improved trap placement in future trapping efforts. Trap placement relative to key habitat features has been show to improve trap success, species detectability and site occupancy estimation for both of these species. Flying squirrels are arboreal species, and traps placed high up along the trunk of trees in the eastern U.S. experienced greater trap success of southern flying squirrels (*Glaucomys volans*) than traps placed lower down along trees closer to the ground (Risch and Brady 1996) similar to what was done for the MSIM small mammal trapping protocol. Similarly, a recent trapping effort aimed at comparing small mammal communities before and after fuels treatments in the Tahoe basin (Upland fuels reduction project) also observed greater trap success for northern flying squirrels in traps placed in trees than on the ground surface (Manley pers. comm.). Traps placed in close proximity to woodrat stick piles were approximately 20 times more successful at trapping woodrats than less targeted trap placement (Laudenslayer and Fargo 2002); we did not target woodrat stick piles in this survey effort. Therefore strategic trap placement may be an important feature to consider in the future design of this monitoring protocol to increase the breadth of species for which detection probabilities are sufficiently high.

The Trowbridge's shrew is the only special status species within the small mammal community (proposed Pathway 2007 species of concern), and it was detected with a low probability of detection (Pd = 0.42) with the Sherman live trapping protocol, and was detected at very few sites (12 sites; 11%). While we could not calculate detection probabilities accurately from pitfall sampling due to small sample size for this method, detectability of this species is likely higher with pitfall trapping than Sherman trapping (see Pitfall and Coverboard sampling results below). Trowbridge's shrew was captured at 44% of the 9 sites sampled with pitfalls compared to 11% of the 105 sites sampled with Sherman traps, and pitfall trapping detected this species at 4 additional sites where Sherman trapping did not detect the Trowridge's shrew. Due to the much higher frequency of capture of Trowbridge's shrews in pitfall traps, they are likely to be more effective than Sherman trapping for detecting this species. This recommendation should be considered with caution, however, as pitfall trapping methods are often associated with high small mammal mortality rates; mortality often exceeds 90%. However, Yunger et al (1992) found that placing 7g (~ 1.5 times the body weight of a shrew) of whitefish in pitfall traps nightly and checking traps twice per day reduced mortality of shrews to < 25%. Therefore, if pitfall trapping methods are pursued for monitoring shrews, the methods of Yunger et al (1992) are recommended.

Alternatively, in a previous study on wildlife communities in riparian habitat in the Tahoe basin, Manley and Schlesinger (2001) reported detecting Trowbridge's shrews at 52% of 80 riparian reaches also sampled with Sherman live traps. Therefore, while pitfall trapping appeared more effective at detecting Trowbridge's shrews in this project, it may have been due to different representation of habitats sampled with pitfall traps compared to those sampled with Sherman traps. Therefore, targeting riparian habitats with Sherman traps for the detection of Trowbridge's shrews may also be a sufficient way to monitor this species effectively without the added risk of high mortality from pitfall traps. However, it is recommended that both these methods be tested for effectiveness and shrew mortality rates within the preferred habitats of the Trowbridge's shrew in the Tahoe basin before proceeding with long-term monitoring.

The 10 species with high detectability (including bushy-tailed woodrat), represented a variety of ecological sub-groups based on both life history and functional characteristics (Table B-1). Sub-groups with the fewest species detected with high detectability included rare species and habitat specialists. All remaining sub-groups, except the development tolerant species, had between 33-55% of species with high detection probabilities. For a listing of species in each ecological sub-group, see Appendix 4 in Manley and McIntyre (2006).

Table B-1. Ecological subgroup representation of small mammal species with high detection probabilities (Pd= 0.8; 80% chance of being detected when present at a site) based on the MSIM Sherman trapping surveys.

	Ecological Subgroup[1]										
	Activity Pattern		Vertical Association		Diet		Habitat Specialization		Other		
Species Name	**Nocturnal**	**Diurnal**	**Canopy Associate**	**Ground Associate**	**Omnivore**	**Herbivore**	**Specialist**	**Generalist**	**Development Intolerant**	**Development Tolerant**	**Rare**
California ground squirrel		√		√	√			√		√	
Deer mouse	√			√		√		√	√		
Douglas squirrel		√	√		√		√			√	
Golden-mantled ground squirrel		√		√		√		√			
Lodgepole chipmunk		√		√		√	√		√		
Long-eared chipmunk		√		√		√				√	
Long-tailed vole	√			√		√		√			
Shadow chipmunk		√		√		√		√	√		
Yellow pine chipmunk		√		√		√		√		√	
Bushy-tailed woodrat	√			√	√			√			√
Total # species in subgroup	9	17	3	23	4	17	14	11	6	4	10
Species with high detectability (#)	3	7	1	9	3	7	2	7	3	4	1
Species with high detectability (%)	33	41	33	39	75	41	14	64	50	100	10

[1] Ecological subgroups are defined in Manley and McIntyre (2006)

Population status

Of all small mammal species detected in MSIM trapping efforts, 8 were detected with sufficiently high detection probabilities (Table 1-2) to indicate that site occupancy estimates were reliably measures of population status. For these species, estimated rates of occupancy were on average < 1% (s.d = 0.6%) greater than observed values, and estimated occupancy rates ranged from 30%-100% (Appendix B-1).

Population change and sampling adequacy

Site Occupancy

Not all species for which site occupancy estimates were reliable indicators of population status were sampled adequately for detecting population change (Table B-2). Based on sample size analysis, we found that species with occupancy rates $\geq$ 65% of sites were adequately sampled to detect a 20% decrease in site occupancy with 80% certainty (i.e., confidence and power).

Six species were sampled adequately to detect 20% decrease in estimated site occupancy over time (deer mouse, golden-mantled ground squirrel and the 4 dominant chipmunk species: lodgepole, yellow pine, long-eared and shadow chipmunks; Table B-2), excluding Douglas' squirrel which was sampled adequately to detect decreases with point count survey methods. Additionally due to the absence of extra large traps during surveys in 2002 (at 40 sites), it is likely that some of the larger bodied small mammals (e.g., California ground squirrels, western gray squirrels, northern flying squirrels, etc) were inadequately detected at those 40 sites, potentially contributing to their associated lack of sampling adequacy. During 2004 and 2005, these species were detected more frequently in the extra large Sherman traps than in the slightly smaller extra long Sherman traps.

Table B-2. Sampling adequacy of the MSIM project for detecting decreases in site occupancy of small mammal species detected with Sherman trapping surveys in Lake Tahoe, 2002 to 2005. Minimum sample size requirements for detecting a 20% decrease (N_{min} dec) in estimated site occupancy (Psi) with 80% certainty (i.e., confidence and power) are shown. Species sampled adequately were those for which minimum sample size requirements for detecting a decrease (N_{min} dec) were less than the number of sites surveyed (105 sites).

				Ecological Sub-group[1]				
Species Name	**Psi (%)**	**Pd**	**Nmin dec**	**Ground Associate**	**Herbivore**	**Development Intolerant**	**Development Tolerant**	**Rare**
Sampled adequately								
Deer mouse	100.0	1.00	24	√	√	√		
Golden-mantled ground squirrel	81.0	1.00	56	√	√			
Lodgepole chipmunk	74.3	1.00	68	√	√	√		
Long-eared chipmunk	74.4	1.00	68	√	√		√	
Shadow chipmunk	68.8	1.00	81	√	√	√		
Yellow pine chipmunk	72.4	1.00	81	√	√		√	
Not sampled adequately								
Bushy-tailed woodrat	13.2	0.94	933	√				√
California ground squirrel	31.9	0.98	380	√			√	
Douglas squirrel	34.5	0.75	301				√	
Long-tailed vole	29.4	0.94	380	√	√			

1 Ecological subgroups proposed for inclusion in index of biological integrity for terrestrial ecosystems (Manley and McIntyre 2006).

Abundance

Of 12 species detected at a minimum of 10 sites, 3 were estimated to be sampled adequately to detect 20% decrease in relative abundance with 80% confidence and power: deer mouse, golden-mantled ground squirrel and northern flying squirrel (Table B-3). The remaining species required from 20 to 211 sites with detections in order to detect a 20% decrease in relative abundance with 80% confidence and power.

Table B-3. Small mammal species estimated to be adequately sampled to detect a 20% decrease in relative abundance with 80% confidence and power at forestwide monitoring sites.

Species name	Mean Abundance	Abundance s.d.	N_{min} dec	Sites with detections (#)
Sampled adequately				
Deer Mouse	42.84	29.49	36	105
Golden Mantled Ground Squirrel	12.32	12.09	71	85
Northern Flying Squirrel	1.53	0.62	14	17
Not sampled adequately				
Lodgepole Chipmunk	20.31	24.76	108	78
Long-eared Chipmunk	10.18	11.73	96	78
Yellow-Pine Chipmunk	23.82	28.05	101	76
Allen's / Shadow Chipmunk	10.86	13.77	117	72
California Ground Squirrel	6.18	8.44	134	33
Long-tailed Vole	2.38	1.82	43	29
Douglas' Squirrel	1.96	1.65	53	27
Bushy-Tailed Woodrat	3.46	3.28	67	13
Trowbridge's Shrew	1.25	0.62	20	12

C. Carnivore track plate and camera surveys

Species detections, site occupancy and abundance

Detections

Twenty mammalian species were detected by trackplate and camera surveys, 15 at camera stations alone and 17 at track plate boxes alone (excluding unidentified rodents, humans or domestic dogs). All 10 target species were detected (Appendix C-1), 6 at camera stations only and 7 at track plate stations only. Targeted species were all non-domestic carnivores (e.g., weasels, felids, canines, skunks, bear, raccoon, etc).

The 10 non-target species detected included: domestic dog (14 sites), yellow-bellied marmot (1 site), porcupine (1 site), western gray squirrel (7 sites), California ground squirrel (23 sites), Golden-mantled ground squirrel (43 sites), Douglas’ squirrel (25 sites), lodgepole chipmunk (25 sites), northern flying squirrel (3 sites) and mule deer (13 sites). While not a targeted species with this protocol, the mule deer is a management indicator species (MIS) for which no other sampling protocol detected. Therefore, we present the population status of mule deer here.

The average number of mammalian species detected per site was 4.9 (s.d. = 1.7) for camera and track plates combined (excluding unknown rodents, humans and domestic dogs), and was 1.9 (s.d. = 0.9) for target carnivore species alone. Carnivore species richness is generally lower than other species groups given the natural history of carnivores (e.g., generally larger body size, larger home range sizes, etc).

Three special status species were detected: American marten (USFWS species of concern, USFS sensitive species and management indicator species-MIS), black bear (MIS) and the mule deer (MIS).

The bobcat and raccoon were the only target species detected solely with trackplates and not with cameras during surveys at monitoring sites. The gray fox and mule deer were the only target species detected solely by cameras. We also detected five birds at camera stations: Common Raven, Golden Eagle, Northern Saw-whet Owl, Steller's Jay, and Turkey Vulture, the most notable being the Golden Eagle, detected in the southern portion of the Lake Tahoe basin. Golden Eagles are a rare occurrence in the Tahoe basin.

Additional carnivores not detected in this effort, but listed as occurring in the Tahoe basin according to the Watershed Assessment (Murphy and Knopp 2000), include: mountain lion, river otter, pacific fisher, striped skunk, mink, and badger. All of these species, except pacific fisher (extirpated from central Sierra; Zielinski et al 2005), would be expected to be detected by the baited trackplate and camera protocol if present. The lack of detection of these species is likely a result of their extreme rarity in the region due to specialized habitat requirements and generally low population densities. Therefore, of target species expected to be detected, MSIM surveys detected 71% (assuming river otter is locally extinct) of species expected in the Tahoe basin.

During carnivore surveys two mammalian species were detected that were not known to occur in the Lake Tahoe basin (Murphy and Knopp 2000): gray fox and ringtail cat. A single gray fox was detected at a camera station in the southeast portion of the Lake Tahoe basin near the Heavenly ski resort; other surveys performed by the USFS in this area also produced detections of this species (L. Campbell pers. com., T. Thayer pers. com.). The single ringtail was detected by track plate on the east shore near the Glenbrook area.

Site Occupancy and Detection Frequency

Black bear and American marten were the most frequently encountered species and were the only 2 target species detected at greater than 50% of sites (66 and 53% respectively; Appendix C-1). The coyote was the next most frequent, detected at 31% of sites sampled, and the non-targeted mule deer was detected at 22% of sites. All remaining species were detected at fewer than 10% of sites.

Compared to historic records, black bear have increased dramatically in their frequency of occurrence; they were recorded as a rare inhabitant of the Tahoe basin in the mid 1900s (Orr 1949). Marten and coyote were both described as common residents of Tahoe historically, and appear to maintain that status today (Orr 1949). The mule deer may have declined slightly since early/mid

1900s, as it was described as a common resident historically, whereas now it appears to be less common but still present.

The marten, where it was present, was detected with the highest detection frequencies per site (mean = 0.43 detections per station per visit; Appendix C-1), followed by the short-tailed weasel, black bear (0.12 detections per station per visit) and ringtail, however, all of these species except the black bear were detected too infrequently (1 site) to indicate reliable detection frequency values.

Carnivore distributions in the Lake Tahoe basin

Carnivore species richness across sub-watersheds within LTBMU (e.g., Hydrologic Unit level 6 watersheds), was loosely correlated with the number of sites sampled in each watershed. Sub-watersheds with the greatest total species richness were Cascade Creek-Tallac Creek-Taylor Creek Frontal, Upper Truckee River and Lake Tahoe -East Shore Frontal / South Half watersheds (Appendices C-2 and C-3). The Lake Tahoe-East Shore Frotal/ North Half and Stateline Point-Third Creek-Incline Creek Frontal watershed had the lowest species richness (Appendix C-2). The Lake Tahoe -East Shore Frontal / South Half and Cascade Creek sub-watershed also had the highest mean richness per site, followed by Ward Creek-Blackwood Creek-Eagle Rock Frontal and the Upper Truckee River watersheds (Figure C-1). Total target species richness per site (total richness /# sites sampled) was greatest in the Lake Tahoe East Shore Frontal/North Half subwatershed (Appendices C-2 and C-3).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was highest for carnivores in the Upper Truckee subwatershed (Appendices C-2 and C-3).

When looking at individual species patterns, 2 (20%) target carnivores and 1 non-target species were broadly distributed across 7 or more sub-watersheds in the Tahoe basin: the coyote, black bear (MIS) and mule deer (MIS). The black bear was the most widely distributed carnivore (Figure C-1), detected in 8 of 9 watersheds in the Lake Tahoe Basin (Appendices C-2 and C-3). The mule deer and coyote were the next most widely distributed target species (7 of 9 watersheds). American marten (USFS sensitive species) was the only carnivore moderately distributed (3-6 sub-watersheds) throughout the Tahoe basin (Figure C-1). Both the coyote and marten were absent from the northeast quadrant of the Tahoe basin (Stateline Point and East Shore North), the marten additionally being absent from the northwestern most sub-watershed (Burton Creek; Figure C-1). Most carnivores, 7 species (70%), had restricted distributions in 2 or fewer sub-watersheds.

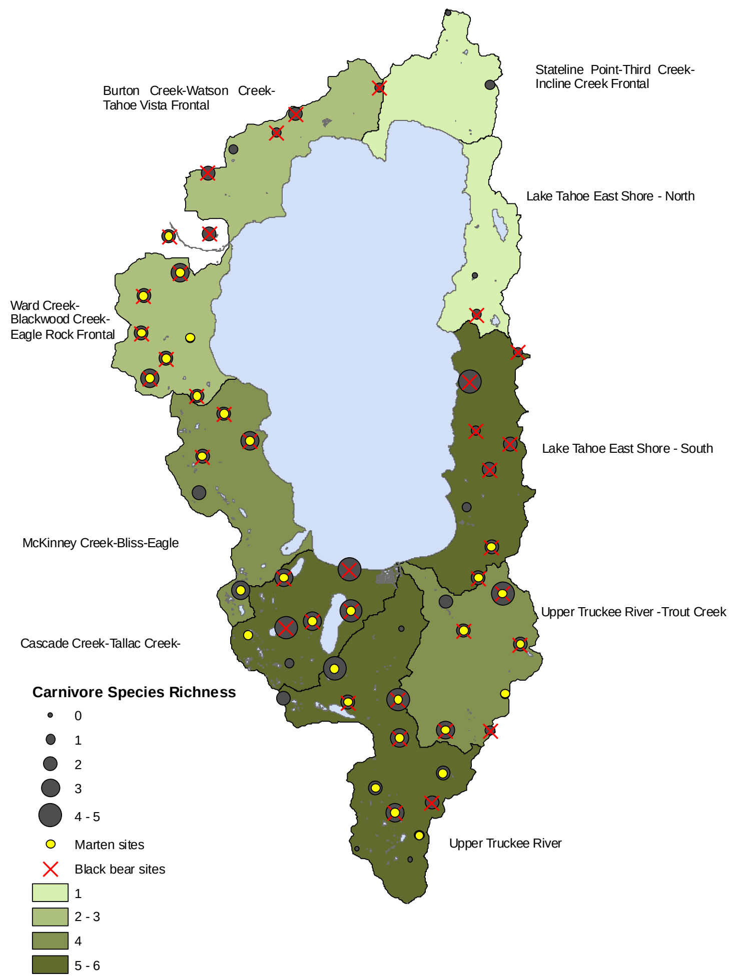

Figure C-1. Mean carnivore richness per site within each of 9 sub-Watersheds (HUC 6) within the Lake Tahoe basin. Dot size reflects relative species richness values per site. Sites with detections of black bear and marten are indicated with red "X" and yellow dot, respectively. Shade of green indicates total species richness values across sites within each sub-watershed.

Track plate and camera protocol effectiveness

Of all 10 target carnivores detected with trackplate and camera sampling efforts, only 2 (20%) had high detection probabilities resulting from all 5 survey visits, American marten (Pd = 1.0) and black bear (Pd = 0.92 ; Appendix C-1). The coyote and mule deer (a non-target species) were each detected with moderate probabilities (0.54 and 0.65, respectively) assuming detectability estimates were reliable; these species were only detected at 18 and 13 sites, respectively. The remaining 7 target species were detected too infrequently to estimate detectability rates with the implemented carnivore sampling protocol (combined trackplate and camera stations).

Detection probabilities were also estimated for each sampling device (e.g., cameras and track plates) separately in order to explore efficiencies of sampling with cameras compared to trackplates. While trackplates detected a wider array of target species across all sites surveyed (8 species) compared to cameras (6 species), camera stations were more effective at detecting marten, black bear, coyote and mule deer (non-target special status species) than track plate stations (i.e., per-visit detection probabilities were higher at camera stations than trackplate stations; Table C-1). Effectiveness of camera stations relative to trackplates could have been a result of the larger bait size or location of the bait on trees, or the camera detection devices themselves. Additionally the combination of 3 camera stations per site was more effective than single camera stations at detecting these 4 species (Table C-1), however the additional combination of 3 camera and 3 trackplate stations per site was no more effective at detecting these 4 species than 3 camera stations alone. Therefore, if detection of the above mentioned 4 species alone are desired for a monitoring program, we recommend reduction of the carnivore sampling protocol to 3 camera stations only per site.

Long and short tailed weasels were detected too infrequently to accurately estimate their detectability, however they were both detected at a greater percentage of sites with small mammal trapping than with trackplate and camera surveys, suggesting small mammal trapping may be a superior protocol for detecting these 2 relatively small carnivores. The remaining 5 target carnivore species were also detected too infrequently to accurately estimate detectabililty, but 3 of the 5 were only detected at track plate stations, and not at camera stations. Therefore, a combination of both track plate and camera stations likely remains optimal when biodiversity monitoring is the objective of carnivore species sampling.

Table C-1. Comparison of estimated per-visit detection probabilities for target carnivore species and non-target special status species based on single or multiple (3) track plate stations, single or multiple (3) camera stations, and a combination of multiple (3) trackplate and camera stations per site surveyed. Bolded values represent the combination of survey methods producing the greatest detection probability for each species with > 10 sites with detections.

	Single Trackplates (n = 174)			Single Cameras (n = 174)			3 Trackplates (n = 58)			3 Cameras (n = 58)			3 Trackplates/Cameras Combined (n = 58)		
Species Name	**p**	**s.e.**	**N**	**p**	**s.e.**	**N**	**p**	**s.e.**	**N**	**p**	**s.e.**	**N**	**p**	**s.e.**	**N**
<u>Target species</u>			-												
American marten	0.49	0.04	41	0.55	0.03	59	0.58	0.05	22	**0.72**	0.04	28	**0.73**	0.04	31
Black bear	0.03	0.01	11	0.26	0.03	59	0.04	0.04	11	**0.41**	0.04	36	**0.40**	0.04	38
Coyote	<0.01		0	0.06	0.03	24	0.00	0.00	0	**0.14**	0.05	18	**0.14**	0.05	18
Long-tailed weasel	0.11	0.13	1	0.33	0.26	1	0.00	0.00	1	0.36	0.25	1	0.20	0.17	2
Short-tailed weasel/Ermine	0.80	0.18	1	-	-	0	0.80	0.18	1	0.00	0.00	0	0.80	0.18	1
Gray fox	<0.01		0	<0.01		1	0.00	0.00	0	0.00	0.00	1	0.00	0	1
Ringtail	0.59	0.23	1	-	-	0	0.59	0.23	1	0.00	0.00	0	0.59	0.23	1
Bobcat	<0.01		3	<0.01		0	0.01	0.01	3	0.00	0.00	0	0.01	0.01	3
Racoon	<0.01		3	<0.01		0	0.20	0.17	2	0.00	0.00	0	0.20	0.17	2
Spotted skunk	0.24	0.14	3	0.08	0.07	2	0.26	0.14	3	0.01	0.00	2	0.28	0.12	4
<u>Non-target special status species</u>			-												
Mule deer	-	-	0	**0.11**	0.01	16	0.00	0.00	0	**0.19**	0.06	13	**0.19**	0.06	13

Population status

For black bear and marten site occupancy estimates were on average 3% (s.d. = 4%) higher than observed site occupancy (range of difference: 0.1- 5%). Site occupancy was estimated to be 71% and 54% of sites in the Tahoe basin, respectively.

Population change and sampling adequacy

Despite high and moderate estimated site occupancy rates for marten and black bear with the MSIM carnivore sampling protocol (0.73 and 0.40 respectively), the current level of sampling effort (58 sites) is not adequate to detect 20% decrease in site occupancy rates with 80% confidence and power (Table C-2) based on the conservative sample size analysis. We estimated that anywhere from 81-134 sites would be necessary to detect the above desired changes in estimated site occupancy for black bear and marten, respectively. Based on a sample size of 100 forest-wide sample sites, however, the black bear would be adequately sampled to detect a decrease in site occupancy.

Table C-2. Sample size requirements for detecting a change in estimated site occupancy rates with 80% confidence and power. Only species with reliable site occupancy estimates were evaluated.

Species Name	Reliable Site Occupancy estimate? [a]	No. of sites occupied	Observed Site Occupancy (%)	Estimated Site Occupancy (%)	Occupancy s.e.	Per-visit Detection Probability (p)	p s.e.	Protocol Detection Probability	N_{min} dec
Black bear	Y	38	65.5	70.8	0.0702	0.4040	0.0402	92.5	81
American marten	Y	31	53.4	53.5	0.0656	0.7279	0.0361	99.9	134
Coyote	likely	18	31.0	57.3	0.1831	0.1444	0.0510	54.1	134

D. Bat mist netting and acoustical surveys

Species detections, site occupancy and abundance

Detections

A total of 9 bat species were detected with mist-netting and acoustic sampling efforts in 2002 (Appendix D-1). Nine species were detected with mist-netting across all 22 sites (3 stations each) sampled during 2002, with a mean of 4.4 (s.d. = 1.9) species detected per site. Sampling occurred in 4 distinct habitat types: lentic (22 stations), lotic (24 stations), forest (9 stations) and meadows (5 stations). Of these habitats, the greatest number of species was recorded at lentic and lotic sites (9 and 8 species, respectively), however, when standardized by survey effort, the mean species richness per site was highest along roads/trails in the forest, than at any other habitat type (Table D-1). This might suggest that bats readily use these gaps in the forest for movement between roosting and foraging habitat.

Table D-1. Sampling frequency, bat detection frequencies and species richness within 4 habitat types sampled with mist-nets on the Lake Tahoe Basin Management Unit, 2002

Habitat	No. of Sites per Habitat Type	No. of Surveys per Habitat Type	Total Individuals	Total Species	No. of Individuals per Survey	No. of Species per Survey
Lentic	22	54	163	9	3.02	0.17
Lotic	24	62	116	8	1.87	0.13
Forest	9	18	8	5	0.44	0.28
Meadow	5	16	4	3	0.25	0.19
Total	**60**	**150**	**291**	**9**		

The 9 bat species detected with mist-netting represent 70% of the 10 bat species expected to occur in the Tahoe basin according to the Watershed Assessment (Murphy and Knopp 2000). One of the three missed species that occur in the Tahoe basin, Mexican free-tailed bat, was detected during a pilot acoustic sampling effort for bats but not during mist-netting that occurred concurrently with this project. The two remaining species, the pallid bat (another Forest Service Sensitive species) and western pipistrelle, while missed in the MSIM survey effort, have recently been recorded in the Tahoe basin. The pallid bat and western pipistrelle were both detected in 1998 during surveys on the east shore near Cave Rock and Heavenly (Murphy and Knopp 2000) and the pallid bat more recently in 2004 via acoustic surveys in the McKinney Creek sub-watershed of the Lake Tahoe basin (Morrison and Borgmann 2004). MSIM surveys probably missed these species due to their generally rarity and habitat specificity within the Tahoe basin and the limited sampling of arid, rocky, and cliffy areas, the likely roosting habitat for these species. This type of habitat (arid, rocky terrain likely to have cave-like features) is also important to the Townsend's big-eared bat, a Forest Service Sensitive species that exists on nearby forests, but is not yet known to occur in the Tahoe basin. A complete assessment of the occurrence or potential for occurrence of this species in LTBMU has never been completed. In order to better sample and monitor the potential array of bat species in the Tahoe basin, including the several species associated with rocky and cliff type features, this habitat type should be additionally sampled in future monitoring efforts.

Three additional bat species were detected that have not been previously identified as occurring in the Tahoe basin; one detected during pilot acousting sampling, the western red bat (detected in 2001 pilot surveys only), and 2 detected during mist-nets, hoary bat and long-legged myotis. The western red bat and hoary bat were both also detected as part of pre-project watershed restoration surveys in 2004 (Morrison and Borgmann 2004), confirming their current presence in the Tahoe basin. Alternatively, the long-legged myotis, while detected only during MSIM surveys, was detected throughout the months of the summer, suggesting that it maintains a breeding population in the Lake Tahoe basin, and should be considered a species occurring in the Tahoe basin. This species is also considered a high elevation species (Warner and Czaplewski 1984), hence its occurrence in the Tahoe basin was considered likely. Therefore, these 4 species currently occur in the Tahoe basin and should be added to the previously established list of currently recognized species in the Watershed Assessment (Murphy and Knopp 2000).

Of all bats detected in this effort and recent pilot acoustic sampling, 3 Federal species of concern (FSC) and a Forest Service Sensitive (FSS) species from an adjacent forest were detected: long-eared myotis, long-legged myotis, fringed myotis and the western red bat (FSS). The former 3 species have been identified as having a medium level of concern/vulnerability in the Sierra Nevada Forest Plan Amendment (USDA 2001), while the western red bat is associated with a high level of concern/vulnerability according to the Western Bat Working Group (www.wbwg.org). All 9 bats, however, are being considered in the forest plan revision process as a potential species group of interest.

Site Occupancy and Abundance

Most frequently detected species, captured at greater than 50% of sites include the long-eared myotis, big-brown bat, little brown bat and the silver haired bat (Appendix D-1).

Compared to historic records of bats in the Tahoe basin (Orr 1949), it appears that the long-eared myotis may have increased in frequency; recorded as rare in the early/mid 1900s, but in this effort was detected at over 50% of sites sampled. Conversely it appears that the yuma myotis may have declined based on a comparison to historical occurrences described by Orr (1949); once common, now detected at only ~20% of sites.

The most abundantly captured species was the little brown bat, with mean capture rate of 1.3 (s.d. = 1.4) captures per site at sites where the species was detected. The next most frequently detected species were the silver haired bat and long-legged myotis (Appendix D-1).

Bat distributions in the Lake Tahoe basin

Total bat species richness was highest in the Lake Tahoe -East Shore Frontal / South Half sub-watershed (9 species) followed by the Burton Creek-Watson Creek-Tahoe Vista Frontal sub-watershed (Appendix D-2). Overall mean richness per site was fairly high across all watersheds relative to the total richness possible. The Lake Tahoe -East Shore Frontal / South Half sub-watershed also had the highest mean species richness per site (6 species per site), followed by the Stateline Point-Third Creek-Incline Creek Frontal sub-watershed with the next highest mean richness per site (Appendix D-2). Total bat richness per site (total richness/# sites sampled) was greatest in the Stateline Point-Incline Creek-Third Creek Frontal subwatershed, followed by both subwatersheds on the east shore of Lake Tahoe (Appendix D-2).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was highest for bats in the Upper Truckee subwatershed (Appendix D-2).

Overall, mean bat richness appeared to be greatest in the eastern and northern sub-watersheds of the Tahoe basin (Figure D-1), however, total sample size in this survey effort was limited, and more comprehensive surveys are necessary to better understand bat diversity and distributions throughout the Tahoe basin.

No bat species were detected across all nine sub-watersheds, due to the fact that no bats were detected at the only site sampled in the Upper Truckee – Trout Creek watershed. Four bat species were detected at 7 or more sub-watersheds, the same 4 species detected at the greatest frequency of sites overall (long-eared myotis, big-brown bat, little brown bat and the silver haired bat). An additional 4 species were detected in 3-6 sub-watersheds (including 2 federal species of concern, the long-legged myotis and the fringed myotis (Appendix D-2). The hoary bat was the only species restricted to fewer than 3 sub-watersheds based on MSIM sampling efforts. However, due to the low sampling effort for bats in this project (only 22 sites sampled in the Tahoe basin), reported distributions should be interpreted with caution. Additional sampling of bat species composition along the western and southern portions of the Tahoe basin was completed as part of various stream restoration projects (Borgmann et al 2006a, b), and could be combined with data from this MSIM project in order to form a more complete representation of bat frequencies and distributions throughout the Tahoe basin.

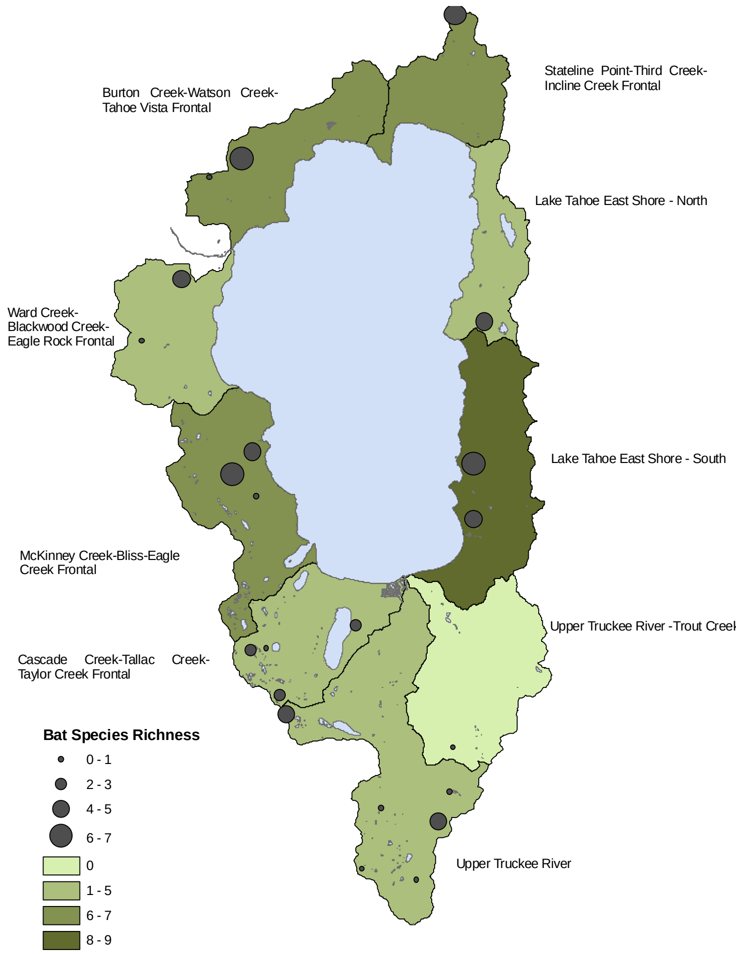

Figure D-1. Mean bat richness per site within each of 9 sub-watersheds (HUC 6) within the Lake Tahoe basin. Dot size reflects relative species richness values per site. Shade of green indicates total species richness values across sites within each sub-watershed.

Bat mist-netting protocol effectiveness

Of all 10 bat species detected, only one species, the long-eared myotis, was detected at sufficient levels (at least 15 sites) to indicate that estimates of detection probability were reliable. Long-eared myotis had moderate detectability with mist-netting (Pd = 0.77; 77% chance of detecting the species at a site if it was present). Three additional species were borderline with regard to having reliable detectability estimates (big brown bat, little brown bat and silver-haired bat). Each of these species was only detected at between 11 and 13 sites, and detectabilities were estimated as moderate (Pd = 0.72) for the big brown bat and high for both little brown bat and sliver-haired bat (Pd = 0.94, 0.89, respectively). The remaining 5 species were detected too infrequently (< 10 sites) to generate reliable estimates. This result is likely due to the very limited sample size in this survey effort; only 22 sites were sampled, therefore only very common species were expected to meet the criteria (15 sites with detections) for reliable detection probability estimates (Table 1-2).

If a more comprehensive survey of bats were to be conducted in the Tahoe basin in the future (~ 100 sites), we would expect to detect nearly all species (8) at a minimum of 20 sites if the proportion of site occupied remains the same, hence generating reliable detection probability estimates for all 8 species.

Population status

Only the long-eared myotis was detected frequently enough to generate reliable detection probabilities to base site occupancy estimates on, however, the detection probability wasn't quite high enough (per-visit detection probability < 0.4, Protocol detection probability < 0.87) to indicate a reliable estimate of species detected in mist-netting efforts, 8 were detected at a minimum of 20 sites and with sufficiently high detection probabilities (Table 1-2) to indicate that site occupancy estimates reliably refect their current "true" population status. For these species, estimated rates of occupancy were on average <1% (s.d = 0.6%) greater than observed values (range of the difference: <1- 2%), and estimated occupancy rates ranged from 30%-100% (Appendix B-1).

Population changes and sampling adequacy

We evaluated the potential ability of this protocol to detect changes in estimated site occupancy for the 4 above mentioned species detected most frequently of all bat species (detected at > 10 sites). Sample size analysis indicated that a sample size of 24-96 would be necessary to adequately detect a 20% decrease in site occupancy with 80% confidence and power for these 4 species (Table D-2). A comparable sample size of 100, similar to other protocols implemented in the Multi Species project, would allow for all 4 species, to be adequately sampled to detect a 20% decrease in site occupancy.

Table D-2. Sample size requirements (N_{min}) for each of the 4 most frequently detected bat species during mist-net sampling in 2002 for detecting a 20% decrease in estimated site occupany over time with 80% confidence and power.

Scientific Name	Common Name	Status	No. Sites Occupied	Observed Site Occupancy (%)	Estimated Site Occupancy %	occupancy s.e.	Detection Probability	N_{min} dec
Myotis evotis	Long-eared myotis	FSC, M	16	76	100	0	77	**24**
Eptesicus fuscus	Big brown bat	M	13	62	94.1	22.1	72	**29**
Myotis lucifugus	Little brown bat	M	12	57	64.3	12.4	94	**96**
Lasionycteris noctivagans	Silver-haired bat	M	11	52	62.6	13.8	89	**96**

E. Pitfall and coverboard surveys for terrestrial vertebrates

Species detections and abundance

Detections

A total of 12 small mammal, amphibian and reptile species were detected with pitfall traps at the 9 sites surveyed in 2002 (Appendix E-1), no animals were found under the cover boards, therefore all data presented represent species detected in pitfall traps. Two species were detected uniquely with pitfall trap arrays and were not detected with any other survey protocol employed: northern (sierra) alligator lizard and sagebrush lizard. In addition to the taxonomic groups mentioned above, both spiders and scorpions were detected in pitfall traps at one site each. Pitfall traps detected 6 (67%) of 9 terrestrial vertebrates targeted with this method (e.g., shrews, moles, pocket gophers, terrestrial reptiles) and expected based on the Watershed Assessment (Murphy and Knopp 2000).

Three special status species were detected in pitfall traps: long-toed salamander (proposed species of interest: 1 site), trowbridge's shrew (proposed species of concern: 4 sites) and Sierra alligator lizard (proposed species of concern: 2 sites). Long-toed salamander was not a species targeted in this protocol, and was detected more frequently with visual encounter survey methods focused at lentic sites (see Lentic Herpetofauna results below); it was detected at 21% of lentic sites compared to only 11% of sites (1 site) sampled with pitfall traps. Trowbridge's shrew, however, was detected with much greater frequency with pitfall traps (44% of sites) than with Sherman live traps (11% of sites) placed on the ground surface (Table E-1) supporting the idea that pitfall trapping techniques are generally more efficient at detecting shrews, and fossorial mammals than Sherman trapping. The alligator lizard was detected at 2 of 9 sites surveyed with pitfall methods, and only approximately 1% of lentic sites surveyed via visual encounter surveys, indicating that this terrestrial lizard is probably best detected with pitfall trapping methods in terrestrial habitats as might be expected.

Similarly, the dusky/vagrant shrew complex and the fossorial mountain pocket gopher were detected with much greater success using pitfall traps than Sherman traps (Table E-1). The remaining small mammals appear best detected by traditional Sherman live trapping techniques.

Pitfall trapping techniques are recommended as the primary sampling method for shrews, pocket gophers, and other fossorial small mammals (such as the broad-footed mole, not detected in this sampling effort) as well as for terrestrial reptiles. Pitfall trapping, however, is often associated with high rates of mortality for small mammals (often $\geq$ 90%), especially shrews (Karraker 2001). In this sampling effort, shrew mortality per site ranged from 0-100% (average =

66%) with Sherman trapping and from 40-83% (average = 68%) with pitfall trapping. Therefore before implementing such a protocol for long term monitoring, alternative strategies must be explored to address this such as either providing an escape mechanism for small mammals (Karraker 2001, Kogut and Padley 1997), or baiting pitfall traps with a sufficient amount of a palatable high energy food such as whitefish (Yunger et al 1992).

Table E-1. Frequency of detection (based on site occupancy) of small mammal species with Sherman trapping and pitfall trapping protocols. Bold values represent the protocol with greatest detection effectiveness.

	Sherman Traps		**Pitfall Traps**	
Common Name	**#**	**%**	**#**	**%**
Mountain pocket gopher	5	1	5	**56**
Trowbridge's shrew	4	11	4	**44**
Vagrant or dusky shrew	2	7	2	**22**
Golden-mantled ground squirrel	2	**81**	2	22
Deer mouse	2	**100**	2	22
Long-tailed vole	2	**28**	2	22
Lodgepole chipmunk	1	**74**	1	11

Site occupancy

The most frequently detected species with pitfall trapping surveys were the mountain pocket gopher (56% sites), Trowbridges shrew (44% sites) and the western fence lizard (33% of sites). Two other species of terrestrial lizard, sagebrush lizard and Northern alligator lizard were both detected at 2 sites (22%) and may be well detected with pitfall traps if employed on a much more comprehensive scale in the Tahoe basin.

Species abundances were not estimated as sampling effort was low and individuals were not individually marked.

Terrestrial vertebrate distributions in the Lake Tahoe basin

Species distributions resulting from pitfall trapping data were summarized by the four major quadrants within the Tahoe basin (north, south east, and west) as opposed to sub-watersheds due to the low sample size of this protocol. Based on these divisions of the Tahoe basin, the pocket gopher was the most widely distributed species detected with pitfall traps, detected in all orientations surrounding Lake Tahoe (Appendix E-1). Lizards were detected only in the east and southeast portions of Lake Tahoe, where arid habitats are more prevalent. Shrews were detected in all quadrants except in the east (Appendix E-1).

Population status

Detection probabilities and site occupancy estimation was not possible with sample sizes and survey design employed in the current pitfall trapping survey effort, therefore future implementation of this protocol at a greater number of sites and with a consistent number of visits at each site is recommended if monitoring site occupancy of shrews, pocket gophers and terrestrial lizards with known detection probability is desired.

F. Lentic Vertebrate Visual Encounter Surveys

Results relevant to this section (detections of amphibians and reptiles) of the report have already been summarized in a recently produced report (Manley and Lind 2005). A brief summary of results is provided below, but additional details and analysis are provided in the report by Manley and Lind (2005).

Species detections, site occupancy and abundance

Detections

We detected four amphibian species and three species of garter snakes known to occur in the Tahoe basin (Murphy and Knopp 2000) (Appendix F-1). Special status species detected included: the long-toed salamander (32 sites), western toad (13 sites), both being considered for species of interest (SOI), and the common, western terrestrial and Sierra garter snakes being considered as a species group of interest..

We also detected three species of terrestrial lizards, non–target species, at a limited number of sites: western skink, western fence lizard, and alligator lizard, (most likely the sierra alligator lizard).

Species detected in this effort constituted 4 of 5 amphibian and 6 of 8 reptile species expected to occur in the Tahoe basin (Murphy and Knopp 2000). The three species not detected were the mountain yellow legged frog, southern alligator lizard and the rubber boa. Mountain yellow-legged frogs were once relatively abundant throughout the Tahoe basin and the high Sierra, historical records exist for at least 15 locations in the Tahoe basin, including locations on the east shore, south shore and north shore. Due to extreme range-wide population declines for this species in the Sierra Nevada, mountain-yellow legged frogs are currently a candidate endangered species. The 2 terrestrial reptiles were likely missed in our sampling since we targeted lentic aquatic habitats, but were also missed by pitfall/coverboard trapping methods. Terrestrial based visual encounter surveys or pitfall trapping should be employed to better detect these terrestrial reptiles if desired. The western skink was not expected and should be added to the list of reptiles occurring in the Tahoe basin (Murphy and Knopp 2000).

<u>Site Occupancy and Abundance</u>

The most commonly detected amphibian species was Pacific treefrog, which was detected at nearly 60% of the sample sites (Appendix F-1). Long-toed salamander and western toad were the next most prevalent, detected at 21% and 9% of the sample sites, respectively. Bullfrog, an introduced exotic, was detected at 5% of the sample sites, dispersed throughout 3 sub-watersheds in the southern and eastern part of the Tahoe basin (Appendix F-1 and F-2). Garter snakes as a group were fairly common, with one or more species being detected at over half of the sample sites (66% of sites). Western terrestrial garter snake was detected at approximately 31% of the sites, while the common and Sierra garter snakes were not as frequently encountered, being detected at around 10% or less of the sample sites (Appendix F-1).

Abundances were highly variable and differed by life stage for most species detected (Appendix F-1). Larvae tended to be the most abundant life stage for amphibians whereas adults (and subadults) were the most abundant life stage detected for garter snakes. Western toad and bullfrog larvae were extremely abundant when encountered, as were additionally subadults of western toad. The larvae of pacific treefrogs were next most abundant followed lastly by larval abundances of long-toed salamander. No adult long-toed salamanders or western toad egg masses were detected during any visual encounter surveys. Results suggest that visual encounter surveys along the perimeter of lentic aquatic sites is effective at detecting larval amphibians and adult garter snakes.

Amphibian and Reptile distributions in the Lake Tahoe basin

Overall species richness for these taxonomic groups was low in the Tahoe basin, however, total native species richness by sub-watershed was greatest in the southwestern watersheds (Appendix F-2). The Cascade creek sub-watershed was most specious primarily due to being the one sub-watershed in which all terrestrial, non-target, herpetofauna were detected (alligator, sagebrush and western fence lizard, and the western skink). Total native herpetofauna richness per site (total richness/# sites sampled) was greatest in the Lake Tahoe- East Shore Frontal/ North Half and Stateline Point-Incline Creek-Third Creek subwatersheds (Appendix F-2).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was highest for native amphibians and reptiles in the Cascade –Taylor-Tallac Creeks subwatershed (Appendix F-2).

Mean richness per site, albeit overall low and fairly uniform throughout the basin, was greatest in Ward Creek-Blackwood Creek-Eagle Rock Frontal, Cascade Creek-Tallac Creek-Taylor Creek Frontal and Burton Creek-Watson Creek-Tahoe Vista Frontal sub-watersheds (Appendix F-2 and Figure F-1).

Distributional patterns of individual species across all 9 sub-watersheds were variable. The pacific treefrog and garter snakes (western terrestrial and common) were most widely distributed throughout sub-watersheds of the Tahoe basin (Appendix F-2). The next most widely distributed species were the the western toad (6 sub-watersheds) and the long-toed salamander (5 sub-watersheds). While the western toad was more widely distributed (found in all quadrants of the Tahoe basin) than the long-toed salamander (southern and western watersheds), the western toad was more sparsely distributed in watersheds where it was present (smaller proportion of sites occupied) than for the long-toed salamander. Species with the most restricted distributions were the Sierra garter snake and as expected the non-targeted terrestrial reptiles.

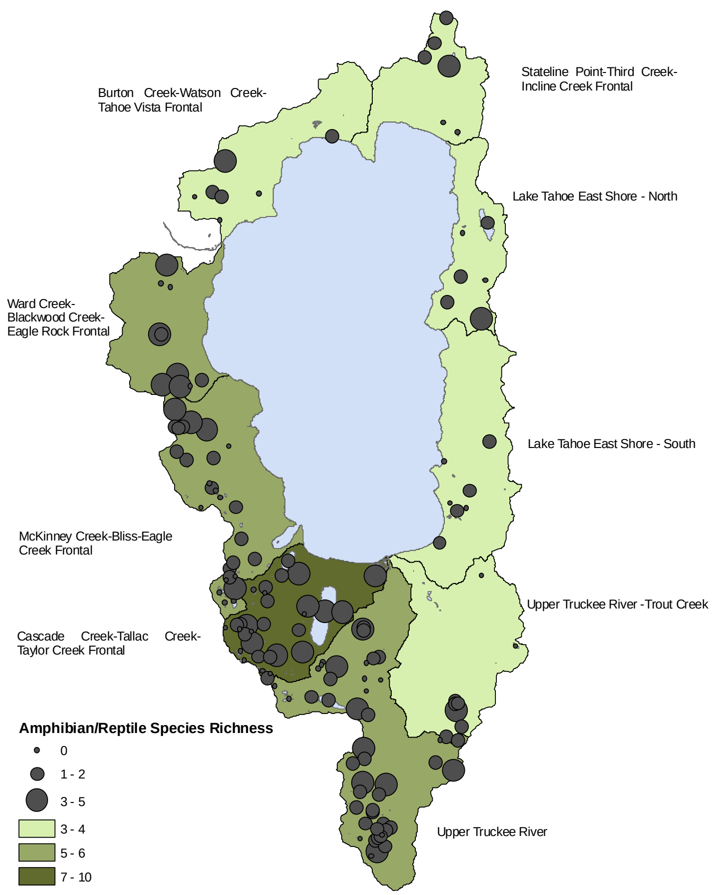

Figure F-1. Mean amphibian and reptile species richness per site within each of 9 sub-watersheds (HUC 6) in the Lake Tahoe basin based on most recent comprehensive MSIM monitoring surveys at 148 lentic sites, 2002-2004. Dot size reflects relative species richness values per site. Shade of green indicates total species richness values across sites within each sub-watershed.

Manley and Lind (2005) also evaluated lentic site "value" in terms of a persistence index based on data collected at a subset of our monitoring sites (84 sites) that were sampled 2 or more times from 1997 to 2005. The persistence index (PI) for each site was based on two factors: occupancy rate (the proportion of years a site was occupied out of all years surveyed) and duration (span of time over which occupancy occurred), and was based on the approach used for the Tahoe yellow cress in the Tahoe basin. The index value is the summation of the values determined for each species, resulting in sites with a greater number of species detected with high occupancy and duration translating into sites with high persistence index values. Persistence index values per site (only sites with one or more species detected within at least 2 years or more) are shown in Figure F-2; sites with high index values are thought to be the most valuable in terms of maintaining amphibian and reptile species diversity over time. While current index values are based on a limited suite of sampling (only a few years of sampling at each site), the value of such a metric will increase dramatically as monitoring continues at these site locations into the future. Current values suggest that the Ward Creek-Blackwood Creek-Eagle Rock Frontal sub-watershed and the northern portion of the McKinney Creek-Bliss-Eagle Creek Frontal sub-watershed harbor many sites with high value to amphibian and reptile biodiversity in the Tahoe basin, with a few other sites scattered at mid elevations in other sub-watersheds to the north and south.

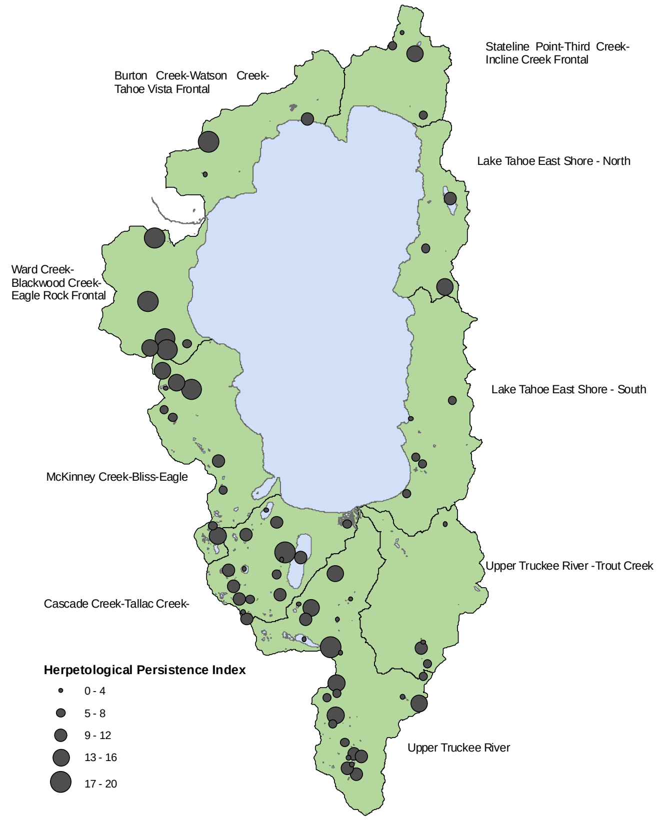

Figure F-2. Herpetological Persistence Index (PI) values (Manley and Lind 2005) for lentic sites sampled 2 or more times from 1997- 2005 within the Lake Tahoe basin. High PI values indicate sites with high rates of occupancy and long spans of duration in occupancy for amphibians and reptiles at respective sites.

Lentic visual encounter survey protocol effectiveness

Of all amphibian (4 species) and aquatic reptiles (3 species) detected, only the pacific treefrog had reliably high detectability with visual encounter surveys at lentic sites (Protocol detection probability (Pd) equal to or greater than 0.8 meaning > 80% chance of detecting the species where it occurred; Appendix F-1). Moderate detectability was observed by the long-toed salamander, western terrestrial and common garter snakes (Pd = 0.5-0.8). The remaining 2 amphibians and garter snake were detected too infrequently to reliably estimate detectability (Appendix F-1), although western toad and bullfrog detectability is likely to be high as well, given the large numbers of larvae that were observed at sites where each species was detected.

The common garter snake, was only detected at 17 sites, but was assumed to have an accurate estimate of detectability. Based on these data, the common garter snake had moderate detectibility (Pd = 0.77) as indicated above. Sampling in the future may help confirm these detectabilities.

Population status

The pacific treefrog was the only species detected with site occupancy estimates that reliably reflect "true" population status; detected at ≥ 20 sites and had estimated detectability of ≥ 0.80. Based on the report summarizing these data (Manley and Lind 2005), estimated site occupancy for the pacific treefrog was 56% (Appendix F-1). Several species were borderline with regard to having reliable site occupancy estimates; long-toed salamander, western toad, Sierra garter snake and common garter snake were detected at between 10-20 sites, and with detection probabitlies > 65%, fairly close to the recommended minimum values (Appendix F-1). Increasing the sampling intensity to at least 3 survey visits per site would likely increase the number of species with reliable site occupancy estimates to include the 4 above-mentioned species, two of which are species of interest being considered for long-term monitoring in Pathway 2007 forest plan revision process (long-toed salamander and western toad).

Sampling Adequacy

Only one species, the pacific treefrog was sampled adequately to be able to detect a 20% decrease in site occupancy (Table F-1). Only one other species was close to being adequately sampled, the western terrestrial garter snake, requiring 196 sites for detecting a similar decrease in site occupancy. The long-toed salamander was estimated to require 933 sample sites to detect changes as small as 20% in site occupancy at the basinwide scale, and the western toad required even greater sampling intensity than the long-toed salamander (Table F-1). These levels of effort for the long-toed salamander and western toad are neither reasonable nor possible (fewer than ~500 lakes/ponds exist in the Tahoe basin) for future monitoring efforts, therefore alternative monitoring designs must be considered for basinwide monitoring of these species. Some considerations include: 1) reducing the suite of sites considered for "population change" analysis to include either only presently occupied sites or only those sites within the historical range of the species in the Tahoe basin and thereby increase analysis power to detect decreases, 2) monitoring for increases in population status (i.e., site occupancy), instead of decreases for species with low site occupancy for increased analysis power; this might be appropriate for species in which population restoration is desired, 3) sampling 100% (i.e. census) of all possible lentic sites in the Tahoe basin (n ~ 350- 500 sites) with sufficient number of survey visits (n ~3-4 visits per site) to assume near perfect detection probabilities, and thereby avoiding the need for "estimates" of site occupancy; observed site occupancy will reflect the true status of the population, 4) considering the use of alternative monitoring metrics (e.g., abundances per site, species richness per site) to monitor condition and trends of individual sites over time, rather than presence/absence distributions of species over broad spatial areas, or using some combination of the above.

Table F-1. Sample size requirements (N_{min}) for amphibian and reptiles detected during lentic aquatic site visual encounter surveys during 2003 and 2004. Sample size requirements were estimated for detecting a 20% decrease in estimated site occupany over time with 80% certainty (i.e., confidence and power).

Species	Detection Frequency[1]	Detection Probability	Estimated Site occupancy	Estimate reliable?[2]	N_{min} decline
Long-toed salamander	32	0.67	0.17	probably	933
Western toad	13	0.91	0.07	possibly	>933
Pacific treefrog	87	0.93	0.56	yes	**134**
Bullfrog	8	1.00	0.06	unknown	n/a
Western aquatic garter snake	11	0.82	0.04	possibly	>933
Western terrestrial garter snake	47	0.60	0.47	probably	196
Common garter snake	17	0.77	0.16	probably	933

[1] Number of sites with detections of respective species. This value represents the sample size for estimating detection probabilities and site occupancy.

[2] Yes = detection frequesncy or number of sites with detections > 20 and detection probability > 0.80, probably = detection frequency > 20, but detection probability 0.5-0.8, possibly = detection frequency 10-20, and detection probability 0.5-0.8, unknown = detection frequency < 10.

Status of Vascular Plants

Vascular plant data were collected at monitoring sites in order to determine species occurrences, distributions, cover (when applicable) and monitoring metrics for the purpose of establishing current status, and evaluating our ability to monitor status over time.

G. Vascular Plant Surveys

Species detections, site occupancy and cover

Across all 105 forest wide monitoring sites we detected a total of 12 tree species, 57 shrub species, 69 grass-like species (including grasses, sedges (*Carex spp*.) and rushes (*Juncus spp*.)), 311 herbacious species (e.g., forbs) and 11 ferns (Appendix G-1).

A total of 33 plant varieties detected in the MSIM sampling effort were not previously listed as documented occurrences in the Tahoe basin (Murphy and Knopp 2000), but instead as potentially present. Therefore, this report confirms the occurrence of these 33 species/varieties in the Tahoe basin (Appendix G-1). An additional 9 species/varieties detected were not recognized as even potentially occurring in the Tahoe basin according to the Watershed Assessment and are now know to exist in LTBMU; all 9, however, were previously recognized by USFS botanists as occurring in LTBMU. Four of these 9 species are invasive weed species (i. e. *Convolvulus arvensis, Grindelia squarrosa, Medicago sativa and Poa bulbosa),* the remaining are herbaceous or grass-like species (*Goodyera oblongifolia, Linanthus nuttallii ssp. pubescens, Piperia leptopetala, Trifolium longipes var. nevadense and Festuca idahoensis*). Additionally, 72 plant species detected in this MSIM effort had not been previously recorded in surveys by LTBMU botanists over the past 5 years. Therefore, the current USFS botanist maintained LTBMU plant list has been updated based on these additional MSIM detections.

The most commonly detected tree species, Jeffrey pine (*Pinus jeffreyi*) was detected at 80% of sites, and red fir was detected at 79% of sites (Appendix G-1). White fir (*Abies concolor*) and lodgepole pine (*P. contorta*) were detected at 69% of sites. Ponderosa pine (*P. ponderosa)* was detected least frequently, at 2 sites.

The most frequently detected shrub species, pinemat manzanita (*Archtostaphylus nevadensis*), was found at 41% of sites (Appendix G-1). The next two most frequently detected shrubs, creeping snowberry (*Symphorocarpus mollis*) and huckleberry oak (*Quercus vaccinifolia*), were detected at 39% and 31% of sites, respectively. The majority of shrub species (55%) were infrequently encountered, detected at less than 5% of sites (Appendix G-1). Mountain whitethorn (*Ceanothus cordulatus*) had the highest average cover where present of 15.3% (± 14.5%), followed by huckleberry oak with average cover of 14.3% (±

9.7%) and sierra gooseberry (*Ribes roezlii var. roezlii*) which had a cover of 11.5% (cover only measured at 1 site).

Herbacious species were overall less frequently detected at monitoring sites throughout LTBMU than shrubs or trees. The most common herbs were spreading groundsmoke (*Gayophytum diffusum*) and broad-seeded rock cress (*Arabis platysperma*), detected at 37% and 34% of sites, respectively (Appendix G-1). Milk kelloggia (*Kellogia galioides*) was the next most commonly detected species at 31% of sites. Of all herbs detected, most species (74%) were detected at less than 5% of sites, and 36% were only detected at a single site. Buckbean (*Menyanthes trifoliata*) had the highest average cover where present of 47.5% but this species was only detected at a single site. All remaining herbaceous species were detected at $\leq$ 6 % cover on average at sites where they were detected. Wooly mules ears (*Wyethia mollis*) had a 5.3% (s.d.= 7.7%) average cover, the greatest average cover of any remaining species. Mountain blue bells (*Mertensia ciliata*) and big leaf lupine (*Lupinus polyphyllus*) followed with 4.3% (s.d. = 0.4%) and 4.1% (s.d. = 4.7%) average cover, respectively.

The most common grass-like species was squirreltail (*Elymus elymoides*), which was detected at 40% of the sites. Of all grass-like species detections, over 10% were never identified to either genus or species and approximately 30% were identified to genus only. This is not surprising as grasses are the hardest taxonomic group to identify to species. The genus least frequently identified to species was Carex, with unknown species detections at approximately 50% of sites. Of grass-like species, meadow barley and tall mannagrass had the highest average cover of 12.6% and 10.1%, respectively, however, again these 2 species were detected at only a single site. All remaining grass-like plants averaged < 10% cover at sites where present, with most averaging < 2% cover.

The most common fern species detected were American rock break (*Cryptogramma acrostichoides*) and western brackenfern (*Pteridium aquilinum*), both detected at 11% of sites. Western brackenfern was detected at the highest average percent cover where present (mean = 4.6%, s.d. =2.7%).

No special status species (i.e., threatened, endangered, CA sensitive, USFS LTBMU sensitive species or proposed P7 special status species) were detected with MSIM survey protocols at the 105 sites. Twenty-one sensitive and special interest vascular plant species occur in the Lake Tahoe basin and vicinity, however, these species' rarity coupled with the relatively small percentage of land area surveyed for plants in this effort (n~ 52 acres, ~0.5% of NFS lands in the Lake Tahoe basin) potentially explains their lack of representation in our dataset.

Plant distributions in the Lake Tahoe basin

Across sub-watersheds within LTBMU (HUC level 6), species richness per watershed was generally proportional to survey intensity (i.e., number of sites surveyed in each) and area within each watershed for each life form group (e.g. trees, shrubs, herbs, grass-like plants and ferns) and for all species groups combined (Appendix G-2). Among the 9 sub-watersheds in the Lake Tahoe basin, we detected the greatest total number of plant species in the Upper Truckee River watershed (239 species), followed by Cascade Creek-Tallac Creek-Taylor Creek Frontal (197 species) and the McKinney Creek-Bliss-Eagle Creek Frontal sub-watersheds (186 species) (Appendix G-2). Total plant richness per site (total richness/# sites sampled) was greatest in both subwatersheds in the northeast corner of the Lake Tahoe basin (Lake Tahoe East Shore Frontal/North Half, and Stateline Point-Incline Creek-Third Creek) (Appendix G-2).

Beta diversity (total richness per watershed/mean richness per site), a measure of species turnover between sites, was highest for plants in the Upper Truckee subwatershed (Appendix G-2).

Alternatively, mean species richness per site was greatest in the Lake Tahoe -East Shore Frontal / North Half watershed and Stateline Point-Third Creek-Incline Creek Frontal watershed (18.3 and 18.2 species per site, respectively). The lowest richness per site was in the Lake Tahoe -East Shore Frontal / South Half watershed (9.0 species per site) (Figure G-1).

When considering distributions of species by life form, we found that trees were the only group of plants for which the majority of species (8 of 12) were distributed broadly throughout LTBMU (occupied $\geq$ 7 sub-watersheds), shrubs were nearly evenly represented among broad, moderate (occupied 3-6 sub-watersheds) and restricted distributions (occupied < 3 sub-watersheds) in LTBMU with approximately one-third of species in each, and the remaining life forms (herbs, grass-like plants and ferns) were dominated by species with restricted distributions in LTBMU (Appendix G-2).

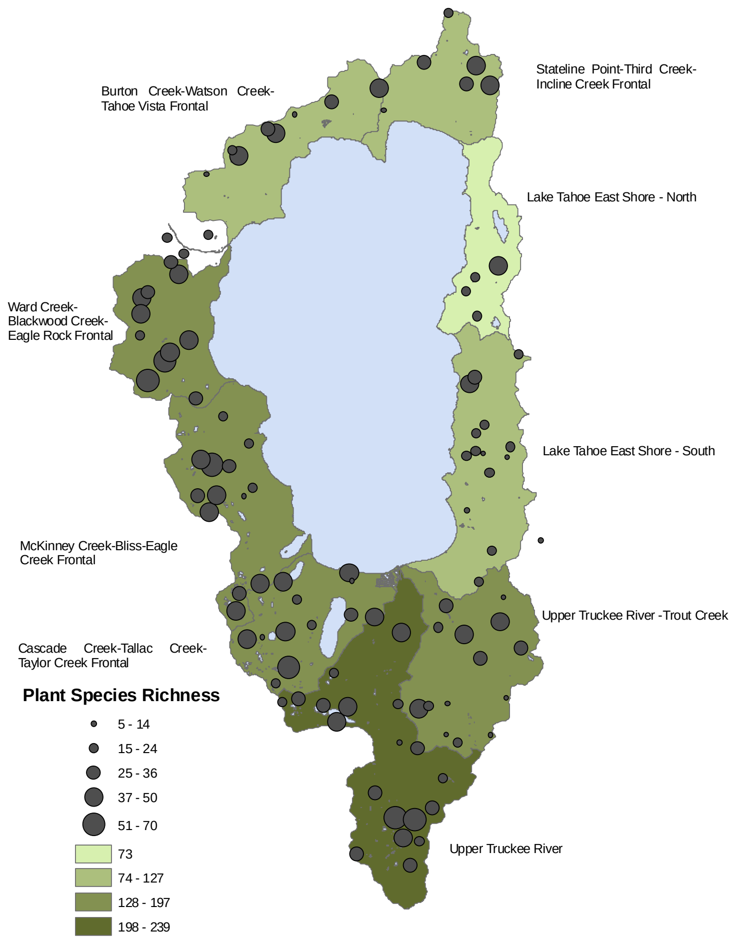

Figure G-1. Plant species richness per site within each of 9 sub-watersheds (HUC 6) in the Lake Tahoe basin based on most recent comprehensive MSIM monitoring surveys at 105 forestwide monitoring sites, 2002-2005. Dot size reflects relative species richness values per site. Shade of green indicates total species richness values across sites within each sub-watershed.

Plant protocol effectiveness

Expected detections

Species detected with MSIM monitoring methods were compared to the vascular plant species listed in Appendix E "Vascular Plants of the Lake Tahoe Basin" from the Watershed Assessment (Murphy and Knopp 2000) in order to 1) assess the efficiency of MSIM sampling on National forest lands at detecting plants potentially occurring in the Tahoe basin, and additionally to 2) field validate existing Tahoe basin and LTBMU plant lists.

The total number of "documented occurrences" of vascular plant species and varieties with the Lake Tahoe basin according to the Watershed Assessment (Murphy and Knopp 2000) is 1,184. The MSIM project detected a total of 460 species/varieties on national forest system lands, 418 (35%) of which were also listed as "documented occurrences", leaving 65% (766 species) of species undetected of those listed in the Watershed Assessment.

Several factors contribute to the apparently low success of MSIM plant surveys at detecting the suite of vascular plant species occurring within the Lake Tahoe basin. Not all species listed in the Watershed Assessment were expected to be detected in the MSIM effort for the following reasons: 1) the Watershed Assessment species list was based on documented occurrences for the greater Lake Tahoe region and includes species that only occur just outside the Tahoe basin (e.g., Carson Pass and Shirley Canyon areas), and 2) MSIM surveys took place only on national forest lands, and not all habitat types existing within the Lake Tahoe basin were represented in our sample; for example the shorezone around Lake Tahoe, fens, riparian habitat, alpine communities and wet meadows provide unique habitat for specialized plant species that were listed in the Watershed Assessment, but which either do not occur or are very rare across the landscape within LTBMU and were missed in our sampling.

When the list of plant species expected to be detected was adjusted based on above mentioned factors and available Lake Tahoe basin specific plant lists (Graf 1999, B. Brenneman, pers comm.), we estimated that MSIM protocols probably detected 71% of 592 vascular plant species expected to be present within LTBMU. While this indicates that MSIM plant surveys were reasonably effective at inventorying plants on national forest lands, it also highlights that many species (> 700) that are a part of the entire Lake Tahoe basin ecosystem were not detected on national forest system lands.

Sampling strategies and/or plant monitoring goals and objectives will need to be adjusted in order to make a future long-term plant monitoring program effective.

Detectability

Of all 460 plant species detected with MSIM botany surveys, only 19 plants were detected sufficiently with quadrat methods (≥ 20 sites) to estimate detection probability reliably and also exhibited high detectabilities (Pd > 0.8) with quadrat sampling techniques. These species included 5 trees, 11 shrubs and 3 herbs and grasses. An additional 14 species (1 tree, 8 shrubs and 5 herbs) were detected at > 15 sites with quadrats and also had high detectabilities (Pd > 0.8). All 33 species were assumed to have sufficient sample sizes for accurate estimation of detection probabilities. In fact, all 33 species (7% of all species detected) had very high detection probabilities (Pd > 0.91 for all but one species), as might be expected for plants. No plant species were detected with moderate detection probabilities, and the remaining 427 species were detected too infrequently (<15 sites) to accurately estimate detection probabilities.

Fewer plant species were detected with high detectabilities (7%) than for vertebrate species groups (20-30% of species with high detectability). While seemingly counter-intuitive, this result is largely due to the low frequency within which most plants were encountered across the landscape. Most plants (>90%) were detected at too few sites to estimate detectability. However, when only considering species with sufficient detections for estimating detectability (detected at 20 or more sites), 100% of plants had high detectabilty, compared to only 30-90% of vertebrates detected at 20 sites or more.

Based on above discussion, it appears that MSIM plant surveys were highly effective at detecting the plant species present within quadrats. However, surveys also indicated that plants were generally rare in distribution across the landscape (i.e., tend to occur at very few sites). Monitoring changes in populations that are rare is difficult and either require intensive sampling and/or alternative sampling strategies.

Sampling method comparisons - Richness

We compared and evaluated three plant sampling protocols implemented in the MSIM project (quadrat, line intercept and point intercept based protocols) in terms of their ability to detect the plant community at each site and their similarity in measurements of plant cover. For both comparisons, we used only data collected at the central monitoring station at each site (i.e., PC1) where all 3 methods were conducted in order to have comparable data across all methods. The objective of this comparison was to determine which methods are most effective at sampling plant diversity and cover at each monitoring site.

First, we evaluated the effectiveness of each protocol alone with respect to the number of species detected per site (e.g., presence/absence data). We found that total plant species richness and richness by life form (ferns, grasses, herbs, shrubs, and trees) was generally greatest when based on all three protocols than when based on any single protocol alone or any combination of 2 protocols (Table G-1). However, depending on plant life form, gains in species richness with additional sampling protocols were not always large.

For ferns, grass-like plants and herbs, species richness values based on any single, or combination of protocols that included quadrat sampling were only marginally different from all 3 protocols combined, but were markedly greater than any single or combination of protocols including line or point intercept methods only (Table G-1). Additionally quadrat and line intercept protocols combined consistently produced greater species richness values than quadrats alone. This suggests the strong influence of the quadrat, and secondarily line intercept protocol, in contributing to more complete species inventories for ferns, grass-like plants and herbs.

Alternately, for shrubs and trees, species richness values based on protocol combinations including point intercept and quadrats were markedly greater than any single protocol or combination without both point intercept and quadrats (Table G-1). Additionally, the combination of our quadrat and line intercept protocols appeared strong in terms of contributions to species richness of shrubs. This result suggests benefit in the incorporation of a transect based protocol in addition to quadrat based sampling for more complete characterization of shrub and tree diversity at monitoring sites.

In summary, the quadrat protocol appeared to contribute the greatest to detecting species composition at a site, with line intercepts likely contributing additional worthwhile gains. This result is similar to what has been shown in previous plant monitoring literature. In their comprehensive summary of plant monitoring methods and sampling design, Elzinga et al (1998) reported that quadrats were more effective at species inventories because of their higher likelihood of detecting rare species than transect sampling approaches.

Table G-1. Average (mean) total plant richness and richness per life form per site based on various combinations of sampling protocols employed at forestwide monitoring sites sampled as part of the MSIM project 2002-2005. Bolded values represent sampling protocols or combinations for which plant richness per site was greatest and for which differences were minimal. Underlined values represent the protocol or combination that offered the greatest efficiency in detecting the greatest species richness for each growth form.

	Quadrats		**Line intercept**		**Point Intercept**		**Quad/Line**		**Quad/Point**		**Line/Point**		**Quad/Line/Point**	
Growth Form	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**	**Mean Plant Richness**	**s.d.**
Ferns	**0.18**	0.48	0.05	0.22	0.04	0.19	**<u>0.20</u>**	0.53	**0.19**	0.48	0.06	0.23	**0.20**	0.53
Grass-like plants	**2.11**	2.05	0.93	1.30	0.48	0.91	**<u>2.32</u>**	2.22	**2.25**	2.17	1.01	1.35	**2.40**	2.26
Herbs	**8.88**	7.48	2.91	3.45	1.48	2.06	**<u>9.55</u>**	7.82	**9.28**	7.69	3.20	3.68	**9.71**	7.92
Shrubs	3.37	2.33	1.96	1.75	2.13	1.83	**3.87**	2.53	**<u>4.05</u>**	2.61	2.47	2.00	**4.16**	2.70
Trees	1.58	1.04	0.72	0.68	2.12	1.11	1.72	1.06	**<u>2.44</u>**	1.21	2.16	1.14	**2.48**	1.25
Total Richness	16.12	9.57	6.57	4.57	6.25	3.61	17.67	10.22	**18.20**	10.08	8.90	5.02	**<u>18.95</u>**	10.46

<u>Sampling method comparisons - Cover</u>

Second, we compared average cover measurements and associated variability in cover estimates produced by each sampling method for the following plant life forms: herbs, grasses and shrubs, in order to inform us of potential protocol biases. Trees were not evaluated because ground cover estimates of trees (e.g., basal area) are not typically measured at the small scale at which these protocols were implemented. Additionally, ferns were never detected at a site with all 3 methods, hence site based comparisons between methods were not possible for ferns.

Point intercept methods consistently produced the highest cover estimates for herbs, grasses and shrubs than either of the other 2 protocols, followed by line intercept and lastly the quadrat protocol (Table G-2) when comparing cover for species that were detected at sites by all three methods. Line intercept and quadrat cover estimates were most similar, within ~2% (range: 0.01 -19%) of one another on average. Point intercept estimates were on average greater than either of the other methods by ~6-7% (range: 0.2-48%). This is unusual in that visual estimates of cover within quadrats have previously been shown to over-estimate plant cover relative to both line and point intercept methods due primarily to observer error in estimation (Elzinga et al 1998). In our study, however, results of this comparison may have been influenced by various inadequacies in sampling intensity and locations. We sampled very few points along point intercept transects relative to what is generally sampled for cover estimation (Elzinga et al 1998), and locations of quadrats were not entirely matched with line and point intercept transects (see Figure A1-5 in Appendix 1-6), although all 3 methods targeted the same sample area.

Table G-2. Percentage of cover estimates (per species per site) that were highest for each plant sampling method employed as part of the MSIM project, 2002-2005.

Life form	Quadrats	Line intercept	Point intercept
Grasses	25.8	51.9	88.9
Herbs	21.6	52.1	96.7
Shrubs	24	29.5	90.8

We also evaluated variability in cover estimates. Quadrats consistently produced estimates with the greatest variability; 52% of cover estimates for species detected at sites by all 3 methods were most variable (had the highest coefficient of variation; CV) based on quadrat methods, followed by line intercept (41% of species) and least variable were cover estimates based on point intercepts (7% of species). When percentage data were transformed via the standard arcsine square root transformation, variability followed the same relative pattern with quadrats being the most variable overall, however, variability (CV) was reduced by 23-34% compared to raw percentage values.

While our results are not entirely conclusive, they do suggest that cover estimates based on point intercept methods with very few sampling points may not be reliable, and that cover estimates based on quadrat sampling are highly variable and may not be the desired method for monitoring changes in cover for most species. Hence, line intercept sampling may be the preferred method for estimating cover of a variety of species. This is consistent with what Elzinga et al (1998) reported on several studies comparing cover estimates and associated variabiltity between these 3 methods (quadrats, line intercepts and point intercepts); in general line ntercept approaches were considered most accurate and least variable for the widest array of species.

Sample method comparisons – Conclusions

Based on results from above method comparisons from the Tahoe basin and previous comparisons between these methods (Elzinga et al 1998) for measuring both plant occurrences (i.e., species richness) and cover for a wide breadth of species; we recommend a combination of quadrat and line intercept based sampling protocol for a future long-term plant monitoring program. We recommend surveying additional quadrats systematically along at least 3 transects placed either systematically or randomly at each monitoring site, perhaps with the intent to sample the various plant communities represented at each site. The frequency of quadrats along transects and total length of transects should depend on plant community diversity at any given site, but probably should be no less than 10 quadrats per transect and at least 3 transects. A similar method that could be considered for basinwide plant monitoring is the protocol currently being employed at several meadow sites in the basin as part of an ongoing regionwide (R5) meadow (i.e., range) monitoring and risk assessment project (Weixelman 2005). The regionwide meadow monitoring protocol (Weixelman 2005) samples three parallel 25-meter transects spaced 5 meters apart and located in a representative area of each meadow. Slightly smaller quadrats (20 cm x 20 cm) are sampled every meter alongside 20 meters of each transect, for a total of 60 quadrats sampled per site. This nearly 6-fold increase in the frequency of quadrats sampled per site relative to the MSIM plant survey protocol (12 quadrats per site) is recommended for future monitoring to both increase the frequency with which plants are encountered across the landscape and also decrease overall sampling variability (Elzinga et al 1998).

Hence, augmenting MSIM surveys with a protocol similar to that described by Weixelman (2005) should be considered for future plant monitoring in the Tahoe basin in order to increase our ability to capture within site diversity and monitor changes over time (see Monitoring metrics and population status section below). Maintaining the existing FIA based protocol used in MSIM plant surveys for future plant monitoring is also important for retaining the ability to contribute to and tier off of existing basinwide and larger scale FIA datasets.

Monitoring metrics and population status

Site occupancy

Thirty-three species were sampled with sufficient frequency to estimate site occupancy rates (species detected at >15 sites and with detectabilities > 80%) For these species, site occupancy estimates for trees ranged from 18-57%, from 14-40% for shrubs, and from 17-23% of sites occupied for herbs. The single grass species with high detectability and reliable site occupancy estimate was estimated at 24% of sites occupied. Because plants that were sampled well (>15-20sites with detections) tended to have very high detection probabilities (Pd > 0.90; >90% chance of detecting the species when it is present), estimated occupancy rates are nearly identical to observed site occupancy rates (e.g., number of sites with detections). Therefore, for long-term plant monitoring, estimating site occupancy may not be necessary; using raw values of observed site occupancy (number of sites with detections) should be sufficient.

Sampling Adequacy

Site Occcupancy/Frequency of occurrence

No plants were sampled adequately to detect a decrease of 20% in site occupancy with 80% confidence and power. This was primarily due to the fact that most plant species occurred very infrequently a forestwide sites throughout LTBMU; the majority of species (91%) were detected at less than 15% of sites. Only species with estimates > 65% of site occupied were expected to be able to detect a 20% decrease in occupancy with 80% confidence and power. The most frequently detected species were trees, only a few detected at 50-60% of all sites.

While the majority of plants detected were limited in distribution throughout the Tahoe basin relative to other species groups (e.g., birds, small mammals, etc), many are associated with distinct vegetation communities and are effectively more specialized than wildlife species. When plant species occurrences were summarized broadly by major CWHR habitat type (e.g., Jeffrey pine, lodgepole pine, white fir, red fir and subalpine), plant species occupied a greater percentage of sites within individual habitat types than across all habitat types combined, and only 54-72% of plants per habitat type were present at <15% of sites compared to 91% among all sites. Similarly, results from a recently implemented meadow monitoring dataset (R5 meadow monitoring), demonstrated that species particularly associated with meadow habitats were detected at much higher frequencies in meadows alone (~3-6 times more frequent) than across multiple habitat types in the MSIM project. This suggests that appropriate stratification of sampling sites based on vegetation communities, spatial elements (e.g., by sub-watershed), or intrinsic characteristics (e.g., based on use of only known occupied or historically occupied sites) may improve our ability to monitor changes in site occupancy of dominant plant species by increasing analysis power. Perhaps a stratification based on a more refined vegetation physical/geomorphical classification system than CWHR may even be necessary, such as vegetation associations (Sawyer and Keeler-Wolf 1995) or the terrestrial ecological unit inventory (TEUI; Slaton et al. 2006). However, monitoring objectives, and the compatability with the wildlife community and perhaps forest structure/seral stages should be considered before deciding on an appropriate stratification scheme. Additionally, both apriori (before selecting sample sites) and post hoc (grouping sites after selecting sample sites) stratification should be considered for efficacy in relation to primary monitoring program objectives.

Abundance/Cover

We evaluated 2 alternative metrics of plant abundance/dominance in terms of their variability and sampling adequacy for detecting changes of 20% with 80% certainty (i.e., confidence and power). Variability is an indication of the ability to detect significant changes in metric values over time; one standard measure of which is the coefficient of variation (CV = [(s.d. of metric)/ (mean value of metric) * 100]); metrics with lower variability (i.e., lower coefficient values) have greater ability to detect changes over time.

The 2 metrics of abundance/dominance evaluated were: 1) plant frequency per site measured as the percent of quadrats sampled at each site (12 total) that were occupied by each species, and 2) the average percent cover across all quadrats per species. While these 2 metrics measure slightly different aspects of plant dominance at a site; frequency measures are more coarse description of "abundance" of a species than estimates of total cover, this comparison does give us a sense of which metric has a greater ability to detect change over time. For both analyses (i.e., comparisons of variability and sampling adequacy), we used the arcsine square root transformed percentages for both metrics as this transformation is a standard transformation for percentage data; and transformed data were less variable than untransformed percentage data by an average of 12-45% depending on the metric and plant life form (e.g., shrubs, herbs, etc.).

Variability was overall lower for the former metric, plant frequency, than the later metric (plant cover) by ~15-30% depending on the life form (Table G-3).

Table G-3. Mean coefficient of variation (CV) per life form for each of 2 plant abundance metrics: percent frequency and percent cover.

Life Form	% Freqency mean CV	% Cover mean CV
Shrubs	34.7	63.5
Herbacious plants	27.7	43.8
Grass-like plants	32.5	59.3
Ferns	23.4	49.5

Similarly, we found that in general sampling adequacy was greater for frequency of occurrence measures (% of quadrats per site with the respective species) than for cover estimates (average % cover across quadrats per site) (Table G-4) in terms of detecting change between two points in time. Results of frequency and cover sampling adequacy for individual species are shown in Appendices G-3 and G-4, respectively. Over twice as many species were adequately sampled for changes in frequency as cover. Therefore, we suggest that frequency of occurrence be considered as a metric for measuring plant "abundance" in future long-term monitoring in the Tahoe basin. If percent cover is a more appropriate metric to meet the objectives of a long-term monitoring program, then additional quadrat sampling may be necessary to adequately monitor this metric relative to frequency values.

Table G-4. Number of plant species per life form detected sufficiently to be able to detect changes of 20% or more in percent frequency and cover estimates per site with 80% confidence and power.

Life Form	Frequency	Cover
Shrubs	16	3
Herbs	48	23
Grass-like plants	3	1
Ferns	0	1
Total	**67**	**28**

Recommended Monitoring Strategy for Plants

Based on above analyses of sampling method efficiency and sampling adequacy for site occupancy and plant abundance metrics, we recommend the following strategy for future long-term plant monitoring in the Tahoe basin.

- Consider an apriori or post hoc stratified sampling design in which strata are based on either biological, spatial or intrinsic factors that increase within strata site occupancy, and that take into account monitoring objectives and compatibilities with wildlife communities in the Tahoe basin.
- Augment plant surveys at each monitoring site with the addition of quadrat and line transect sampling that is similar to other previously established protocols (e.g., Weixelman 2005).
- Utilize both site occupancy and abundance measures as metrics to monitor changes in plant species composition over time, with focus on the dominant species and key species of interest for each plant community strata identified.
- Abundance measures based on the frequency of quadrats occupied per site (versus the average cover per quadrat per site) are recommended for highest sampling efficiency (e.g., both in terms of minimizing sampling effort and metric variability). This metric should be used when appropriate to indicate species abundance at a given site.

Habitat Condition

H. Forestwide habitat condition

Habitat condition (e.g., vegetation composition and structure) was measured at monitoring sites for the purpose of describing current baseline forest vegetation conditions, wildlife habitat and current fuels loading.

General Description of Forestwide Sites

Forestwide monitoring sites were classified into habitat types (and size/density classes) using the California Wildlife Habitat Relationhip (CWHR) classification system (CDFG 2005b) applied to field collected data. Habitat types were determined for each of the 4 stations at each site based on mean canopy cover measurements taken with a spherical convex densiometer, tree species composition data collected in fixed area plots, and shrub/herbaceous species composition data from quadrats and vegetation transects as needed to define non-tree dominated habitat types (Appendix H-1). Size classes (Mayer and Laudenslayer 1988) were based on quadratic mean diameter of trees recorded in fixed area tree plots (Appendix 1-7) and density classes (Mayer and Laudenslayer 1988) based on mean canopy cover estimates recorded via densiomter measurements at each station.

A total of 14 habitat types were represented across the 105 forestwide monitoring network of sites; 9 tree, 3 shrub, 1 herbaceous-dominated habitat type, and the developed urban type (Appendix H-2). Of these, white fir habitat occurred most frequently (43 sites). Red fir and Jeffrey pine were the next most frequently encountered habitat types, occurring at 40 and 30 sites, respectively. Wet meadow habitat was encountered at 5 sites, and aspen at 3 sites. The wet meadow habitat type included special aquatic habitat types such as fens, in addition to non-fen wet and dry meadows. The urban and sagebrush types only occurred at one site each. Additional habitat types existing in the Tahoe basin (based on IKONOS v.4) that were not recorded at MSIM monitoring sites include: barren (1% of Tahoe basin), mixed chapparrel (0.5%) and perennial grassland (1%). All three of these habitat types are very limited in distribution in the Tahoe basin, often occurring in small pockets that were missed by MSIM broad scale sampling. It is also likely that such areas, when encountered, contained tree densities characteristic of an open canopy forest or alternative shrub habitat type based on the dominant features at the monitoring site, and thus may have been classified as a different habitat type.

Multiple size and density classes were represented within each of the habitat types encountered among MSIM monitoring sites (Appendix H-2). Most habitat types and size/density classes were well distributed across all watersheds within LTBMU, with the exception of alpine dwarf shrub (ADS), juniper (JUN), lodgepole pine (LPN) and subalpine conifer (SCN) habitats. Both ADS and JUN were primarily encountered in the southern watersheds of the Tahoe basin and SCN and LPN in southern and western watersheds (Appendix H-2).

Remotely sensed data accuracy

In addition to classifying CWHR habitat types based on field collected data, we also classified habitat types based on the IKONOS v.4 GIS data layer in order to determine the frequency of concurrence of the 2 datasets. A total of 410 out of the 420 stations sampled (4 stations were sampled at each of 105 sites; Appendix 1-7) had both GIS and field based CWHR classification data for comparison. Overall, the habitat types varied significantly with regard to the agreement between GIS generated and ground truthed data collected at MSIM stations in the field (Table H-1).

Wet meadow, Jeffrey pine, lodgepole and subalpine conifer habitat types had the highest frequency of concurrence between remotely sensed and ground truthed data, with and average of 68% agreement (range: 50-100%; Table H-1). Red fir and white fir habitat types had moderate levels of concurrence; 39% of red fir and 43% of white fir stations, as classified by IKONOS, were classified as the same habitat type in the field. Red fir and white fir habitats overlap and mix at intermediate elevations increasing the likelihood for cross classification of these 2 habitat types. Habitat types with very poor rates of concurrence included: aspen, montane chaparral, montane riparian, sagebrush and sierran mixed conifer. Again, some of these types overlap with other habitat types hence increasing the potential for these habitats to have features of multiple types, with classification outcomes becoming dependent upon the dominant features perceived by the classification scheme (remote sensed data- versus on the ground characteristics).

These data highlight some of the potential biases of remotely sensed habitat datasets available for management planning. Management activities are often dependent upon the use of habitat data at some level for planning, evaluation and/or monitoring and understanding potential biases is important for selecting the most appropriate dataset and in interpreting the dataset for management objectives. Vegetation data collected as part of this MSIM effort could be used to help improve such GIS datasets used for land management planning in the Lake Tahoe basin.

Table H-1. Comparison of CWHR (California Wildlife Habitat Relationships) habitat classification of stations sampled at each of the 105 forestwide monitoring site based on 1) remotely sensed (IKONOS) and 2) field collected data. Four stations were sampled for habitat conditions at each site (see Appendix 1- 7). Values represent the number of stations classified as each CWHR habitat type based on the indicated method. Concurrence represents stations classified as the same habitat type based on field collected data as was assigned based on the IKONOS data layer.

CWHR Habitat Type	IKONOS (# stations)	Concurrent field based data (# stations)	% concurrence
Aspen	9	0	0
Barren	6	0	0
Jeffrey Pine	49	32	65
Lacustrine	2	0	0
Lodgepole Pine	7	4	57
Mixed Chaparral	5	0	0
Montane Chaparral	50	3	6
Montane Riparian	8	1	13
Perennial Grass	4	0	0
Red Fir	83	32	39
Sagebrush	56	0	0
Sierran Mixed Conifer	12	1	8
Subalpine Conifer	34	17	50
Wet Meadow	1	1	100
White Fir	75	32	43

Forestwide Vegetation Structure

Vegetation structure data were summarized across all monitoring sites and according to 3 primary strata of importance to management planning in LTBMU (e.g., CWHR habitat type, sub-watershed, and wildland urban intermix zones) in order to highlight patterns observed in association with these strata (Appendices H-3, H-4 and H-5). The following general observations were made with regard to vegetation structure across all monitoring sites and according to individual strata. In general, most components of vegetation structure were highly variable; coefficients of variation near and above 100% were very common. Vegetation structure data were not summarized for the sagebrush and urban habitat types (only 1 site sampled in each of these types).

Vegetation conditions across all monitoring sites

Coarse Woody Debris

- Overall coarse woody debris biomass (logs > 3 in diameter) were high; an average of 15.5 (s.d. = 18.2; range = 0-108.6) tons/acre of coarse woody

debris were observed per site. Approximately 50% of sites had total log volumes of > 10 tons/acre, and ~30% of sites were >20 tons/acre.
- A greater volume of large (> 12 in diameter) and soft (decay class 3-5) coarse woody debris was observed than small (< 12 in diameter) and hard (decay class 1-2) coarse woody debris.

Tree/Snag Size and Densities
- Small tree densities (~50 trees/acre) and small snag densities (~4 snags/acre) were greater than and much more variable than large tree densities (~ 4 trees/acre) or large snag densities (~ 1 tree/acre), respectively.
- The ratio of small/medium (< 24 in dbh) to large/extra large (>24 in dbh) tree densities at monitoring sites was on average 16:1 reflecting the dominance of younger trees in the forests surrounding Lake Tahoe, whereas that for snags was about 4-5:1.
- Overall tree densities were much greater than snag densities.
- Approximately 40% of sites had total tree densities greater than 100 live stems/acre and greater than 10 snags/acre.
- Approximately 17% of sites had greater than 3 extra large snags (>30 in dbh) per acre and 2% of sites had greater than 6 extra large trees (>30 in dbh) per acre.
- Quadratic mean diameter values averaged 19.5 inches per site (s.d. = 5.6); and stand density index values averaged 195 stems/acre (s.d. = 102) across all sites.
- Canopy cover values averaged 50% cover (s.d. = 20%) per site across sites sampled in LTBMU, and canopy cover was less variable among sites in the same sub-watershed (Appendix H-4 than among sites within the same habitat type (Appendix H-3), when based on the mean coefficient of variation (CV) across respective strata.
- Of 37 sites sampled for tree regeneration via seedling/sapling counts, we observed tree regeneration (presence of live seedlings/saplings) at 95% of sites.
- An average of 229 (s.d. = 286) seedlings (< 1 inch dbh) per acre were observed; ranging from 0 to 1178 per acre.
- An average of 75 (s.d. = 52) saplings (1-12 in dbh) per acre were observed; ranging from 0 to 193 per acre.

Vertical Vegetation Structure
- Live vegetation was observed most frequently (~50% of transect points sampled) between 0-1 meters from the ground surface compared to all other height intervals, and relatively few sites contained vegetation above 25 meters (~75 ft).

Ground Cover

- Ground cover was dominated most consistently by litter (~ 50%) with other cover types (e.g., shrubs, rock, grass, bare ground etc) less common overall.
- Litter depth values varied much more dramatically by habitat than by the other 2 strata (sub-watersheds and wildfire threat zone)

Vegetation conditions across habitat types (Appendix H-3)

Coarse Woody Debris

- Habitats with the highest mean coarse woody debris (CWD) volumes were Sierran mixed conifer, red fir, white fir, and subalpine conifer; all 4 habitat types had greater than 15 tons/acre on average of CWD. This pattern was driven primarily by the dominance of large (> 12 in diameter) CWD within these habitat types.
- Highest mean small (< 12 in diameter) CWD volumes were observed in aspen, Sierran mixed conifer and white fir habitat, however all small CWD volumes were less than ~ 3 tons/acre.

Tree/Snag Size and Densities

- Large and extra large (> 24 in dbh) tree and snag densities were greatest in red fir, white fir and Sierran mixed conifer habitat types; similarly mean canopy cover was greatest in these 3 habitat types as well.
- Small and medium (< 24 in dbh) tree and snag densities were greatest in white fir, Sierran mixed conifer, aspen and lodgepole pine forests.
- Tree dominated habitat types with the largest mean QMD per site were juniper and red fir
- Stand density indices were highest in red fir followed by white fir and sierra mixed conifer

Vertical Vegetation Structure

- Habitat types associated with higher water tables (aspen, montane riparian and wet meadows) most frequently contained vegetation in the lowest height interval (0-1 meters above ground)
- Montane riparian habitat was the most vertically structurally complex habitat type with vegetation consistently present in all height intervals up to 40 meters, with red fir and white fir habitat types next most structurally complex

Ground Cover

- Mean litter depths were greatest in montane riparian habitat as well as red fir, white fir and Sierran mixed conifer habitats
- Litter was the dominant ground cover in all coniferous forest types, shrub cover was second most dominant ground cover across most habitat types especially in Aspen, Jeffrey pine and white fir habitat- least in lodgepole and subalpine conifer, rock cover was highest in shrub dominated habitats and herbs and grasses as expected were observed as a greater proportion of ground cover in wetter habitat types (wet meadow, montane riparian and aspen)

Red fir, white fir and Sierran mixed conifer habitats were the most dense, structurally diverse habitats sampled in LTBMU. These 3 habitat types may have the greatest potential to contribute to old growth conditions in the Tahoe basin based on their high densities of large and very large trees and snags. Additionally, red fir, white fir and Sierran mixed conifer contain the highest densities of trees and snags, greatest stand density index values, coarse woody debris volumes and litter depths.

Vegetation conditions across sub-watersheds (Appendix H-4)

Coarse Woody Debris

- Greatest mean total coarse woody debris (CWD) biomass was observed in Lake Tahoe East shore south, Upper Truckee-Trout, Ward-Blackwood-Eagle Rock and Burton-Watson-Tahoe Vista sub-watersheds. All 4 sub-watersheds had greater than 15 tons/acre on average, with Lake Tahoe East Shore – South having nearly 30 tons/acre on average.
- Mean biomass of large CWD (> 12 in diameter) varied from ~5-25 tons/acre while biomass of small CWD (< 12 in diameter) varied from an average of 0.2-almost 2 tons/acre.

Tree/Snag Size and Densities

- Large tree densities were greatest in Upper truckee-Trout and Ward-Blackwood-Eagle rock watersheds, while large snag densities were greatest in Ward-Blackwood-Eagle rock and East shore south watersheds.
- Mean quadratic mean diameter values were greatest in Lake Tahoe East Shore- South Half, Ward Creek-Blackwood Creek-Eagle Rock Frontal and McKinney Creek-Bliss-Eagle Creek Frontal sub-watersheds
- Stand density index values were also greatest in the Ward Creek-Blackwood Creek-Eagle Rock Frontal sub-watershed
- Canopy cover was between 40-60% on average in all watersheds.

Vertical Vegetation Structure

- All watersheds had fairly consistent and even vertical distributions of vegetation up to 25 meters height, with the the height interval 0-1 meters containing vegetation most frequently.

Ground Cover

- Litter depth was greatest in Burton-Watson-Tahoe Vista and East shore south watersheds
- Litter was the most common ground cover (~50% in most watersheds), with shrub, bare ground and rock cover next most important at monitoring sites.
- Shrub cover was on average greatest in Burton-Watson-Tahoe Vista
- Bare ground had greatest cover in Stateline-Third-Incline
- Rock was most dominant in Cascade-Tallac-Taylor watershed

The following 3 watersheds appear to have the greatest old growth contributing features (high large tree/snag densities, high large CWD volumes): Ward-Blackwood-Eagle rock, East shore south and Upper Truckee-Trout. The same 3 sub-watersheds, in addition to Burton-Watson-Tahoe Vista sub-watershed also appear to contain the highest mean densities of trees/snags, greatest stand density index values, coarse woody debris volumes and litter depths.

Vegetation conditions across wildland urban interix (WUI) zones (Appendix H-5)

Coarse Woody Debris

- In general, mean total coarse woody debris (CWD) biomass was greatest in threat zone, averaging nearly 30 tons/acre, while the defense zone and area outside the wildland urban intermix zone had lower mean CWD biomass, closer to ~15 tons/acre.
- Small CWD (<12 in diameter) ranged from ~1-2 tons/acre and large CWD (> 12 in diameter) biomass ranged from 12-24 tons/acre.

Tree/Snag Size and Densities

- Snag densities (small and large), and tree densities (all but the largest size classes) were greatest in threat zone, followed by the defense zone and least at sites outside the defense/threat zone
- Mean quadratic mean diameters were smaller in the threat and defense zones than outside of them, but differences were small
- Stand density index values were higher in the threat and defense zone than outside them

- Canopy cover was greatest on average in the threat/defense zones.

Vertical Vegetation Structure

- Vertical vegetation structure was fairly similar across all zones, with 40% of most sites containing vegetation within 1 meter of the ground, and 20% of most sites containing vegetation fairly evenly distributed from 1- 25 meters above ground.
- On average, ~25-30% of the area at sites within the WUI defense and threat zone contains live vegetation between 1 and 10 meters in height, whereas ~ 21-22% of defense and threat zone sites contained live vegetation between 10-25 meters in height.

Ground Cover

- Ground cover composition was also fairly similar across zones; the dominant ground cover type was litter (~45-60% cover among zones), followed by shrub cover (~15%).
- Litter depths were also greatest in the threat/defense zones

Monitoring sites in the WUI threat and defense zones overall contained higher CWD biomass, litter depth, small and medium tree and snag densities (<24 in dbh) than sites outside those zones in the general forest.

Late Seral Old Growth monitoring at MSIM sites

Late seral old growth habitat is of particular importance in the Lake Tahoe basin and the greater Sierra Nevada due to its inherent ecological functional significance, the long time periods required for its development and the drastic reduction in extent that has been observed over the past century throughout the Sierra Nevada due to tree harvest practices (Murphy and Knopp 2000, Franklin and Fites-Kaufmann 1996). Franklin and Fites-Kaufmann (1996) evaluated the current status of Sierra wide late-seral old growth areas and identified habitat types particularly deficient at Sierra wide scale: mixed conifer and east side pine. Only approximately 8% of forests of the Sierra Nevada are ranked high (value of 5) in terms of their relative contribution to old growth habitat in the Sierra (14% with values 4-5), with 30% of red fir habitats throughout the Sierra Nevada ranked high, a habitat type less impacted by logging at lower eastside sites.

Additionally their assessment of late-seral old growth habitat on national forests throughout the Sierra Nevada (Franklin and Fites-Kaufmann 1996) indicated that < 15% of forests are ranked as highly or very highly contributing to old growth function, with currently only 5% of forests in the Lake Tahoe basin currently in old growth status. Desired conditions for LTMBU are 75-85% old growth (Murphy and Knopp 2000), and periodic sampling (e.g., every 5 years) of key old growth characteristics at MSIM forestwide monitoring sites could provide a means to monitoring progress towards this goal, especially at sites within old forest emphasis areas (48 MSIM monitoring sites are in old forest emphasis areas).

Vegetation characteristics (e.g., canopy cover, large tree and snag densities and coarse woody debris loads) described above provide a comprehensive picture of the current status of forest condition in the Tahoe basin and help to inform us of the potential for old-growth recovery in particular areas of interest: sub-watersheds, habitat types, etc (Figure H-1).

Approximately 20% of MSIM forestwide monitoring sites contained at least one station classified as CWHR size density class 6; containing the largest trees and the most structurally diverse habitat based on CWHR habitat classification. However, most of these sites had only 1-2 stations (each ~ 1 hectare in size) of 4 stations sampled at each of the 105 sites, in such status, reflecting a very small patch size that may or may not be ecologically functional. Based on all 420 stations sampled, only 5% of stations were in the 6 size/density class, similar to that indicated in the Lake Tahoe Watershed Assessment (Murphy and Knopp 2000). Monitoring stations classified as size density class 6 generally had greater densities of large trees and snags and greater large sized coarse woody debris volumes than other stations (USFS unpubl. data) suggesting that "old growth" typical features were associated with stations classified as 6, as would be expected. This late seral habitat classification (i.e., 6) occurred in the following habitat types and lcoations of the Tahoe basin: Jeffrey pine in the east, lodgepole in the south, red fir primarily in the west, but additionally scattered in northern and southern sub-watersheds, Sierran mixed conifer in the north and east, subalpine conifer in the south and west and white fir in the east, south and west (Appendix H-2).

Regardless of the criteria used to indicate old growth, habitat conditions at MSIM monitoring sites could be monitored to help us better understand current old growth condition, identify areas with future old growth potential, and to monitor movement towards desired conditions. For example monitoring sites within old growth emphasis areas (48 sites), or in areas of Sierra Nevada old growth rating values 4-5 (17 sites) could be monitored for old growth condition in order to specifically to track changes towards desired conditions.

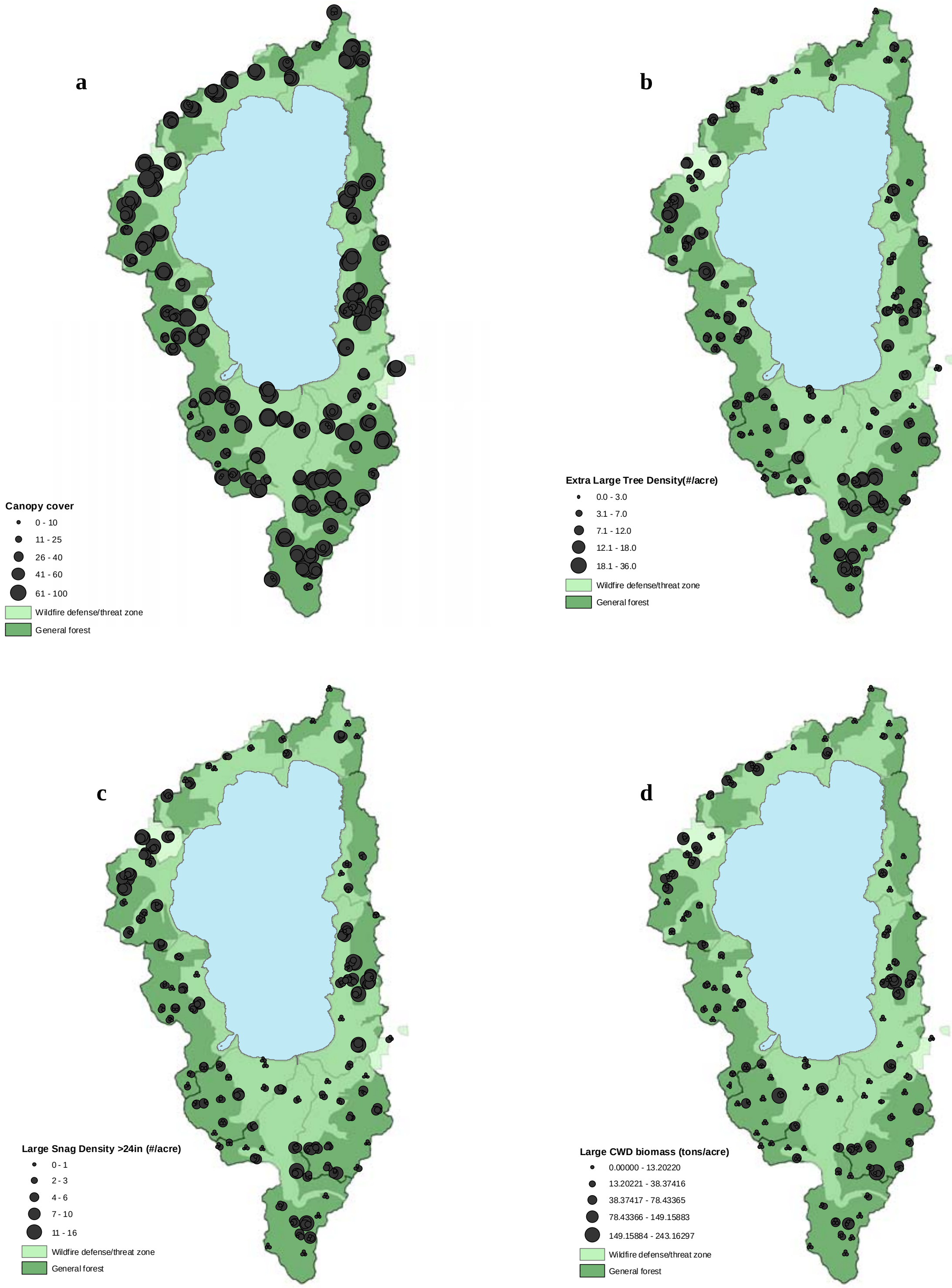

Figure H-1. Mean percent canopy cover (a), large tree densities (>30 in dbh) per acre (b), large snag densities (>24 in) (c), and coarse woody debris (CWD) biomass (d) at 105 MSIM monitoring sites, 2002-2005.

Habitat metric evaluation

Habitat metric variability

The following habitat condition metrics had the least variability (coefficient of variation < ~100%) among sites: proportion of live vegetation per height interval (vertical structure), basal area, canopy cover, quadratic mean diameter and stand density index. Trends in forest conditions are more likely to be statistically detectable with these metrics than with the other metrics that had greater variability. Coarse woody debris biomass, tree and snag densities, litter depths and percentage ground cover estimates were more highly variable.

We also compared metric varibility (mean coefficient of variation values) among 4 stratification schemes (HUC 6 sub-watersheds, Terrestrial Ecological Unit Inventory (TEUI) subsections, CWHR habitat types and Wildland-Urban intermix zones). We found that grouping sites by sub-watershed reduced within strata (i.e., sub-watershed) variability most for the majority of metrics. Grouping sites by TEUI subsections reduced metric variability almost as effectively as by sub-watershed. This suggests that sub-watersheds may be the optimal strata for monitoring forest conditions.

Associations with wildlife

We evaluated associations between habitat metrics and wildlife and plant occurrences to additionally inform us about the utility of the various habitat measures for a long-term comprehensive monitoring program. A series of covariate analyses were conducted for each species (single-factor logistic regression models modified by species detection probabilities; MacKenzie et al 2006), in order to quantify the number of wildlife or plant species that were significantly associated with each of the numerous habitat variables tested. Habitat variables tested were grouped into categories based on similarity in the type of data that were collected. The number of species significantly associated with at least one variable in each variable group was a relative indicator of the importance of those habitat variables to the wildlife and plant species in the Tahoe basin. A list of specific habitat variables included in each variable group is shown in Appendix H-6.

As a result of the covariate analysis, we found the following variables to be most important to site occupancy of wildlife as a whole: tree and snag densities, spatial location in the basin, habitat context, vertical structure, canopy cover, ground cover and disturbance (Table H-2). Thirteen or more species of wildlife were significantly associated with each of the above mentioned variable groups. However, species groups differed in the relative importance of each variable group (Table H-2). Birds seemed most responsive to spatial variables (e.g., elevation, watershed location) and habitat context (e.g., habitat matrix surrounding each site). Small mammals were most influenced by habitat context and tree and snag densities. Carnivores were primarily influenced by tree and snag densities, and secondarily by tree size, basal area, slope, coarse woody debris and spatial location. Lastly bat occupancy was most often associated with habitat context and vertical structure.

The following variable groups were most important to the occurrence of plant species: spatial variables, canopy cover and year of survey. Secondarily important habitat variables to plant occupancy were: soil type, amount of litter and ground disturbance.

Table H-2. Associations between wildlife and plant species and various habitat metrics sampled at MSIM forestwide monitoring sites, 2002-2005. Values indicate the number of species in each species group for which site occupancy was significantly associated with at least one habitat variable within the identified variable group. An "x" denotes a variable group not tested in modeling for the respective species group.

Covariate group	Birds	Small mammals	Carnivores	Bats	Botany	Wildlife Species	All Species
Spatial	26	6	2	0	31	34	65
Tree/snag Density	22	9	4	2	x	37	37
Canopy Cover	15	2	1	0	14	18	32
GIS Habitat	24	0	x	3	x	27	27
Field habitat	14	10	x	x	x	24	24
Vertical Structure	13	7	x	3	x	23	23
Disturbance	8	5	x	x	7	13	20
Year	6	1	x	0	12	7	19
Ground Cover	7	7	x	x	x	14	14
Amount of Litter	x	3	x	x	7	3	10
Soil Type	x	x	x	x	7	0	7
Tree size	2	0	2	0	x	4	4
Coarse Woody Debris	x	1	2	x	0	3	3
Basal Area	x	x	2	x	x	2	2
Slope	x	x	2	x	x	2	2
Protocol Intensity	x	1	x	x	x	1	1
Distance to water	x	x	0	x	x	0	0
Tree decadence features	x	x	x	0	x	0	0
Lentic habitat availability	x	x	x	0	x	0	0

Summary of habitat metric evaluation

Several habitat metrics with the lowest inherent variability were also important for describing site occupancy for a number of wildlife and plant species: canopy cover, vertical structure and basal area. One additional variable that was important for wildlife occupancy, tree and snag densities, while determined to be highly variable in raw form, was less variable when calculated as the commonly used metric stand density index. Therefore, at minimum it appears that the above mentioned habitat metrics, canopy cover, vertical structure, tree and snag basal area and stand density index could be incorporated into a long term monitoring program for the purpose of monitoring trends in forest conditions and wildlife habitat elements over time at the basinwide scale due to considerations of metric variability and importance to wildlife.

Alternatively, ground cover and coarse woody debris volume, while found to be important to a variety of wildlife and plant species, were also identified as highly variable metrics. We recommend using a measure of variability for these habitat variables (and potentially for all habitat variables) as a monitoring metric in addition to the "average", because biological diversity is often related to habitat diversity. While individual species may respond to specific conditions in part of a given stand, communities (and diversity) often reflect the variability within the stand.

I. Lentic habitat condition

Habitat condition (vegetation composition and structure) was measured at lentic sites for the purpose of describing current baseline conditions and interpreting how conditions relate to historic and desired conditions, and how they contribute to wildlife biodiversity.

General Description of Lentic Sites

MSIM lentic monitoring sites comprised 4 aquatic habitat types: wet meadows, small lakes (< 1 acre), medium lakes (1-10 acres) and large lakes (> 10 acres). These habitat types were distributed across most watersheds and elevations of the Tahoe basin (Table I-1), with a few exceptions. Large and medium-sized lakes were less frequently sampled in watersheds in the north and the east, small lakes were absent from our sample in the northernmost watershed along the west shore, and meadows were absent from low elevations in watersheds in the north. Aquatic associated habitat types not sampled in this effort include streamside riparian, marshes and Lake Tahoe shoreline habitat.

Table I-1. Sampling frequency of lentic habitat types within each of the 9 sub-watersheds (HUC level 6) within the Lake Tahoe basin, 2003-2004.

		North		East		South			West	
Habitat Type	**Elevation**	**Burton-Watson-Tahoe Vista**	**Stateline Point-Third-Incline**	**East Shore North**	**East Shore South**	**Upper Truckee River**	**Upper Truckee-Trout**	**Cascade-Tallac-Taylor**	**McKinney-Bliss-Eagle**	**Ward-Blackwood-Eagle Rock**
Meadows	≥ 7,500 ft			1	1	5	2	2	1	2
	< 7,500 ft	3		1	3	1		3	2	3
Small lakes	≥ 7,500 ft		4			6	5	8	3	
	< 7,500 ft	3		1	2	9		2	4	
Medium lakes	≥ 7,500 ft	1				11		3	8	2
	< 7,500 ft		1	1	1	7		4		1
Large lakes	≥ 7,500 ft			1		7	1	5	6	
	< 7,500 ft			1		1		4	3	2
Total		7	5	6	7	47	8	31	27	10

The landscape context (i.e., area within 200 meters) of lentic monitoring sites sampled most consistently comprised the following habitat types: lodgepole pine, Jeffrey pine, red fir, subalpine conifer and slightly less frequently white fir, sagebrush and mixed chapparel; however, this varied by sub-watershed (Table I-2). Lentic sites in the northwestern portion of the Tahoe basin were dominated by white fir and mixed chapparal, while those on the east shore were dominated by Jeffrey pine, those in the Upper Truckee river drainage basins were quite diverse, with the greatest lodgepole pine component than any other watersheds. Impervious surfaces (i.e., Urban type) were most common in the vicinity of lentic sites in the southern watershed along the east shore reflecting the high development intensity in this region of the Lake Tahoe basin.

Table I-2. Proportion of each habitat type (based on IKONOS v.4) within 200 meter buffer of all lentic monitoring sites within each watershed (HUC level 6).

	North		**East**		**South**			**West**	
Habitat Type	**Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 7)**	**Stateline Point-Third Creek-Incline Creek Frontal (n = 5)**	**Lake Tahoe -East Shore Frontal / North Half (n = 6)**	**Lake Tahoe -East Shore Frontal / South Half (n = 7)**	**Upper Truckee River (n = 47)**	**Upper Truckee River - Trout Creek (n = 8)**	**Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 31)**	**McKinney Creek-Bliss-Eagle Creek Frontal (n = 27)**	**Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 10)**
Aspen			8	3	1		3		
Sierran Mixed Conifer	2	**11**	2	8	6	1	4	4	2
Jeffrey Pine	8	8	**51**	**35**	**10**		**13**		
White Fir	**66**				< 1		4	**25**	**48**
Red Fir			**14**	**10**	**17**	4	3	2	3
Lodgepole Pine		**11**	< 1	< 1	**13**	**50**	3	6	2
Subalpine Conifer	< 1	**20**	< 1		**9**	**23**	7	9	**20**
Barren	1	< 1	< 1		1	1	4	4	1
Mixed Chapparal	**16**	**13**	**13**	**11**	**22**	4	**18**	**22**	**11**
Sagebrush*	1	**16**	3		**10**	**14**	**37**	**22**	2
Perrenial Grassland	1		4	**12**	4	< 1	< 1	1	2
Montane Riparian	1	**16**	1	4	4	2	1	3	**10**
Wet Meadow	< 1				1			< 1	1
Laclustrine	1	1	2	3	2	< 1	1	2	< 1
Urban (impervious)	2	5	1	**15**	1		1		

* Sagebrush habitat type polygons from IKONOS that overlapped significantly with the impervious surfaces GIS layer were re-assigned to the "Urban" habitat type (Sean Parks, pers. comm.). This habitat type is known to have been over-assigned in the IKONOS datalayer

Manley and Lind (2005) reported on littoral zone habitat characteristics at lentic sites; silt was the most common littoral zone substrate, present at 98% of sites, and silt exceeded 75% of littoral zone substrate cover at the majority of sites. The remaining larger sized substrate types (e.g., sand, cobble, bedrock, etc) were only present at 40 to 60% of the sites, and few sites exceeded 25% cover of any of the remaining substrates. Of these, sand and cobble were the next most common secondary substrates.

Logs were prevalent, but were typically not abundant in the littoral zone at most sites (Manley and Lind 2005). Approximately 70% of sites contained one or more logs in the littoral zone, with most sites having less than 25% of the littoral zone occupied by logs.

Emergent plants were both prevalent and abundant at lentic sites (Manley and Lind 2005). Emergent plants were present at over 90% of all sites, and the majority of sites (60%) had emergent plants occupying 25% or more of the littoral zone. Submergent vegetation was the next most common vegetation life form;

approximately 30% of sites had submergent plants occupying 35% or more of the littoral zone.

Upland habitat characteristics (area within 3 meters of waterline) of lentic sites are described here for the first time. Similar to the littoral zone, silt substrates dominated the upland shoreline of lentic sites (Table I-3). However, cobble and bedrock were each consistently detected along ~15% of the shoreline around large lakes. Availability of coarse woody debris in the upland for cover was low overall, but greatest on average and most variable at small lakes. Herbaceous ground cover was the most widespread covertype in the upland surrounding lentic sites; sites on average contained 60-80% herbaceous cover in the upland, followed by shrub cover (30-50%) and tree cover (20-30%)(Table I-3). Small lakes appeared to have the lowest percentage of vegetative cover in the upland for each cover type compared to all other lentic sites.

Table I-3. Upland substrate and vegetation characteristics adjacent to lentic sites sampled in the Lake Tahoe basin as part of the Multi Species Project during 2004.

Upland Characteristic		Meadows (n =5)	Small Lakes (n = 24)	Medium Lakes (n = 13)	Large Lakes (n = 10)
Substrate Cover (%)[1]					
Silt	**Mean**	**84**	**77**	**77**	**46**
	s.d.	28.7	26.4	20.8	25.7
Sand	**Mean**	**0**	**2**	**4**	**8**
	s.d.	0.0	11.0	12.4	8.9
Pebble	**Mean**	**3**	**4**	**4**	**7**
	s.d.	5.8	10.1	6.3	4.0
Cobble	**Mean**	**5**	**3**	**2**	**16**
	s.d.	7.0	4.8	2.5	11.3
Boulder	**Mean**	**1**	**5**	**6**	**9**
	s.d.	1.2	8.6	9.2	3.8
Bedrock	**Mean**	**7**	**9**	**7**	**15**
	s.d.	16.4	13.2	9.5	15.5
Coarse Woody Debris[2]					
Transects with logs (%)	**Mean**	**5**	**11**	**6**	**5**
	s.d.	5.2	15.1	5.8	4.1
Vegetative Cover (%)[3]					
Ground Cover (Herbs, sedges/rushes)	**Mean**	**89**	**63**	**81**	**80**
	s.d.	14.9	37.0	30.5	14.6
Shrub Cover	**Mean**	**46**	**30**	**47**	**54**
	s.d.	33.6	24.2	25.1	24.5
Tree Cover	**Mean**	**35**	**17**	**32**	**19**
	s.d.	40.8	19.4	18.7	11.1

[1] Average percent of cover along upland transects covered by each substrate type indicated

[2] Average percent of upland transects with logs intersecting them

[3] Average percent of upland transects with each cover type present along them. Ground cover = rushes, sedges, grasses and herbs, shrub cover = willow, mountain alder and other non-tree woody stemmed plants, tree cover = aspen, cottenwood, lodgepole pine, and any other conifer or deciduous tree

On average lentic sites had a single inlet and a single outlet, with the exception of large lakes which tended to have an average of 2 inlets and a single outlet (Table I-4). Small and medium lakes frequently did not have any inlets or outlets; they are likely sustained in large part by snowmelt.

Table I-4. Connectivity of lentic monitoring sites to surrounding aquatic sites in the Lake Tahoe basin. Inlets and outlets included all channels > 4 inches wide that either contained water during the survey or where apparently ephemeral channels.

	Meadows (n =5)	Small Lakes (n = 24)	Medium Lakes (n = 13)	Large Lakes (n = 10)
Number of inlets	**1.0**	**0.6**	**1.0**	**2.0**
s.d.	1.0	0.6	1.2	1.3
Number of outlets	**1.0**	**0.5**	**0.8**	**1.0**
s.d.	1.2	0.5	0.4	0.5
Sites without inlets (%)	**20**	**46**	**38**	**10**
Sites without outlets (%)	**20**	**50**	**15**	**10**

Remotely sensed data accuracy

The site selection process for lentic monitoring sites brought to our attention that there is no comprehensive map of aquatic habitats currently available for the Lake Tahoe basin. Current GIS layers exist for waterbodies (i.e., Waterbody layer), wet meadow/marsh habitat types, streams and riparian vegetation within various remote sensed vegetation layers (Terrestrial Ecological Unit Inventory-TEUI, eveg, IKONOS, drgs), however, there is no single layer representing this compiled dataset. Aquatic habitats are a critical to maintaining ecosystem biodiversity and such a data layer should be developed if we expect to manage and monitor this component of the ecosystem effectively.

In addition to compiling such datasets into a single GIS layer, ground truthing will likely be necessary to improve accuracy of existing layers, as current remotely sensed data with respect to aquatic/riparian habitat types is suspected to be lower than desired. For example, 346 lakes/ponds were identified within the California portion of LTBMU based on data from 7.5 minute map quads (J. Hanson pers. comm.), however the LTBMU's "waterbody" layer only recognizes 305 lakes/ponds in this same area. Similarly, there is no single comprehensive layer for wet meadows; a compilation of wet meadow habitat polygons from TEUI, eveg and IKONOS indicate 149 meadow polygons in the Tahoe basin, but the accuracy of these is not known. Therefore, while MSIM did a good job of representing various aquatic habitat types throughout the Tahoe basin, we did not have complete GIS data for LTBMU to work with. Future monitoring efforts should consider developing a more accurate and comprehensive map (via GIS) of all known aquatic habitat types within the LTBMU before finalizing monitoring strategies.

Lentic Wildlife-Habitat associations

Manley and Lind (2005) previously reported on basic habitat relationships for amphibians and aquatic reptiles (garter snakes). Key results are summarized below.

Individual species associations:

- Long-toad salamander and Pacific treefrog occurred more frequently at smaller-sized sites.
- Western toad occurred more frequently in drier environments with a greater abundance of riparian vegetation, similar to the Sierra garter snake.
- Western terrestrial garter snake appeared to occur more frequently at larger-sized sites at lower elevations.
- Common garter snake was associated with low elevation and high precipitation, suggesting that it was most frequently occurring at lower elevations on the west side of the basin.
- Long-toed salamander and Pacific treefrog were both less common at sites where fish were detected, though some co-occurrence of fish and amphibians was observed
- Western toad was detected too infrequently to evaluate their co-occurrence relative to fish.

Associations with amphibian and reptile persistence at sites:

- Site persistence index values were generated for sites which accounted for the proportion of survey years with occupancy of native amphibian and reptile species and the duration of occupancy across 2 sampling periods (1997/1998 and 2002-2004)
- Forest cover within 200 meters of sites and precipitation were positively associated with persistence indices.
- Elevation and development within 50 m of sites were negatively associated with persistence indices.

Manley and Lind (2006) reported in depth on specific landscape and local level habitat relationships for the long-toed salamander (*Ambystoma macrodactylum*) in the Lake Tahoe basin. Key findings can be viewed in their report (Manley and Lind 2006). Their approach to single-species habitat modeling identified habitat elements important to both occupancy and abundance. This approach should be a model for evaluating species-habitat relationships of other species in the future.

Project Synthesis

Below is a synthesis of key results on the status and distribution of wildlife and plants detected, the effectiveness of sampling protocols implemented and adequacy of sampling that occurred as part of the Multi-Species Inventory and Monitoring project. This section is a compilation of results reported in individual sections above. It is intended to provide a comprehensive and comparative display of results among all taxomomic groups sampled to allow for easier interpretation for developing monitoring recommendations.

Wildlife and plant biodiversity

First is a summary of biodiversity among sub-watersheds in the Lake Tahoe basin as indicated by total and mean species richness among taxonomic groups. Three sub-watersheds located in the southwestern portion of the Tahoe basin harbored the greatest total number of species per watershed (i.e., gamma biodiversity) for the most taxonomic groups: 1) Cascade Creek-Tallac Creek-Taylor Creek Frontal, 2) McKinney Creek-Bliss-Eagle Creek Frontal, and 3) Upper Truckee River (Table J-1). Sub-watersheds with the lowest gamma biodiversity for the majority of species groups were in the north: 1) Lake Tahoe - East Shore Frontal/North Half and 2) Burton Creek-Watson Creek-Tahoe Vista Frontal. This pattern, however, was likely driven by the species-area relationship concept; land area and hence sampling intensity (i.e., number of sites) were greater in sub-watersheds in the south compared to those in the north.

Subwatersheds with the greatest forestwide habitat diversity also appeared to have the greatest total species richness at forestwide sites (Table J-1), with the exception of the Cascade and Upper Truckee-Trout sub-watersheds. Species richness was high for most species groups relative to habitat diversity in the Cascade sub-watershed, whereas species richness was low relative to habitat diversity in the Upper Truckee-Trout sub-watershed. This might suggest a depauperate wildlife community in the Upper Truckee-Trout sub-watershed relative to what would be expected based on habitat diversity or may reflect the the generally less productive environment on the arid east shore.

When sampling intensity was taken into account, total species richness per site (total richness per watershed/# sites sampled per watershed) was greatest for all wildlife species groups and for plants in the Lake Tahoe-East Shore Frontal/North Half subwatershed, followed by other subwatersheds in the northern portion of the Lake Tahoe basin (e.g., Stateline Point, Burton Creek subwatersheds). This likely indicates that individual sites in northern subwatersheds, are more representative of subwatershed level condition with respect to total species richness than sites in other subwatersheds.

Conversely when looking at beta diversity per subwatershed, a measure of species turnover between sites, we found that nearly all species groups had the greatest beta diversity in the Upper Truckee subwatershed, with the exception of small mammals (greatest in Upper Truckee Trout) and herpetofauna (greatest in Cascade-Taylor-Tallac). Therefore, species turnover between sites among watersheds was greatest in southern subwatersheds. This suggests that subwatersheds in southern LTBMU would require greater sampling intensities than those in northern LTMBU (lower beta diversity) if the intent of the monitoring program is to capture the complete species composition of individual subwatersheds.

Table J-1. Total species richness per sub-watershed by species group. Data are compiled from results of Appendices A-2, B-2, C-2, D-2, F-2 and G-2. Bolded numbers indicate sub-watersheds with the greatest total richness or habitat diversity values[1].

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal	Stateline Point-Third Creek-Incline Creek Frontal	Lake Tahoe - East Shore Frontal / North Half	Lake Tahoe - East Shore Frontal / South Half	Upper Truckee River - Trout Creek	Upper Truckee River	Cascade Creek-Tallac Creek-Taylor Creek Frontal	McKinney Creek-Bliss-Eagle Creek Frontal	Ward Creek-Blackwood Creek-Eagle Rock Frontal
Forestwide Network									
Avian richness	58	59	58	74	70	**91**	**76**	**79**	66
Small mammal richness	15	15	14	**16**	**16**	**20**	**20**	15	15
Carnivore richness	2	0	1	**5**	4	**6**	**6**	4	3
Bat richness	**7**	**6**	5	**9**	0	5	5	**6**	4
Tree richness	8	8	6	9	**11**	**12**	**12**	10	9
Shrub richness	22	19	13	25	24	**38**	**37**	**30**	27
Herbacious richness	86	71	41	72	107	**155**	118	**122**	**121**
Grass-like plant richness	11	9	13	18	**22**	**27**	**26**	21	16
Fern richness	0	2	0	2	3	**7**	**4**	3	**4**
Total plant richness	127	109	73	126	167	**239**	**197**	**186**	177
Lentic Network									
Avian richness	55	43	59	61	41	**93**	**87**	**70**	60
Native herp richness	4	3	4	3	3	**6**	**10**	**6**	5
Habitat diversity[1]	15	15	11	24	**30**	**37**	22	**31**	20

1 Habitat diversity = the number of California Wildlife Habitat Relationship (CWHR) habitat type, size and density classes that were present at forestwide sites sampled in each sub-watershed.

When evaluating mean species richness per site, subwatersheds with the greatest mean species richness values per site (i.e., alpha biodiversity) for the majority of species groups occurred along the westshore and in the northeast: 1) Ward Creek-Blackwood Creek-Eagle Rock Frontal, 2) McKinney Creek-Bliss-Eagle Creek Frontal, 3) Cascade Creek-Tallac Creek-Taylor Creek Frontal and 4) Lake Tahoe East Shore Frontal/North (Table J-2). The sub-watershed with the lowest overall alpha diversity was Upper Truckee River - Trout Creek.

Similar to patterns for total species richness at forestwide sites, mean species richness per watershed generally followed patterns of habitat diversity, but not in all cases. Per site species richness also may have been influence by overall site productivity; as wetter environments, such as on the west shore, support higher plant productivity and are likely to support greater richness of species.

Table J-2. Mean site species richness per sub-watershed across by species group. Data are compiled from results of Appendices A-2, B-2, C-2, D-2,F-2 and G-2. Bolded numbers indicate sub-watersheds with the greatest mean richness or habitat diversity values[1].

Taxonomic Group	Burton Creek-Watson Creek-Tahoe Vista Frontal	Stateline Point-Third Creek-Incline Creek Frontal	Lake Tahoe - East Shore Frontal / North Half	Lake Tahoe - East Shore Frontal / South Half	Upper Truckee River - Trout Creek	Upper Truckee River	Cascade Creek-Tallac Creek-Taylor Creek Frontal	McKinney Creek-Bliss-Eagle Creek Frontal	Ward Creek-Blackwood Creek-Eagle Rock Frontal
Lentic Monitoring Network									
Mean avian richness	**22.3**	17.4	**24.2**	20.6	16.6	18.7	19.0	18.0	**23.0**
s.d.	9.0	6.5	11.0	9.5	6.7	7.8	8.2	8.0	9.3
Mean herp richness	1.2	1.2	1.2	0.6	1.1	1.2	**1.6**	1.2	**2.1**
s.d.	1.6	1.1	1.2	0.5	0.8	1.3	1.3	1.2	1.7
Forestwide Monitoring Network									
Mean avian richness	28.0	29.2	**32.3**	**29.5**	25.3	28.3	27.4	**29.5**	**31.9**
s.d.	6.8	6.2	5.6	4.7	7.2	6.0	5.3	7.0	4.0
Mean small mammal richness	7.9	**8.0**	7.5	7.3	6.0	7.9	**8.3**	7.5	6.8
s.d.	2.0	0.9	1.9	1.2	1.6	2.1	1.0	1.7	1.9
Mean carnivore richness	1.2	0.5	0.5	1.5	1.9	1.6	**2.3**	**2.0**	**2.1**
s.d.	0.8	0.7	0.7	0.9	1.1	1.3	1.4	0.0	0.7
Mean bat richness	3.5	**6.0**	**5.0**	**6.0**	0.0	1.3	2.0	3.7	2.0
s.d.	4.9	n/a	n/a	1.4	n/a	2.1	0.8	3.2	2.8
Mean plant richness	28.6	28.5	24.5	19.2	22.9	**32.6**	32.5	**32.6**	**40.5**
s.d.	13.9	13.8	9.4	8.9	13.6	14.8	17.3	13.7	12.5
Habitat diversity[1]	15	15	11	24	**30**	**37**	22	**31**	20

1 Habitat diversity = the number of California Wildlife Habitat Relationship (CWHR) habitat type, size and density classes that were present at forestwide sites sampled in each sub-watershed.

Species groups

Patterns of species richness among sub-watersheds of the Lake Tahoe basin appeared to differ by species group. In general, bird richness tended to be fairly uniform throughout the Tahoe basin relative to other taxonomic groups (Table J-1 and J-2). Small mammal species richness appeared greatest in the southwestern watersheds of the Tahoe basin. Carnivores and amphibian/reptile richness per site showed stronger differences across watersheds in the basin, with sites in the southern portion generally having the greatest per site richness for carnivores, and sites in the south and west having the greatest richness for herpetofauna. Plant richness was lowest on the east side of the Tahoe basin.

Individual species

Distributions of individual species throughout the Tahoe basin also differed by species and by species group. Overall, birds, bats and aquatic reptiles tended to have the broadest distributions throughout the Lake Tahoe basin compared to other species groups (Table J-3). Of plants, shrubs and trees contained nearly equal or greater percentage of species with broad distributions (29 and 67% of species, respectively) than species with more restricted distribution, while herb, grass and fern species were most often limited in their distribution (Table J-3). Monitoring at the basin-wide scale (such as was conducted in this project) is likely to be more effective for species with broad distributions than those with restricted distributions. Species groups with more restricted distributions might require a more targeted (or stratified) monitoring design compared to broadly distributed species groups.

Table J-3. Number of species within each respective species group surveyed in the Multi Species project detected with broad (detected in 7-9 sub-watersheds), moderate (detected in 3-6 sub-watersheds) and restricted (detected in < 3 sub-watersheds) distributions in the Lake Tahoe basin.

Species Group	Broad Distribution (#)	Moderate Distribution (#)	Limited Distribution (#)	Broad Distribution (%)	Moderate Distribution (%)	Limited Distribution (%)
Wildlife						
Birds	63	37	34	47	28	25
Small mammals	9	13	5	33	48	19
Carnivores	2**	1	7	20	10	70
Bats*	4	4	1	44	44	11
Amphibians	1	3***	0	25	75	0
Aquatic reptiles	2	1	0	67	33	0
Plants						
trees	8	3	1	67	25	8
shrubs	17	18	23	29	31	40
herbs	32	88	191	10	28	61
grasses	4	19	46	6	28	67
ferns	0	3	8	0	27	73

*Bat results are less reliable than other species groups as they are based on sampling at 22 sites only in the Tahoe basin.
** Mule deer, a non-target species detected in carnivore surveys, was additionally detected with broad distribution across the Tahoe basin.
*** includes thedistribution of the exotic bullfrog

Effectiveness of MSIM protocols

MSIM protocols implemented during 2002-2005 were overall highly effective at detecting species expected to be detected within most species groups, and at detecting all species occurring in the Tahoe basin, with a few exceptions (Table J-4). Species expected to be detected were a subset of species known to occur in the Tahoe basin (Murphy and Knopp 2000) based on knowledge of species characterisitics suitable for detection with protocols (e.g., size of animal for fitting into traps, activity pattern of animal relative to sampling time of protocol) and habitats sampled as part of this project; LTBMU does not represent all habitat types that exist in the Tahoe basin (e.g., shorezone).

Overall less than 30% of species, expected from any species group, were missed (Tale J-4). Birds, small mammals and aquatic herpetofauna (amphibians and reptiles) were detected most effectively (> 80% of species detected). Most species missed from individual species groups are rare in the Tahoe basin, and would likely require sampling protocols that target individual species or a much greater number of monitoring sites in order to detect them. More realistically, it is not recommended that the success of future monitoring rely on these rare species.

Additionally for most species groups, implementation of MSIM protocols on National Forest Lands alone was effective at detecting the majority of species that occur in the Tahoe basin (Table J-4), with the exception of birds and plants. This observation suggests that birds and plants are more specialized species groups in terms of their patterns of habitat use throughout the Tahoe basin. Therefore, a future comprehensive monitoring program for wildlife and plants in the Tahoe basin should incorporate additional habitats or land types that are either not present, extremely rare on national forest lands, or not well sampled in the MSIM project (e.g., Lake Tahoe shorezone, marshes, riparian habitats, etc); thus requiring coordination and cooperation between Tahoe basin agencies and potentially private landowners if necessary.

Table J-4. Species detected with the MSIM project surveys, 2002-2005 compared to species known to occur in the Tahoe basin, and those expected to be detected based on habitats and protocol techniques.

Species Group	MSIM Species detected	Species expected[1]	Species that occur in Tahoe basin (WA)	% of expected species detected	% of Tahoe basin species detected
Birds	134	137-151[2]	217	89-98	62
Small mammals	27[3]	29	29	93	93
Carnivores	10	14	14	71	71
Bats	9	10	10	70c	70c
Terrestrial reptiles	4	5	5	80	80
Aquatic reptiles	3	3	3	100	100
Amphibians	4	5	5	80	80
Plants	460	592	1184	71c	35c

1 Expected species list generated from current species in Appendix G in the Lake Tahoe Basin Watershed Assessment (Murphy and Knopp 2000), knowledge about species groups targeted with each protocol and habitats sampled at monitoring sites.

2 Value is expressed as a range due to uncertainties associated with the overlap of some species geographic or elevational range in the Tahoe basin. The low value assumes we would not expect to detect the species with uncertainty, and the high value assumes we would expect to detect those species.

3 Detections include an additional small mammal species, yellow-bellied marmot, that was only detected during bird point counts and was never trapped in Sherman live-traps.

We also evaluated protocol effectiveness based on individual species detectability; the likelihood that each species was detected when it was present at a site (Table J-5). Birds and small mammals had the greatest *total number* of species with moderate-high detectability of all species groups sampled; 44 birds and 9 small mammals. All species groups, however, had at least two species with moderate-high detectability (Table J-5). Amphibians, garter snakes and bats had the highest *proportion* of species within their respective species group detected with high confidence (i.e., with moderate-high detectability) (Table J-5).

It is important for a monitoring program to sample species with known detectability, especially species with moderate to high detectability, or else monitoring results are not likely to reflect true patterns in populations over time. Results from the detectability evaluation (Table J-5) demonstrate that MSIM protocols detect at least 97 species with high confidence.

Several species with unknown detectability, especially birds and plants, would likely have been detected with high confidence if we had sampled in habitat types more appropriate for detection of those species, but were under-represented or missed due to our randomized sampling approach (e.g., riparian habitats, marshes, aspen, Lake Tahoe shorezone, etc). Additional available datasets (e.g., Riparian biodiverisity, birds and small communities in aspen stands, etc.) should be explored or pilot studies initiated to more appropriately determine protocol effectiveness for species with unknown detectability.

Table J-5. The effectiveness of Multi-species Inventory and Monitoring (MSIM) protocols at detecting species with various levels of confidence (high, moderate and low detectability).

Protocol	**Species with high detectability (≥ 80%)**	**Species with moderate detectability (50-80%)**	**Species with low detectability (< 50%)**	**Species with unknown detectability[1]**	**Special Status Species with high detectabiltiy**
Forestwide protocols					
Bird point counts[2]	39	8	4	86	4
Sherman trapping	10*	1	0	17	0
Camera and track plates	2	1	0	7	2
Bat mist-netting	2	2	0	5	2
Terrestrial reptiles	n/a	n/a	n/a	n/a	n/a
Lentic aquatic protocols					
Aquatic reptiles	0	2	0	1	0
Amphibians visual encounter surveys	1	1	0	2	0
Botany[3]	33	0	0	427	0

1 Number of species detected too infrequently for detection probability estimates to be reliable (e.g., detected at <20 sites). For bat mist-netting (only 22 sites sampled in total), the minimum sample size was reduced to 10 for reliable estimates.

2 Results for bird point counts includes sampling at both forestwide and lentic monitoring sites.

3 Only data from quadrat sampling were used for estimates of species detectability for plants

*Includes the Douglas' squirrel which was detected with high probability of detection with point count surveys.

We additionally conducted a cost-benefit analysis of MSIM protocols in terms of the monetary costs associated with implementation of each protocol on a per-site basis and the minimum benefits associated with the number of species detected with confidence (i.e., high to moderate detectability). This analysis may be useful for prioritizing implementation of MSIM protocols in a future monitoring program, for better understanding differential costs associated with various components of a comprehensive monitoring program and for highlighting protocols for which alternatives should be sought.

Bird surveys resulted in the greatest number of species detected with moderate to high detectability (i.e., confidence) per unit of survey cost, followed by aquatic amphibians and reptiles, small mammals and carnivores. The pitfall trapping protocol, as implemented in this project, was least cost effective and is not recommended for a long-term monitoring program; unless monitoring of the few species for which it appeared to detect more effectively than other sampling protocols (pocket gophers and shrews) is desired. Consideration of pitfall trapping protocol in future monitoring should also be sure to address some of the negative impacts of this protocol before implementation (e.g., high shrew mortality rates and ground disturbance).

Bat mist-netting surveys were the second least cost effective in terms of number of species detected with confidence per unit cost (Table J-6). However recent and expected future advances in acoustic sampling technology for bats are likely to markedly reduce costs and improve effectiveness of sampling for bats. Acoustic sampling was implemented in very limited scope in this project, but should be considered in the design of a future monitoring program.

Table J-6. Cost-benefit analysis of MSIM protocols in terms of the number of species detected effectively (with moderate to high (mod-high) probability of detection).

Protocol	Cost per site[1]	Species mod-high detectabitliy	Cost-benefit ratio
Bird point counts	1012	44	43.5
Small mammal trapping	2880	9	3.1
Track plate – camera protocol[2]	2328	3	1.3
Bat mist netting	4600	4	0.9
Pitfall coverboards	1000	0	0
Plant quadrat surveys	500		
Lentic amphibian/reptile surveys	450	4	8.89

1 Costs are based on implementation at 20-105 sites, depending on the protocol (see Methods section of report for details)

2 Results are based on the protocol implemented during 2005 only.

Sampling Adequacy

Birds, small mammals and bats had the greatest *number* of species that were sampled adequately to be able to detect significant decrease of 20% or more in site occupancy or abundance (for birds and small mammals) over time (Table J-7). Only a single carnivore (black bear), and amphibian (tree frog) were sampled adequately based on protocols implemented at random locations on LTBMU lands.

Bats had the greatest *proportion* of their species assemblage sampled adequately to detect decreases in site occupancy (44%), followed by amphibians (25%), small mammals (23%) and birds (18%).

A greater number and proportion of birds were sampled adequately for abundance than site occupancy, whereas the opposite was true for small mammals (Table J-7), suggesting that abundance may be a stronger metric for long-term monitoring of birds, whereas occupancy is the stronger metric for small mammals.

Table J-7. Number of species estimated to be adequately sampled to detect decreases in site occupancy or abundance values of 20% or more with 80% certainty (i.e., confidence and power) based on a sample size analysis for all species groups.

Species Group	Site occupancy metric	Abundance metric
Birds	25	32
Small mammals	6	3
Carnivores	1	n/a
Bats	4	n/a
Terrestrial reptiles	n/a	n/a
Aquatic reptiles	0	n/a
Amphibians	1	n/a
Plants	0	n/a

Additional species may be monitored effectively (e.g., sampled adequately) for changes in site occupancy with the current sampling design if apriori or post hoc stratification of sites is conducted; a method to artificially inflate the site occupancy rates and thereby increase the power of the monitoring analysis. With a sample size of 105 sites, species must be detected at $\geq$ 68 sites (65%) in order to be able to detect a decrease of 20% in site occupancy over time with 80% certainty (confidence and power). However, with appropriate stratification (e.g., currently occupied sites), a species detected at as few as a 22 sites can be effectively monitored to detect 20% decreases in occupancy rates with 80% certainty is site occupancy within the selected strata (currently occupied sites) is close to 100%. This approach could be used in conjuction with consideration of a larger sub-set of the dataset (e.g., all historically occupied sites, all sites within a subwatershed, or all sites in the Tahoe basin), in order to evaluate if any increases in site occupancy occur over time or changes in distribution.

By manipulating the strata or groupings of sites of interest, we can ask and answer various monitoring questions about populations of individual species with appropriate power of the analysis that otherwise may not be feasible when considering only the full suite of sites sampled.

Species richness per site appeared to be an efficient alternative monitoring metric for long-term comprehensive monitoring; all species groups (including plants, but excluding bats and reptiles), were sampled adequately with 105 sites in order to detect changes of 20% in species richness with 80% certainty (using a paired-t test sample size analysis; Table J-8). Birds (both at terrestrial sites and lentic monitoring sites), small mammals and nearly plants were also sampled adequately to detect 20% change in species richness with 90% certainty. Species richness should also be considered in addition to site occupancy and abundance as a primary monitoring metric for long-term monitoring of biological integrity.

Table J-8. Estimated minimum sample size required for detecting a 20% change (increase or decrease) in species richness per site with 80% and 90% certainty (e.g., confidence and power), respectively. Analysis was based on a pre- packaged paired t-test sample size analysis in SigmaStat (v.3.5).

Species Group	**Minimum Sample Size required (80% certainty)**	**Minimum Sample Size required (90% certainty)**
Terrestrial Birds	13	22
Aquatic Birds	38	70
Small mammals	17	29
Carnivores	75	140
Bats	174	328
Aquatic reptiles	223	422
Amphibians	87	163
Plants	63	118

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Appendices

Appendix 1-1. Forest wide bird point count protocol

Spatial arrangement

A total of seven stations were surveyed using bird point count methods (Figure A1-1) at each monitoring site established within the Lake Tahoe Basin Management Unit during 2002, 2004-2005. Six point count stations were located in a hexagonal array around a central point count station (Figure A1-1). All stations were 200 m apart. When any count station occurred in dangerous, extremely noisy, or otherwise unsuitable terrain (e.g., on cliffs, near loud creeks or rivers, in lakes), the station was re-located to the nearest suitable location in a direction away from other stations (e.g., along the same trajectory from the central station), and maintaining a 200 m minimum distance between stations. Five stations were noted to have been moved due to such unsuitable terrain features.

Survey protocol

Point count surveys were conducted at monitoring sites from mid May through mid to late July in each survey year corresponding to the bird breeding season in Lake Tahoe. Surveys conducted during this period of time are expected to have constant site occupancy for both resident and migratory species. Two to 3 survey visits were conducted to each site and were separated by at least 1 week (i.e., 7 days).

During each year, surveys were conducted first at lower elevations and on the east side of the Lake Tahoe basin and then followed to the south, north and west and progressed up in elevation, to ensure that counts spanned the breeding season similarly across elevational bands (~6200-7500ft, 7500-8500ft, >8500ft). During each survey visit to each site in each year, all 7 count stations associated with a given site were surveyed on the same day, starting no earlier than fifteen minutes after sunrise and finishing no later than 4 hours after sunrise. Counts lasted 10 minutes at each station, with data recorded in 3 time intervals: the first 3 minutes, the next 2 minutes, and the final 5 minutes. During the 10 minute counts, observers recorded detections of each bird species and of the following mammals by both sight and/or sound: Douglas' squirrels (*Tamiasciurus douglasii*), yellow-bellied marmots (*Marmota flaviventris*) and pika (*Ocotona princeps*). The following amphibians were also recorded as incidentals when detected: Pacific tree frog (*Hyla regilla*) and bullfrog (*Rana catesbiana*). For surveys conducted during 2002, detections were recorded at 50 m intervals: 0-50 m, 51-100 m, and >100 m. During 2004 and 2005, detections were recorded at 25 m distance intervals: 0-25 m, 26-50 m, 51-75 m, 76-100 m and >100 m. Individual birds detected were recorded only once in the distance and time interval during which they were first detected. Birds detected flying over head without landing nearby were recorded in the distance band ">100 m".

Weather conditions were recorded at the start of each point count survey including cloud cover, wind condition (Table A1-1) and precipitation. Counts were not conducted if precipitation was occurring (e.g., drizzle, sprinkle, rain or snow) or if the wind was greater than a slight breeze (twigs moving; Beaufort wind scale number 3, Table A1-1). No more than 1 visit at a given site was conducted by the same observer, and each time a site was revisited, the observer arbitrarily changed the order in which stations were surveyed with respect to the previous order of counts at that site.

Table A1-1. Beaufort wind rating scale.

Beaufort Rating	Observed Feature
1	No wind
2	Leaves moving (rustling)
3	Twigs moving
4	Small branches moving
5	Large branches moving
6	Trees moving (swaying)

Appendix 1-2. Small mammal live trapping survey protocol

Spatial arrangement

Sherman™ live traps were deployed along 8 transects, each 200 m long, arranged in a hexagonal pattern that was bisected down the middle (Figure A1-1 below). Trapping transects connected point count stations at each monitoring site. Traps were placed 20 m apart along each transect (15 m apart in 2002), starting at each apex (point count station) and ending 20 m before the next point count station or apex; totaling 79 traps per site (103 traps per site in 2002). Every other trap, starting with the second trap along each transect, was an extra large folding Sherman™ live trap (model type XLF15), the intervening traps were extra long folding Sherman™ live traps (model type XLK). Only extra long folding traps (XLK) were used in 2002.

Survey protocol

Small mammal live trapping occurred from mid May through mid September in each survey year, depending on seasonal weather patterns. Surveys at lower elevations and the east side of the basin were conducted first and surveys at higher elevations and protected orientations (e.g., west shore) around Lake Tahoe were conducted later in the season, in an attempt to follow the seasonal breeding phenology of small mammals.

Traps were placed level on the ground within two meters of the intended trap station location at habitat features such as logs, burrows, the base of trees, runways and, always in areas that provided cover/protection from weather extremes (e.g., under shrubs, in tall grass). Traps were covered with naturally available litter in order to buffer the metal trap environment from extreme heat or cold. During 2004 and 2005 Coroplast™ covers (i.e., corrugated plastic) were used to protect traps when sufficient natural material was absent.

Sherman™ traps were baited with a mixture of rolled oats, birdseed with sunflower seeds, peanut butter, and small mealworms (~1 in long). Mealworms were frozen prior to use as bait so they would remain in the traps during the entire survey period. Polystyrene batting was placed in every Sherman™ trap to provide warmth at night and was replaced as necessary during surveys.

All traps were set, baited and opened, no earlier than 1500 hrs on the first day of survey, and checked twice daily starting on the second day; morning trap check started no later than 0700 hrs and was completed no later than 1130 hrs, afternoon trap check started no earlier than 1600 hrs and was completed no later than 1930 hrs. Trap checks started on the morning of the second day for 3 ½ consecutive days (3 days in 2002), for a total of 7 visits (6 visits only in 2002). During each visit all traps were checked for sufficient bait and batting, and for functionality. Traps were checked and removed on the last trap check during the morning of the fifth day.

Captured animals were identified to species, marked (by trimming an obvious patch of hair from the dorsal surface near the base of the tail), sexed, aged, examined for breeding status, weighed, and measured (depending on genera), then released. One clear diagnostic photo was taken of each representative species captured at each site in order to photo document species captured during small mammal surveys and to aid in identification of any unusual, unexpected, unknown or questionable species detected in traps.

Observers also indicated 1) did animal escape from handling prior to completion of required data collection 2) was capture a mortality 3) was trap functional 4) was trap triggered, (door closed but without a capture).

During 2005, at every monitoring site (while traps were in place), the habitat type was determined for each trap location using CWHR (California Wildlife Habitat Relationship system, Mayer and Laudenslayer 1988).

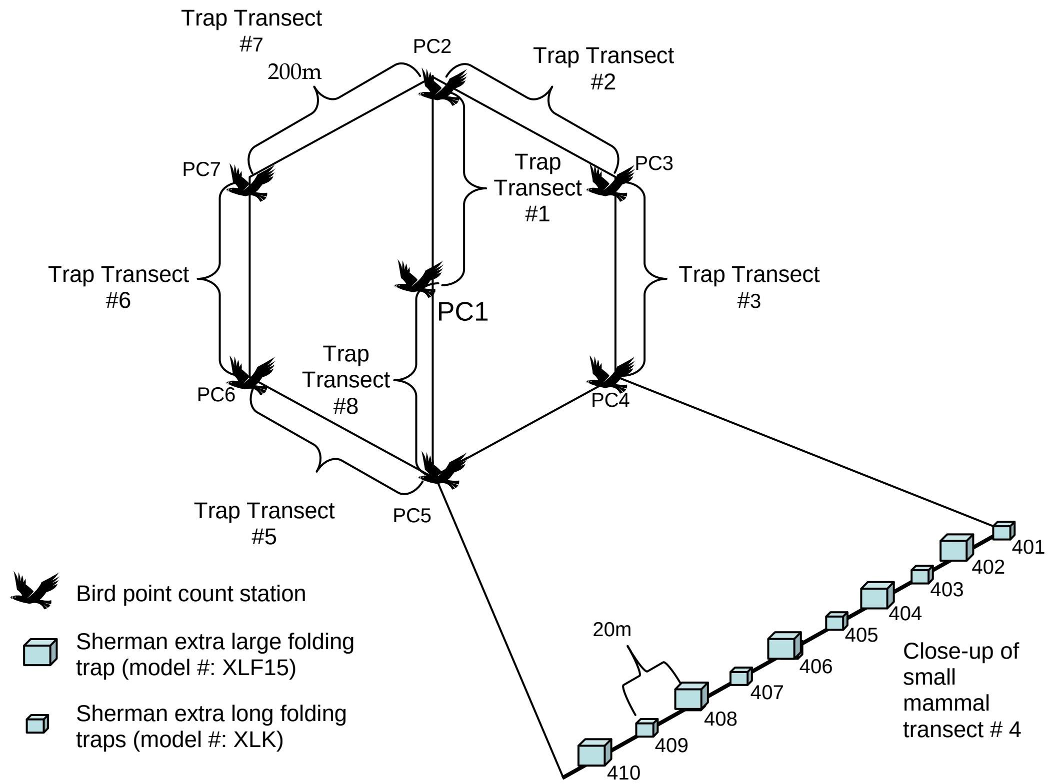

Figure A1-1. Small mammal live trapping transect configuration implemented during 2004 and 2005, MSIM, Lake Tahoe basin, CA and NV. During 2002, a total of 13 (instead of 10) traps were placed 15 m apart along each of 8 transects and only extra long folding traps (model # XLK) were used.

Appendix 1-3. Carnivore track plate and camera survey protocol

Spatial arrangement, equipment and settings

Three baited track plate stations and three baited Leaf River™ digital camera stations were established in association with each monitoring site during 2005. Track plate stations were located at the central monitoring station of each site (PC1- point count station 1) and two other stations at 500 meters from center at 90° and 270° (Figure A1-2). One camera station was located 100 meters from the central track plate station at a random azimuth and the two additional camera stations were located 500 meters from the central monitoring station at 0° and 180° (Figure A1-2).

Six baited track stations and four baited Trail Master™ camera stations were established in association with each monitoring site in 2002. Track plate stations were located at the center monitoring station (PC1) and five other stations arrayed at 72 ° angles, 500 m away from the center point (Figure A1-3). Four camera stations were co-located with 4 randomly chosen track plate stations (Figure A1-3). The other two track plate stations did not have an associated camera station. Camera stations were approximately 100 m away from the track plate station at a randomly chosen azimuth. Camera stations consisted of a

35mm Cannon Sureshot A1™ camera in conjunction with a Trail Master TM550™ passive infra-red detector.

In both survey years, one covered track plate was associated with each track plate station, and one motion and heat activated camera was associated with each camera station. Each track plate was placed within 2 meters of the intended station location. The exact location of each camera was based on the nearest tree to the station, to which the camera and bait were attached.

Track plate stations consisted of a single baited covered track plate box placed on level ground, and oriented such that the opening was unobstructed. Covered track plate boxes were constructed of a two-piece high-density polyethylene cover or a Coroplast™ cover, and an aluminum track plate bottom. The resultant covered track plate box resembles the shape of a mailbox. The front entrance remains open and unobstructed, the back of the box was covered by mesh steel, and track plates covered with Con-tact™ paper and soot were inserted on the bottom of box. The "box entrance" end of each track plate was covered with soot, an adjacent section was covered by inverted Con-tact™ paper (i.e., sticky side up), and the back end remained uncovered for placement of the bait. Chicken drummets were used as bait and located at the back of each track plate box.

Baited camera stations consisted of a single camera aimed at the bait. The Leaf River™ digital camera unit (used in 2005) was set for 24 hour operation, flash was set to auto, resolution was set to medium, sensitivity switch was set just short of the maximum setting and photo delay was set at 3 minutes. Settings for the Trail Master TM550 passive infrared detector (used in 2002) were P = 5, and Pt = 2.5 such that five full windows had to be interrupted for at least 2.5 seconds for the camera to be triggered and the camera delay between photo events was 2 minutes. The bait (one frozen half chicken) was attached to a tree, or other appropriate substrate, 0.5-1 m above the ground, using a basket constructed of chicken wire. In both years, the camera mounting location was 3 to 8 meters from the bait and at a similar height.

For both camera and track plate stations a mixture of Gusto™ and lanolin were used as long-distance chemical attractant for carnivores. A large chicken or turkey feather was hung using nylon string above each track plate box and near the bait but outside the detection area of the camera unit; as an attractant for felids.

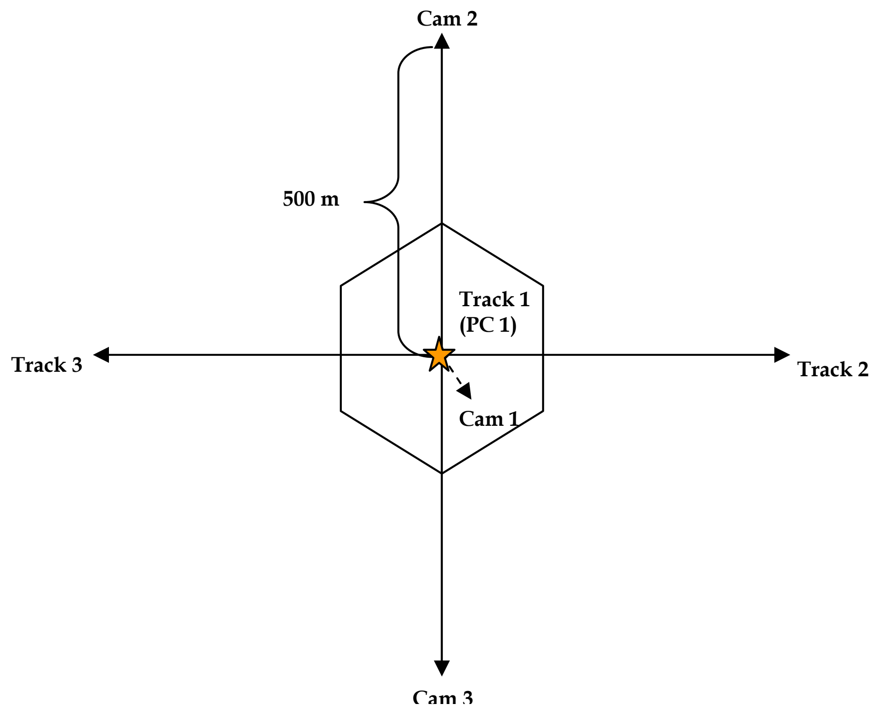

Figure A1-2. Spatial arrangement of track plates and camera stations around each monitoring site, MSIM, Lake Tahoe basin, CA and NV, 2005. Hexagonal pattern at center of diagram indicates sampling array for bird point counts and small mammal trapping described in Appendices 1-1 and 1-2 above.

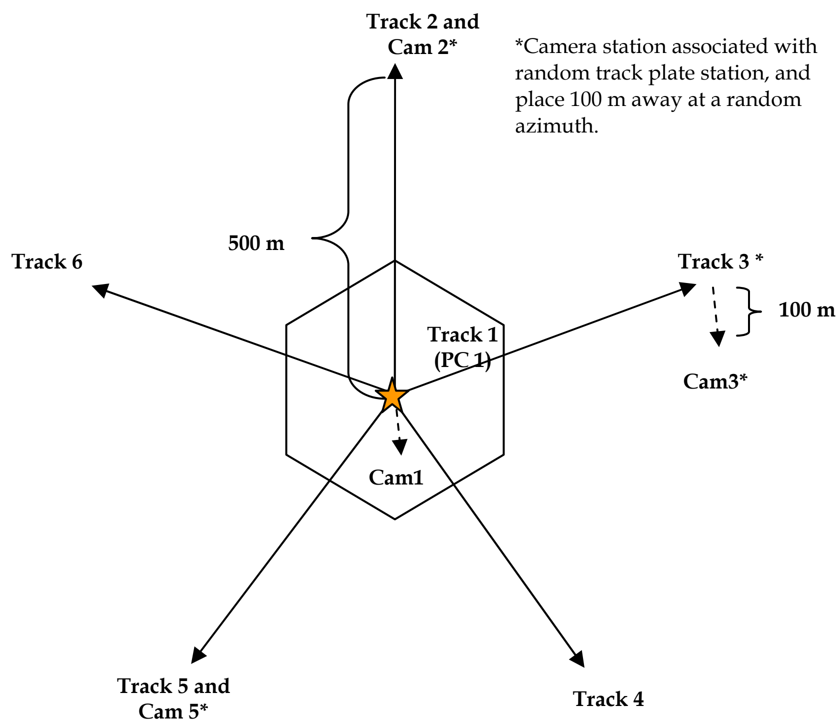

Figure A1-3. Spatial arrangement of track plates and camera stations around each monitoring site, MSIM, Lake Tahoe basin, CA and NV, 2002. Hexagonal pattern at center of diagram indicates sampling array for bird point counts and small mammal trapping described in Appendices 1-1 and 1-2 above.

Survey protocol

During both 2002 and 2005, each site was surveyed over a 10-day period during the survey season: May through October. The track plate and camera stations were established and then visited every other day for a total of five visits.

On each of the five visits to every station, track plates and/or memory cards/film and bait were replaced as necessary. Track plates were replaced at stations when tracks were present or the plate was damaged by events such as precipitation. Memory cards were replaced during each visit, and film (used in 2002) was replaced any time 18 or more exposures were recorded on any given visit. Bait was replaced at all stations when it was absent or when the observer deemed necessary. Memory cards/film and track plates removed from stations constituted the primary survey data and were carefully transported and stored until tracks and images could be identified to species, or the lowest taxonomic level possible according to Taylor and Raphael (1988).

Appendix 1-4. Bat mist netting protocol.

Spatial arrangement

Bat mist netting surveys were conducted at 3 stations in association with each of 22 sites. Only 22 of the 105 monitoring sites were surveyed due to survey effort/logistics constraints and limitations due to surveyor permitting requirements for bat sampling. Handling of bats requires an approved MOU with the state of California requiring many hours of supervised netting experience with a regional expert. The 3 stations surveyed in association with each site were chosen by searching for the nearest suitable habitat within a 1 km radius circle from the central monitoring station at each site. Five types of habitat were considered suitable for surveys: streams, ponds, lakes, meadows, and roads. Streams and ponds were considered the best habitat for sampling, so at least one station per site was a stream or pond if available. The remaining two stations were randomly selected from the remaining suitable habitat types, with the objective of having three different habitat types per site.

Survey protocol

Bat surveys were conducted between May and September during 2002, representing the breeding season for bats in the Lake Tahoe region. Surveys conducted during this period of time are expected to have constant site occupancy for all species present. Each of the 3 stations per site was surveyed on at least two separate occasions (i.e., visits). One randomly selected station associated each of 15 sites received and additional 2 visits, for a total of four visits. Repeat visits to individual stations were conducted a minimum of six days apart to spread their occurrence across the breeding season. During the first 2 survey visits to a site, all three stations per site were surveyed during the same or consecutive nights.

Each survey night at each station consisted of setting up three nets, varying in length from 6 to 18 meters depending on the station habitat characteristics (e.g., nets were intended to match the width of the stream, road or trail that they were place across). Nets were monitored approximately every 10 minutes. On nights with little to no bat activity, the nets were checked less often, every 15 minutes approximately. Nets were opened at sunset and kept open for 210 minutes. Netting did not occur on nights with precipitation.

Data collected on all bats included: time and temperature (Celsius) of capture, species, sex, reproductive status, age (by checking epiphyses of third and fourth metacarpal for full or partial ossification), and forearm length (mm). In addition, comments regarding the potential stage of reproduction for females were noted and include a physical description of the condition of nipples and vulva, as well as indications that the animal had never bred (i.e. mammary extremely small and difficult to locate). All *Myotis* species were measured for ear, thumb, and foot length (mm), and the calcar was checked for a keel to confirm species identification. Additional identifying characteristics were noted to distinguish between similar *Myotis* species.

Appendix 1-5. Pitfall trap and cover board survey protocol.

Spatial arrangement

Two pitfall trapping arrays and 6 coverboard stations were established and sampled at each of 9 monitoring sites during 2002 with the intent of surveying terrestrial herpetofauna.

One pitfall array was centered 30 m due west and the other 70 m due east of the central monitoring station at each of the 9 sites. Each array consisted of 6 pitfall traps placed in sets of 2 on opposing sides of 3 drift fences, each fence which radiates out from the center of the array like spokes of a wheel (Figure A1-4). Drift fences consisted of aluminum flashing, 0.3 m tall and 5 m long from the center of the array to the pitfall traps. The drift fence was sunk into the ground 2 to 5 cm and then soil was pressed along each side of the fence along its length to ensure that animals could not crawl under. Wooden stakes stapled to the flashing were used to steady the fence vertically. Pitfall traps consisted of 1.5 gallon plastic buckets sunk in the ground such that the top of the bucket was flush with the ground surface. Pitfall traps were covered with cedar shingles, propped above the top of the trap during sampling, to entice individuals to crawl under the cover and fall into the trap. A handful of duff and soil was put into each bucket to provide warmth and protection to captured animals. In addition, twine and bait were used experimentally to evaluate their effect on survival and capture rates (Karraker 2001). One of the two buckets at the terminus of each fence line was equipped with a length of twine that was attached to the cover and reached the bottom of the bucket. Twine was hung from the edge of underside of the cover, to facilitate the escape of small mammals which are not the target taxa of interest in pitfall sampling (see Appendix 1-2 for small mammal sampling protocol) and often have high rates of mortality in pitfall traps. In the easternmost array, a mix of grains and mealworms was provided.

A single cover board (1m^2 sheet of thin plywood) was placed 30 m away from the central monitoring station (PC1) along each of the 6 azimuths at which point count stations were established (Figure 1-1).

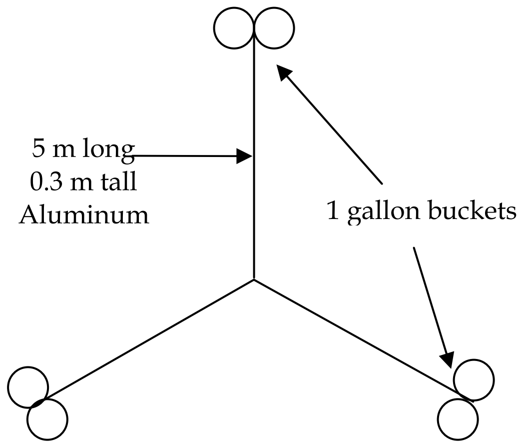

Figure A1-4. Pitfall trap array configuration, MSIM, Lake Tahoe basin, CA and NV, 2002

Survey protocol

Pitfall traps and cover boards were established in the spring as soon as snow melted enough to access sites and the ground, and were checked approximately twice per week through August. In August the traps were closed using plastic lids that snap tight to the buckets, with additional materials placed on the lid (e.g., rocks) to ensure that lids remain in place. The traps were reopened in late September for two weeks to evaluate the value of late-season trapping. After the September sample period, fences were taken down and buckets closed for the remainder of the winter season.

Checks consisted of lifting the cover and taking stock of the contents of the bucket. All animals were removed with each visit. Poisonous invertebrates, such as scorpions, were removed with care using tongs or long tweezers. Target taxa were removed one at a time, identified to species, weighed (in the case of small mammals) and released. Observers' hands were clean - free of all chemical and lotions to mimimize impacts when handling amphibians.

Cover board checks consisted of slowly lifting up the cover board and capturing all individuals present beneath the boards. Observers processed individuals in order of decreasing likelihood of escape. Individuals were processed the same as described for pitfall traps. Individuals were not placed back under the cover board but were released next to it.

Appendix 1-6. Plant sampling protocol

Spatial arrangement

Botany surveys were conducted using a combination of Forest Inventory and Analysis (FIA) protocols and additional measures. FIA measures consisted of 12, 1m^2 quadrats imbedded within 4, 7.3 m radius subplots (three quadrats per subplot). Subplots were arranged in a Y shape with the first subplot centered on the central monitoring site station (PC1), and the other three subplots centered 36.4 m from station PC1 along the following azimuths: 30°, 150^o and 270^o (Figure A1-5). In 2002, subplots were arranged as an inverted Y, along the following azimuths: 0°, 120° and 240°. In all survey years, three quadrats were located in each subplot on the right (i.e., clockwise) sides of lines at azimuths 30^o, 150^o, and 270^o totaling 12 quadrats per site (Figure A1-5). The lower and upper left corners of each quadrat were permanently marked with ¼" rebar at 4.57 and 5.57m from the subplot center (Note: wooden dowels were used to mark quadrat corners in Wilderness areas).

In addition to subplots and quadrats, two 25 m vegetation composition transects (placed perpendicular to one another) were established at the central monitoring station at every site (Figure A1-5). Two similarly arranged (i.e., perpendicular) 25 m transects were established at three additional stations, corresponding to point count stations 2, 4 and 6 (Figure 1-1), at the 65 sites surveyed in 2005 due to available botany expertise. During 2002, transects were placed at 180° and either 90° or 270° (randomly chosen), and in 2005 transects were placed at 220° azimuth, and either 130° or 310° (randomly chosen) (Figure A1-5). Each transect started at the central monitoring station and extended outward for 25 m.

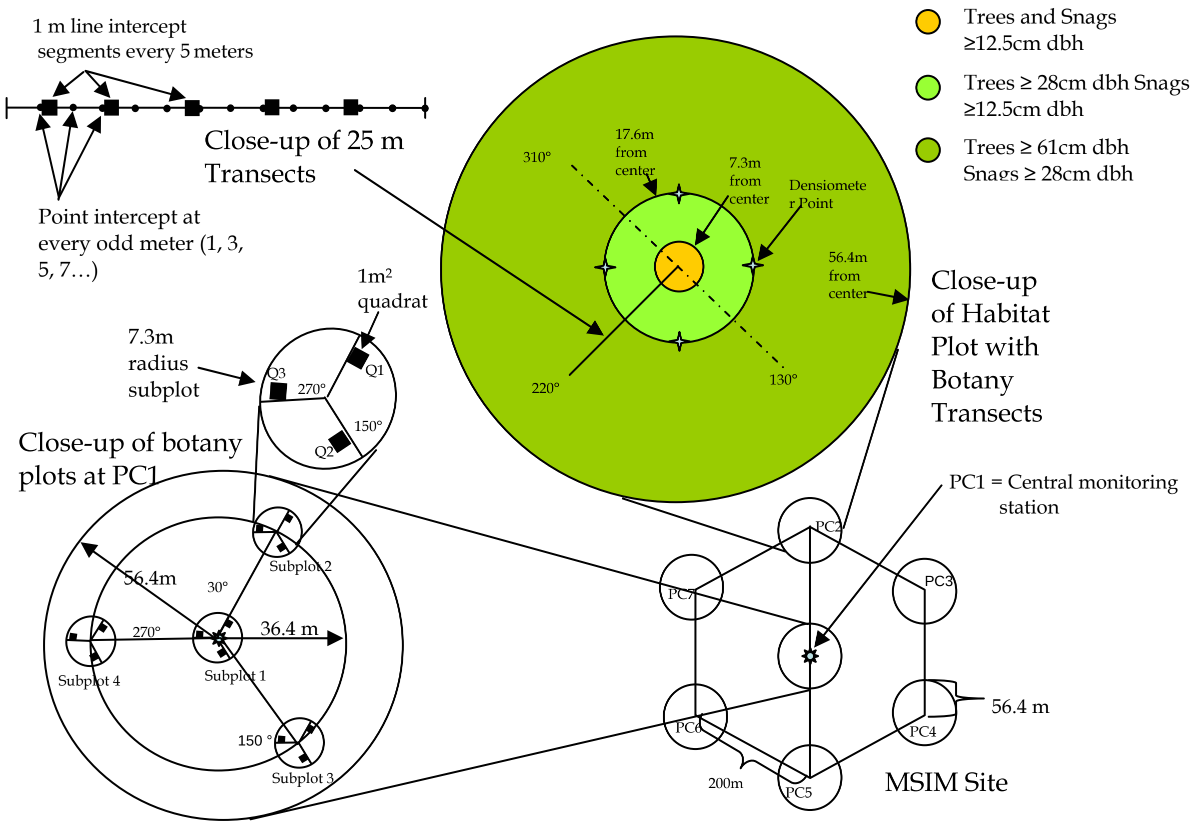

Figure A1-5. Spatial arrangement of botany and habitat data survey protocols conducted at monitoring sites, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005

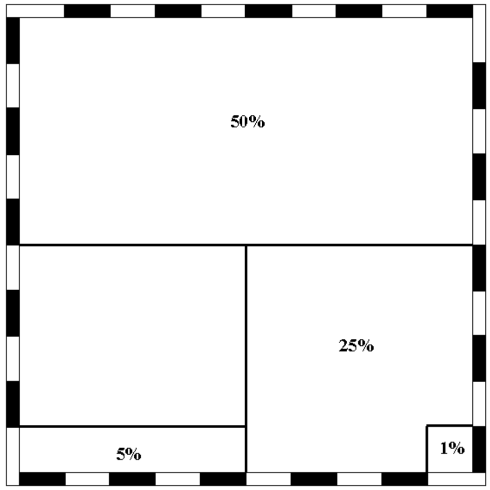

Figure A1-6. Diagram of 1m x 1m quadrat frame painted in 10 cm intervals and cover levels, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005

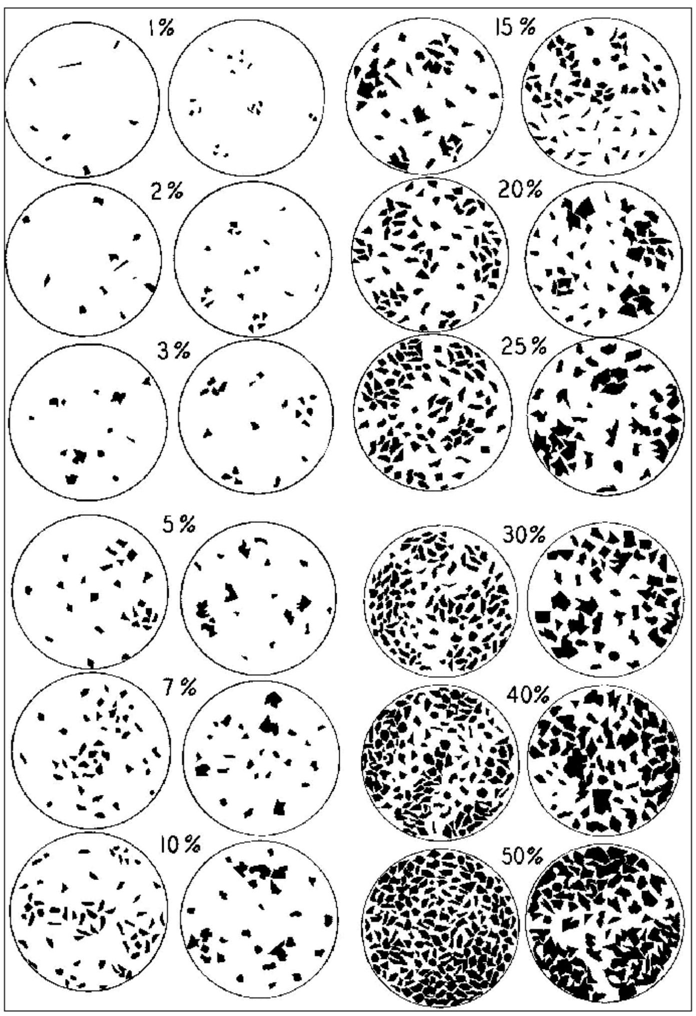

Figure A1-7. Reference plots for plant cover estimation in subplots, MSIM, Lake Tahoe basin, CA and NV, 2002 and 2005

Survey protocol

Botany surveys were performed between June and September in 2002 and 2005. Quadrat, subplot and vegetation composition transect sampling at the central monitoring station occurred on 2 survey visits at 85 of the 105 monitoring sites, only 1 visit occurring to the remaining 20 sites (Table A1-2). Transects at the 3 peripheral stations at 65 sites in 2005 received only a single survey visit (Table A1-2). Only data collected from quadrat sampling at the central monitoring station of each site was used in calculations of monitoring metrics: estimated detection probabilities and site occupancy rates. Data from peripheral stations were used for the generation of species detection lists only.

TABLE A1-2 Survey methods used to collect plant and habitat data at the various stations at each of the 105 MSIM sites and the number of sampling occasions to each station during a single growing season.

Station	Vascular Plant Survey Methods	Number of Sampling occasions per site
PC1	Subplot*	2
	Quadrat	2
	Fixed area tree plots	1
	Vegetation transects	2
PC2	Fixed area tree plots	1
	Vegetation transects	1
PC4	Fixed area tree plots	1
	Vegetation transects	1
PC6	Fixed area tree plots	1
	Vegetation transects	1

*includes additional 15 minute search protocol

Subplots and quadrats: Quadrat frames were carefully placed at each designated location along transects. The first measurement required the installation of permanent pins to mark the corner locations of each quadrat. Each quadrat was leveled prior to measurement. The surveyor was careful not to flatten any vegetation under the quadrat frame, and returned vegetation to its original structure before cover estimates were made to avoid overestimating the cover of flattened plants.

One habitat type code (1-9, see below) was assigned to each quadrat. When a quadrat contained more than one habitat type, the observer assigned the code for the habitat type that occupied the greatest area in the quadrat. When the quadrat could not be physically occupied (e.g., hazardous, large water) the corresponding habitat type number was entered and the remaining quadrat items were left blank. This variable is primarily utilized in large scale analysis as part of the Forest Inventory and Analysis program, but has limited application to monitoring vegetation conditions at the forest administrative unit level. Therefore we did not summarize this variable in this report, and do not recommend collection of this variable in future monitoring efforts.

1 Forested land (trees present)
2 Small water (1-4.5 ac. standing water, or 30-200 ft. wide flowing water)
3 Large water (standing water >4.5 ac., or flowing water >200 ft. wide)
4 Agriculture (cropland, pasture, orchard, Christmas tree plantation, etc.)
5 Developed-cultural (business, residential, urban buildup, etc.)
6 Developed-rights-of-way (improved roads, railway, power lines, canals, etc.)
7 Rangeland
8 Hazardous (cliffs, hazardous/illegal activity, etc.)
9 Other (beach, marsh, meadow,etc.) (explain in comments)

A trampling code was also assigned to each quadrat. Trampling was defined as damage to plants or disturbance of the ground layer by humans or wildlife. This does not include trampling done while surveying the site. This variable is of primary use in habitats that are most affected by trampling (e.g., wet meadows, fens, riparian areas, etc). Because this variable was collected at forestwide and not lentic sites, it was not summarized in this report. This variable is recommended for inclusion in future monitoring efforts of trampling sensitive habitats indicated above.

1 = Low: 0-10% of quadrat trampled
2 = Moderate: 10-50% of quadrat trampled
3 = Heavy: >50% of quadrat trampled

Vegetation classifications were determined for each subplot via the classification system of Sawyer and Keeler-Wolfe: *A Manual of California Vegetation* (1995).

Cover was estimated for each species within each quadrat to the nearest 1% for plants or portions of all vascular plants that fell inside the quadrat frame and were less than 6 feet above the ground. For each plant species, cover was estimated based on a vertically projected polygon described by the outline of each plant, ignoring any normally occurring spaces that exist between the leaves of a plant when the canopy was full. This measure reflects the plant's above- and below-ground zone of dominance. The only exception to this technique was for species represented by plants that were rooted in the quadrat, but had canopies that did not occur in the quadrat or that were more than 6 feet above the ground; cover for these species was estimated based on their basal area. Percent cover estimates were based on the current years' growth, by including both living and dead material from the current year. Overlap of plants of the same species was ignored such that plants of the same species were grouped together into one cover estimate. Occasionally the canopy of different plant species overlapped, therefore the total cover for a quadrat sometimes exceeded 100%. All trace cover estimates were recorded as 1%. The percent cover was recorded for the exact amount present at the time of the visit. The percent cover was not adjusted for the time of year that the visit was made (i.e., for immature or wilted plants). The boundary and cover estimates within the quadrats were aided by using actual frames to define quadrat boundaries, having each quadrat frame calibrated (painted in 10 cm sections) (Figure A1-6), and reference cover examples (Figure A1-7). Percent cover for all species was estimated at 0.5 m above the ground surface in the subplot. The growth form for each plant species within a quadrat was recorded as: Tree, Shrub, Grass, Forb or Fern.

A fifteen minute search was conducted and all new non-woody vascular plant species (i.e., not already recorded in quadrats) detected within the four subplots were recorded. This gave us a complete species list for species present in subplots. Search time did not include time required to identify or collect plant species. Only one observer conducted the 15 minute search per subplot, recording as many different plant species as possible within the search time.

Lastly, within each subplot, the cover of all woody stemmed plants and invasive weeds were recorded.

All plant species were recorded using standardized codes from the national Natural Resource Conservation Service Plants database (USDA, NRCS, 2000). If the standardized code was not available during the survey, the entire species name was to be recorded and then corrected with the proper code after returning from the field.

Line transects: Twenty-five meter long transects were established at each station by threading a meter tape through the vegetation, not over or under it and pulled taught.

Vertical structure of the plant community using the point intercept method was sampled along each transect. Starting at 1 m, every odd meter was sampled (i.e. 1, 3, 5…21, 23, and 25) for a total of 13 sample points per transect. All plant species (live stems only) intersecting the left edge of the transect tape at any height above or below the tape were recorded separated into 1 meter height intervals up to 10 meters, then 5 meter intervals up to 45 meters. Height intervals were checked periodically with clinometer to assure data quality. For points that have no vegetation intersecting any interval along the line extending up to infinity, the non-vegetative ground cover at that point was recorded (i.e. rock, litter, bare soil, coarse woody debris). Coarse woody debris was defined as any non-living, non-standing woody stems > 7.6 cm (3 in) in diameter at the large end.

Litter depth measurements were taken at the same 13 point intercept locations used to sample vertical structure (only three points along each transect were measured for litter depth during 2002 surveys). Litter depth was measured by digging a small profile (perpendicular to the ground surface) through the litter layer down to the mineral soil layer; measuring from the top of the mineral soil layer to the top of the litter layer (i.e., O horizon layer) using a small transparent ruler.

Ground cover measurements using the line intercept method along each transect were recorded every five meters, starting at 1 m for a total of five-one meter long segments along the transect. Along each transect segment, all plant species and non-vegetative ground cover (bare soil, litter, rock, coarse woody debris) were measured for percent cover based on the length of the one meter section intersected by live foliage of each plant species when looking down from 0.5 m above the ground surface. Ground cover types were the same as used at point intercepts (see above). Non-vegetative ground cover was only recorded for portions of the one-meter segment that had no live vegetation beneath 0.5 meters above the ground surface. All plants were identified to species in the field; when this was not possible surveyors either collected a specimen for further examination (when possible) or returned to the site at a later date to observe additional diagnostic features (e.g., flowers). Combined cover estimates for ground and vegetation cover of each line intercept may exceed 100% due to overlap of the canopies of herbaceous and shrub species. Total cover by life form was also recorded for each one-meter line segment. Life forms included trees, shrubs, grasses, forbs and ferns.

Along each transect, the following information was recorded for each downed log > 7.6 cm (~3 in) diameter at the large end, which intercepted or touched the transect line: diameter at small end, diameter at large end, length to the nearest 0.5 m, and decay class (Table A1- 3 and Figure A1-8). For logs that were broken into pieces, each portion was considered a single log, provided that the pieces were completely separated.

Table A1-3. Decay class for logs, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005, based on Thomas (1979).

Decay Class	Structural Integrity	Texture of Rotten Portions	Color of Wood	Invading Roots	Branches and Twigs
1	Sound, freshly fallen, intact logs	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches were present, fine twigs were still attached and have tight bark
2	Sound	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches were present, many fine twigs were gone and remaining fine twigs have peeling bark
3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through-out	Branch stubs pull out
5	None, piece no longer maintains its shape, it spreads out on ground	Soft; powdery when dry	Red-brown to dark brown	Through-out	Branch stubs and pitch pockets have usually rotted down

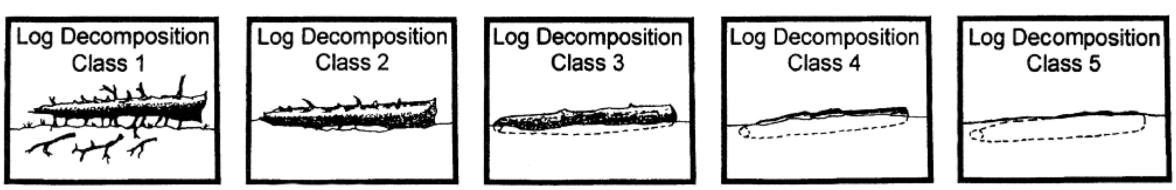

Figure A1-8. Illustration of decay class for logs, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005

Appendix 1-7. Terrestrial habitat condition protocol

Spatial arrangement

Habitat surveys were conducted at four stations (PC1, PC2, PC4, and PC6) at all monitoring sites. FIA protocols serve as the primary habitat measurements at all four stations. As per FIA, 3 nested, circular plots (e.g., fixed area plots) with radii of 56.4 m (hectare plot), 17.6 m (1/4 acre plot), and 7.3 m (24ft subplot) were centered on each of the four station centers and were used to describe habitat conditions (Figure A1-5).

Survey protocol

Habitat types using CWHR (Mayer and Laudenslayer 1988) was determined based on vegetation characteristics throughout the 56.4 m radius plot. Habitat classification was assigned to each station based primarily on the canopy cover, and tree composition and size class data collected in nested plots (Appendix H-1 below).

During the 2002 field season slope angle was measured two times with a clinometer, recording uphill and downhill and slope aspect was determined with compass bearing, both were measured from plot center. During 2004 and 2005 GIS layers were used to determine these variables.

Disturbance was estimated within 30 m radius of each station center by estimating the area in m^2 that had compacted soil and/or impermeable surfaces. GIS layers were used to determine disturbance levels rather than these measurements in 2005. Distance to roads and trails within 100 m radius of plot center were recorded. GIS layers were used to determine distances to roads and trails rather than field based measurements in 2005. The distance to water bodies within 100 m radius of plot center, and waterbody type (in 2005 only) was recorded. During 2004 surveys distance to water sources within 100m were determined with GIS layers.

Canopy cover estimates were taken using a convex densiometer, with four readings being taken in each of the four cardinal directions at the perimeter of the 17.6 m plot, a total of 16 measurements per station.

Within each 7.3 m radius plot, the following measurements were recorded:

- Ocular estimate of percent cover for the following: litter, vegetation, rock, and bare soil. Cover was estimated at 0.5 m above the ground surface and the sum of percentages equaled 100%.
- For each tree $\geq$ 12.5 cm diameter at breast height (dbh), species, dbh, height, and all decadence features (Table A1-4).
- For each snag $\geq$ 12.5 cm dbh, the species, dbh, height and decay class (Table A1-5 and Figure 11).
- A total count of all seedlings (< 2.5 cm dbh or no dbh due to being less than breast height) and saplings (>2.5 cm, but < 12.5 cm dbh) were made for each species. Live and dead stems were recorded in a seperate columns. These data were only collected at 65 of the 105 forestwide monitoring sites (in 2005).

Within each 17.6 m radius plot, the following measurements were recorded:

- For each tree $\geq$ 28 cm dbh, the species, dbh, height, and all decadence features (Table A1-4).

- For each snag ≥ 12.5 cm dbh, the species, dbh, height and decay class (Table A1-5 and Figure A1-9).

Within each 56.4 m radius plot, the following measurements were recorded:

- For each tree ≥ 60 cm dbh, the species, dbh, height, and all decadence features (Table A1-4).
- For each snag ≥ 30.5 cm dbh, the species, dbh, height, and decay class (Table A1-5 and Figure A1-9).

Table A1-4. Decadence codes for live trees, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005

Decadence code	Decadence feature
1	Conks (bracket fungi)*
2	Cavities greater than 6 inches in diameter
3	Broken top
4	Large (> 12 inches in diameter) broken limb
5	Loose bark (sloughing)*
6	Mistletoe Broom
7	Dead top*
8	Split top*
9	Thin canopy*
10	Light foliar color*
11	Leaf necroses (dead leaves)*
12	Frass exudation (due to bark beetle infestation)*
13	Sap exudation (clear fluid exuded- not bark beetle damage)*

*Decadence codes not used in carnivore track plate and camera station habitat protocol

Table A1-5. Decay classes for snags, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005, based on Thomas (1979).

Decay class stage (code)	Limbs and branches	Top	% Bark Remaining	Sapwood presence and condition*	Heartwood condition
1	All present	Pointed	100	Intact; sound, incipient decay, hard, original color	Sound, hard, original color
2	Few limbs, no fine branches	May be broken	Variable	Sloughing; advanced decay, fibrous, firm to soft, light brown	Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown
3	Limb stubs only	Broken	Variable	Sloughing; fibrous, soft, light to reddish brown	Incipient decay at base, advanced decay throughout upper bole, fibrous, hard to firm, reddish brown
4	Few or no stubs	Broken	Variable	Sloughing; cubical, soft, reddish to dark brown	Advanced decay at base, sloughing from upper bole, fibrous to cubical, soft, dark reddish brown
5	None	Broken	Less than 20	Gone	Sloughing, cubical, soft, dark brown, OR fibrous, very soft, dark reddish brown, encased in hardened shell

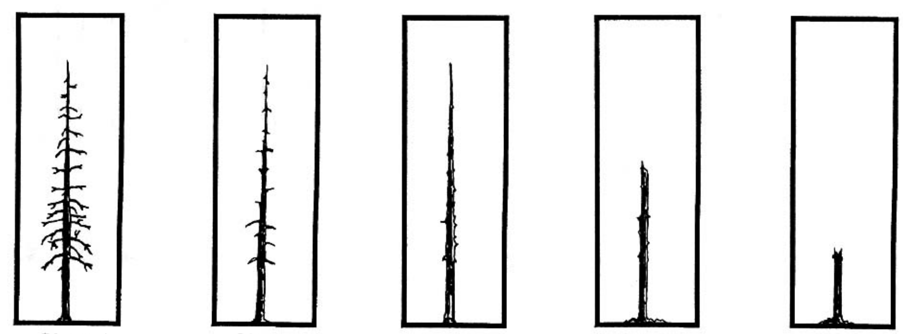

Figure A1-9. Illustration of decay classes for snags, MSIM, Lake Tahoe basin, CA and NV, 2002, 2004 and 2005

As a result of plant and terrestrial habitat condition surveys, we measured a total of 23 different variables, several of which are similar to one another and some which are not summarized in this report due to limited value of the variable to the monitoring sites sampled in this effort (Table A1-6).

Table A1-6. List of variables measured as part of the 5 main plant and habitat condition sampling methods employed at forestwide monitoring sites, 2002-2005: quadrats, subplots, line intercept, point intercept and fixed-area plots. Variables that can be generated from available GIS layers (IKONOS v.4) are also indicated.

Botany/Habitat Variable	Quadrats	Subplots	Line intercept	Point intercept	Fixed-area plots	GIS
Plant Sampling Variables						
Habitat type code[1]	x					
Trampling code[1]	x					
Vegetation Classification[1]		x				
Species composition	x	x	x	x	x (trees only)	
Percent cover (per species and life form)	x		x	x		
Vertical structure of vegetation				x		
Percent non-veg ground cover by type: Litter, rock, bare soil, coarse woody debris			x	x	x[2]	
Litter Depth				x		
Coarse Woody Debris (CWD) volume			x			
CWD biomass (1000 hr fuels)			x			
Habitat Condition Variables						
CWHR habitat type					x	x[3]
Slope angle[1]					x	x
Area of disturbance and type within 30 m					x	x[3]
Distance to roads/trails and type within 100 m					x	x[3]
Distance to nearest water by type within 100 m					x	x[3]
Percent canopy cover					x	x
Live tree density by size class					x	
Decadence features for live trees					x	
Basal area of live trees	x				x	x
Quadratic mean diameter (live trees)					x	x[4]
Stand density index (live trees)					x	
Snag density by size and decay class					x	
Tree regeneration (seedling/sapling densities)					x	

1 Variable not summarized in this report
2 Rock, litter and bare soil cover types only were measured in the smallest fixed area plots (7.3 m radius plot).
3 Accuracy of variable from IKONOS GIS layer is likely not acceptable relative to data collected on the ground
4 Variable in IKONOS GIS layer is the mean diameter at breast height per stand, not exactly the quadratic mean diameter, but similar.

Several variables measured in association with plant and habitat condition surveys required calculations from raw data collected in the field. Calculations and associated references, when relevant, are provided below (Table A1-7).

Table A1-7. Vegetation variable calculations for data collected during plant and habitat condition surveys at forestwide monitoring sites.

Variable	Metric	Calculation	Reference
Coarse woody debris volume	ft^3/acre	$V_{ft} = [(pi/8)*(D_s^2 + D_L^2)*l] / 144$ V_{ft} = Volume in cubic feet per acre D_s = diameter of small end of log in inches D_L= diameter of large end of log in inches L = log length in feet	Waddell (2002); Smalian's formula
Coarse woody debris biomass (1,000 hr fuels)	tons/acre (CWD > 3 in diameter)	CWDb = (V_{ft}) * (62.4 lb/ft3 /2000 lb/ton) * SpG * DCR CWDb = biomass of coarse woody debris in tons/acre V_{ft} = Volume in cubic feet per acre SpG = Specific gravity of fresh green wood; we used a value of 0.37 (average value of fir and pine according to Forest Products Laboratory (1987). DCR = Decay reduction factor; we assumed all logs were softwood, and used a value of 0.9 for all logs of decay class 1-2, and a value of 0.58 for logs of decay classes 3-5	Waddell (2002), Forest Products Laboratory (1987)
Vertical vegetation structure per interval: 0-1 m 1-5 m 5-10 m 10-25 m 25-40 m	Proportion of each height interval with live vegetation	Pts_{veg} / Pts_{all} Pts_{veg} = Number of point intercept points along transects at each station per site that contained live vegetation in the specified height interval (0-1 m, 1-5 m….) Pts_{all} = # point intercept points sampled along transects at each station per site in the specified height interval Note: values averaged across all 4 stations sampled per site	n/a
Snag density by size and decay class: 5-11 in 11-24 in 24-30 in >30 in	#/acre	5-11 in: (Cnt * 4.16) / # stations 11-24 in: Cnt /# stations 24-30 in: Cnt / # stations >30 in: Cnt / # stations Cnt = Number of snags (i.e., dead stems) recorded for each respective size class within all 3 nested circular plots measured for the respective size class at all 4 stations per site. The numeric value multiplied by this count was the conversion factor to standardize the count per acre # stations = Number of stations for which tree/snag data were collected within the 3 nested circular plots.	n/a
Live tree density by size class: 5-11 in 11-24 in 24-30 in >30 in	#/acre	5-11 in: (Cnt * 24.16) / # stations 11-24 in: (Cnt * 4.16) / # stations 24-30 in: Cnt / # stations >30 in: Cnt / # stations Total tree density: sum of all above values Cnt = Number of trees (i.e., live stems) recorded for each respective size class within all 3 nested circular plots measured for the respective size class at all 4 stations per site. # stations = Number of stations for which tree/snag data were collected within the 3 nested circular plots.	n/a

Variable	Metric	Calculation	Reference
Live tree basal area	ft^2/acre	5-11 in: [$Sum_{(all\ trees)}$ [Pi*(Dbh_{ft}/2)^2]] * 24.16 / # stations 11-24 in: [$Sum_{(all\ trees)}$ [Pi*(Dbh_{ft}/2)^2]] * 4.16 / # stations 24-30 in: [$Sum_{(all\ trees)}$ [Pi*(Dbh_{ft}/2)^2]] / # stations >30 in: [$Sum_{(all\ trees)}$ [Pi*(Dbh_{ft}/2)^2]] / # stations Total basal area = sum of all above values Pi = 3.1416 Dbh_{ft} = diameter at breast height in feet # stations = Number of stations for which tree/snag data were collected within the 3 nested circular plots.	Note: equation for the area of a circle with radius equal to ½ diameter at breast height utilized for basal area calculation of each tree
Canopy Cover	%	Calculation per measurement: 100– ($Cnt_{open\ dots}$ * 1.04); Measurements averaged per station and then across stations per site.	Note: convex densitometer conversion calculation to canopy cover
Litter Depth	in	Average value across all measurements taken per station along transects. Per station average was averaged across all stations per site.	
Ground Cover by category: Shrub Herb Grass Rock Litter Bare Ground	%	$Length_{categoryr}$ / $Length_{total}$ * 100 $Length_{categoryr}$ = length (in cm) of ground cover transect segments covered by respective ground cover type at each station $Length_{total}$= length (in cm) of all ground cover transect segments measured for ground coverat each station Note: values averaged across all 4 stations per site	

Quadratic Mean Diameter (QMD)	in	Sqrt[($BA_{ft2/ac}$ * 144 $_{in2/ft2}$) /# trees per acre / Pi] * 2
		
		Sqrt = square root of the value in parentheses
		$BA_{ft2/ac}$= Total basal area measured per station in units ft^2 per acre (summed across all tree size classes).
		144 $_{in2/ft2}$ = conversion factor from ft^2 per acre to in^2 per acre.
		# trees per acre = Total number of trees per acre (summed across all tree size classes)
		Pi = 3.1416
			Note: value represents the diameter (dbh) of a hypothetical tree that represents the average tree basal area at a site

Stand Density Index	# of 10 in dbh tree equivalent s/acre	# trees per acre * [(QMD_{in}/10)$^{1.605}$] # trees per acre = Total number of trees per acre (summed across all tree size classes) QMD_{in} = Quadratic mean diameter in inches	

Appendix 1-8. Lentic site bird point count protocol.

Spatial arrangement

A total of 1-8 stations (approximately 250-500 m apart) were established and surveyed at each lentic site, depending on site size and visibility along the shoreline of ponds/lakes or edge of meadows (Figure 1-2). The primary objective was to achieve complete survey coverage of sites and to minimize survey overlap between stations. Ralph et al. (1993) recommended that point counts be located a minimum of 250 m apart; given the open environment associated with many lentic units, therefore count stations were generally established 500 m apart around the perimeter of each sample unit to ensure point counts were independent, however, in some cases were placed closer together as needed to ensure complete visibility of lentic habitat at the site collectively across all stations (Figure 1-2). In 2003 many of the smaller sites had only one station. Some of the sites surveyed in 2003 were resampled in 2004, original stations were surveyed and if necessary additional stations were added to the site (33 of the sites surveyed in 2003 had stations added to them when surveyed in 2004).

Survey protocol

One survey visit was conducted to each site in 2003 and 2 were conducted to all sites surveyed in 2004. At sites with multiple visits, surveys were separated by at least 1 week (i.e., 7 days).

Point count surveys were conducted at monitoring sites from beginning of June through late August in each survey year. All count stations associated with a given site were surveyed on the same day, starting no earlier than fifteen minutes after sunrise and finishing no later than 4 hours after sunrise. Counts lasted 20 minutes at each station, with data recorded in 4 time intervals: the first 3 minutes, 3 to 5 minutes, 5 to 10 minutes, and the final 10 minutes. During the 10 minute counts, observers recorded detections of each bird species and of the following mammals by both sight and/or sound: Douglas' squirrels (*Tamiasciurus douglasii*), yellow-bellied marmots (*Marmota flaviventris*) and American pika (*Ocotona princeps*). The following amphibians were also recorded as incidentals when detected: Pacific tree frog (*Hyla regilla*) and bullfrog (*Rana catesbiana*). For surveys conducted during 2003, detections were recorded at 50 m intervals: 0-50 m, 51-100 m, and >100 m. During 2004, detections were recorded at 25 m distance intervals: 0-25 m, 26-50 m, 51-75 m, 76-100 m and >100 m. Each individual detected at each station was recorded in the time and distance interval in which it was first detected. Birds detected flying over the observer during the point count without landing nearby were recorded in the ">100 m" distance category. Individuals detected at multiple stations were noted such that a total count of the number of individuals at a given site could be generated.

Weather conditions were recorded at the start of each point count survey including cloud cover, wind condition (Beaufort wind scale, Table A1-1) and precipitation. Counts were not conducted if precipitation was occurring or if the wind was greater than a slight breeze (small twigs moving; Beaufort wind scale number 3). No more than 1 visit at a given site was conducted by the same observer, and each time a site was revisited, the observer arbitrarily changed the order in which stations were surveyed over time with respect to the previous order of counts at that site.

Appendix 1-9. Lentic vertebrate visual encounter survey protocol.

Spatial arrangement

Visual encounter surveys were conducted for herpetofauna at lakes and ponds by walking the entire perimeter of the site. In meadows, observers zigzagged from side to side covering the entire width of the meadow with each new trajectory. In meadows, when standing water was too deep to walk through, observers walked the perimeter of the water body.

Survey protocol

Visual encounter surveys were conducted between 0700 and 1815 hrs from mid May and September. All sites were visited twice and all visits were separated by at least one week.

In all habitat types, observers spent approximately 15 minutes per 100 m surveyed, to identify species, count tadpoles, or maneuver around obstacles. Observers spent most of the time walking in the water, searching through emergent vegetation with a long-handled dip-net and overturning rocks, logs, and debris to reveal amphibians and reptiles (Fellers and Freel 1994). Less time was spent searching in areas of less suitable habitat. All amphibian and reptile species captured, seen or heard were recorded, including species, life stage (egg, tadpole, juvenile, adult), and number of individuals (or egg masses); substrates associated with the individual detection were also recorded during some surveys.

The presence or absence of fish was recorded during amphibian and reptile surveys, identifying them to the lowest taxonomic level possible (at minimum observers recorded whether trout or non-trout fish species were present at sites with fish). Wet meadows and ponds < 1 m deep were visually scanned for fish from above the water surface, as observers could readily see the bottom. At sites > 1 m deep, if no fish were observed during amphibian and reptile surveys, then the site was snorkeled. At larger sites, snorkeling was conducted from an inflatable raft. Lakes were snorkeled until fish were observed or for a maximum of 10 min for lakes less than 1 acre with two additional minutes per acre (for a maximum of 30 min) for larger lakes.

Appendix 1-10. Lentic habitat condition protocol

Spatial arrangement

A total of 30 (during 2002-2003) to 50 (during 2004) 3 m long and 0.25 m wide littoral zone transects were established at each of the 148 lentic monitoring sites. For lakes and ponds, each littoral transect ran perpendicular to the shoreline and extended 3 m from the shoreline into the water. For wet meadows and fens, a randomly determined starting point was selected for a straight line across the longest dimension of the meadow, and transects were sampled perpendicular to and centered on this line. At all site types, transects were evenly spaced, either along the length of the meadow or around the perimeter of the pond/lake, in order to fit all 30 or 50 transects at the site.

At sites sampled in 2004 (52 sites), an additional 50 upland vegetation transects were sampled at lakes and ponds that extended upland 3 m from the shoreline to describe upland habitat features.

Survey protocol

Habitat measurements were taken once at each site and during either one of the two vertebrate perimeter survey visits or within two days of the vertebrate survey.

The following site based variables were either collected in the field or generated using GIS:

- Maximum depth was measured using either a 1-2 m long pole, fishing line with a sinker attached to the end, or for large sites of known depth, depth was based on Schaffer (2002). Maximum lake depth was recorded as the greatest depth obtained from 5 measurements in locations likely to be at or near the deepest part of the sample unit.
- Disturbance within 10 m and 30 m of the high watermark was measured in the field as the following:
    - area of each type of road (m^2) - highway, paved road, primary use dirt road, secondary dirt road
    - area of trails (m^2)
    - Additional area (m^2) of compacted soil and impermeable surfaces.
- Number of inlets and outlets $\geq$ 10 cm wide existing at the time of survey, and the total number likely to have existed at some point during the season (if ephemeral).
- Proportion of area developed within 50 m and 200 m of the sample site. The area developed was represented by a spatially explicit GIS model of development derived from land use designations on county parcel maps combined with roads and trails from U.S. Forest Service transportation

maps (Manley et al 2007). Development included any area where native vegetation was removed.
- Site elevation, orientation (cardinal direction around Lake Tahoe), and size (based on GIS) were also recorded. Site size was calculated as the surface area of each lentic site based on the available GIS water body layer for the Lake Tahoe Basin Management Unit (i.e., water body coverage) and field corroboration by pacing average length and width of the sample site. Field measurements were checked against digital data, when available.
- Area of each CWHR vegetation type (Mayer and Laudenslayer 1988) present within 200 m of each lentic site based on GIS analysis using an available vegetation layer (IKONOS v4).

The following vegetation, structure and substrate variables were collected along each littoral transect:

- Water depth at 1, 2 and 3 m along transect
- Percent of each transect occupied by each of six different substrate types: silt, sand, pebbles, cobbles, boulders, or bedrock
- Proportion of each transect occupied by emergent vegetation (all sites/all years), and additionally the proportion of submergent, floating and hanging vegetation along transects at sites sampled during 2004 only
- Presence of coarse woody debris (≥ 10cm at large end of lot) intersecting the transect

The following vegetation, structure and substrate variables were collected along each upland transect measured in 2004:

- Percent of each transect occupied by each of six different substrate types: silt, sand, pebbles, cobbles, boulders, or bedrock
- Presence of coarse woody debris (≥ 10cm at large end of lot) intersecting each transect
- Presence of each of the following vegetation types along each transect: rush, sedge, grass, pond lily, other unknown herb species, willow, alder, other unknown shrub species, aspen, cottonwood, lodgepole pine, other unknown pine species, fir species (e.g, white fir or red fir), unknown deciduous species, unknown conifer species.

Appendix A-1. Detection frequencies, abundances and estimated site occupancy and detection probabilities for all species detected (excluding accidental species detections) at forestwide and lentic network monitoring sites in the Lake Tahoe basin, CA and NV, 2002-2005. Monitoring metrics were calculated based on methods described in McKenzie et al (2002), and detection probabilities calculated based on methods described in data analysis section. Estimated site occupancy values are less reliable for species detected at fewer than 20 sites and with detection probability estimates less than 0.80.

		Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
Common Name	Species Status[1]	# of Sites	% of Sites	% of Sites - L100	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites
Special Interest species																		
Bald Eagle	MIS, FT								0.00	1	1			100.0	17.9	0.01	1	< 1
Blue Grouse	MIS	32	30	22	0.11	0.02	63.0	29.6	0.40	10	7	0.42	0.09	100.0	1.2	0.10	42	17
Mallard	MIS, waterbird	10	10	3	0.24	0.07	3.4	2.0	0.90	58	39	2.68	0.95	46.3	6.8	0.88	68	27
Peregrine falcon	MIS, FSS																0	0
California Spotted Owl	MIS, FSS, SOC																0	0
Northern Goshawk	MIS, FSS, SOC	4	4	2	0.05	0.00	100.0	7.4	0.02	3	2	0.25	n/a	100.0	5.9	0.04	7	3
Willow Flycatcher	MIS, FSS, SOC																0	0
Pileated Woodpecker	MIS, SOI	10	10	6	0.05	0.00	100.0	1.5	0.07	5	3	0.25	0.00	100.0	3.5	0.06	15	6
Bank Swallow	SOC																0	0
Yellow Warbler	SOC	7	7	7	0.11	0.03	20.6	17.7	0.37	5	3	0.47	0.11	7.7	5.5	0.64	12	5
American Dipper	SOI	1	1	1	0.07	n/a	100.0	37.9	0.01	8	5	0.38	0.12	100.0	1.7	0.07	9	4
Black-backed Woodpecker	SOI	12	11	11	0.12	0.05	39.6	33.0	0.33	9	6	0.26	0.05	100.0	1.2	0.11	21	8
Brown-headed Cowbird	SOI	65	62	60	0.50	0.07	66.1	5.5	0.95	41	28	0.82	0.08	52.2	18.9	0.52	106	42
Lincoln's Sparrow	SOI	14	13	13	0.26	0.04	18.5	6.0	0.78	34	23	0.99	0.15	37.3	7.8	0.79	48	19
Osprey	SOI	5	5	1	0.05	n/a	100.0	14.9	0.01	6	4	0.24	0.06	7.7	5.5	0.64	11	4
Spotted Sandpiper	SOI	5	5	5	0.25	0.11	5.2	2.3	0.95	23	16	0.57	0.11	33.3	13.9	0.56	28	11
White-headed Woodpecker	SOI	55	52	48	0.15	0.02	62.6	8.1	0.82	27	18	0.41	0.13	33.3	13.9	0.56	82	32
Wilsons Snipe	SOI	2	2	2	0.11	0.04	2.4	1.8	0.87	4	3	1.00	n/a	100.0	5.9	0.04	6	2
Yellow-headed Blackbird	SOI	1	1	1	0.24	n/a	100.0	14.9	0.01	4	3	0.64	0.07	100.0	5.9	0.04	5	2

		Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
Common Name	**Species Status[1]**	**# of Sites**	**% of Sites**	**% of Sites - L100**	**Abundance per count**	**Abundance s.e.**	**Estimated Site Occupancy (% of sites)**	**Occupancy s.e.**	**Probability of Detection**	**# of Sites**	**% of Sites**	**Abundance per count**	**Abundance s.e.**	**Estimated Site Occupancy (% of sites)**	**Occupancy s.e.**	**Probability of Detection**	**# of Sites**	**% of Sites**
American Coot	waterbird	1	1	1	0.07	n/a	100.0	37.9	0.01	3	2	1.44	0.71	2.8	2.5	0.89	4	2
Black-crowned Night Heron	waterbird								0.00	1	1	0.17	n/a	100.0	17.9	0.01	1	< 1
Bufflehead	waterbird								0.00	10	7	2.54	1.39	12.5	6.1	0.69	10	4
California Gull	waterbird	1	1						0.00	4	3	1.00	n/a	100.0	17.9	0.01	5	2
Canada Goose	waterbird	8	8						0.00	13	9	6.31	3.44	14.8	5.8	0.75	21	8
Caspian Tern	waterbird								0.00	1	1						1	< 1
Clark's Grebe	waterbird								0.00	1	1			100.0	8.9	0.02	1	< 1
Common Loon	waterbird	1	1						0.00							0.00	1	< 1
Common Merganser	waterbird	8	8	1	0.29	n/a	1.0	0.9	1.00	17	11	1.67	0.49	9.3	3.5	0.93	25	10
Eared Grebe	waterbird								0.00	1	1			100.0	17.9	0.01	1	< 1
Forster's Tern	waterbird	1	1						0.00	1	1					0.00	2	1
Gadwall	waterbird								0.00	8	5	0.93	0.21	25.0	2.4	0.40	8	3
Great Blue Heron	waterbird	1	1						0.00	1	1	0.25	n/a	100.0	17.9	0.01	2	1
Green-winged Teal	waterbird	1	1	1	0.14	n/a	100.0	14.9	0.01	2	1	1.33	1.17	100.0	8.9	0.02	3	1
Northern Pintail	waterbird								0.00	1	1			100.0	17.9	0.01	1	< 1
Northern Shoveler	waterbird								0.00	1	1	0.13	n/a	100.0	17.9	0.01	1	< 1
Pied-billed Grebe	waterbird	1	1						0.00							0.00	1	< 1
Ring-billed Gull	waterbird	1	1	1	0.07	n/a	100.0	37.9	0.01							0.00	1	< 1
Ring-necked Duck	waterbird								0.00	4	3	0.72	0.40	100.0	8.9	0.02	4	2
Ruddy Duck	waterbird	1	1						0.00	2	1	0.75	0.50	100.0	17.9	0.01	3	1
Sora	waterbird								0.00	1	1	0.25	n/a	100.0	17.9	0.01	1	< 1
Wilson's Phalarope	waterbird	1	1						0.00							0.00	1	< 1
Wood Duck	waterbird								0.00	1	1	0.25	n/a	100.0	17.9	0.01	1	0
<u>High Frequency Species</u>																		
American Robin		105	100	96	0.67	0.04	97.6	2.0	1.00	120	81	1.00	0.06	93.0	4.3	0.96	225	89

Common Name	Species Status[1]	Forestwide Sites (n = 105): Frequency of Detection[2]: # of Sites	% of Sites	% of Sites - L100	Abundance[3]: Abundance per count	Abundance s.e.	Monitoring Metrics[4]: Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	Lentic Sites (n = 148): Frequency of Detection[2]: # of Sites	% of Sites	Abundance[3]: Abundance per count	Abundance s.e.	Monitoring Metrics[4]: Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	All Sites (n = 253) Frequency of Detection: # of Sites	% of Sites
Brown Creeper		88	84	83	0.38	0.03	86.2	3.9	0.99	77	52	0.66	0.05	83.8	7.5	0.85	165	65
Cassin's Finch		80	76	75	0.31	0.04	91.8	6.7	0.86	61	41	0.67	0.10	100.0	0.6	0.37	141	56
Clark's Nutcracker		85	81	66	0.40	0.08	73.1	5.5	0.94	75	51	0.58	0.16	73.3	6.5	0.91	160	63
Dark-eyed Junco		105	100	100	1.54	0.07	100.0	0.0	1.00	129	87	1.85	0.14	96.4	2.5	0.99	234	92
Dusky Flycatcher		94	90	90	0.63	0.05	91.3	3.1	0.99	61	41	0.64	0.06	100.0	0.0	0.40	155	61
Fox Sparrow		91	87	85	0.97	0.09	86.3	3.6	0.99	60	41	0.58	0.05	100.0	0.2	0.37	151	60
Mountain Chickadee		105	100	100	1.59	0.06	100.0	0.0	1.00	141	95	2.08	0.11	99.1	1.3	1.00	246	97
Northern Flicker		92	88	75	0.20	0.02	97.7	7.4	0.85	84	57	0.44	0.06	86.7	5.5	0.94	176	70
Olive-sided Flycatcher		87	83	70	0.31	0.03	78.1	5.3	0.94	77	52	0.61	0.06	71.4	8.3	0.83	164	65
Pine Siskin		88	84	64	0.24	0.02	96.4	11.3	0.74	53	36	0.75	0.08	100.0	0.3	0.40	141	56
Red-breasted Nuthatch		100	95	94	0.78	0.05	94.9	2.3	1.00	107	72	1.02	0.07	92.0	3.2	0.99	207	82
Steller's Jay		104	99	96	0.99	0.07	96.5	1.9	1.00	132	89	0.98	0.07	98.6	1.8	0.99	236	93
Townsend's Solitaire		85	81	72	0.24	0.02	82.3	5.5	0.93	50	34	0.42	0.05	71.8	11.6	0.72	135	53
Warbling Vireo		72	69	68	0.35	0.04	76.5	5.7	0.94	55	37	0.90	0.11	74.2	27.9	0.45	127	50
Western Tanager		90	86	83	0.61	0.05	84.4	3.8	0.99	56	38	0.50	0.08	72.6	15.5	0.63	146	58
Western Wood-pewee		83	79	70	0.45	0.05	76.0	5.0	0.96	107	72	0.88	0.05	83.7	4.9	0.96	190	75
White-breasted Nuthatch		87	83	81	0.32	0.03	91.1	4.9	0.93	63	43	0.57	0.06	74.1	14.7	0.65	150	59
Yellow-rumped Warbler		104	99	99	0.90	0.05	99.1	1.0	1.00	95	64	1.14	0.08	86.4	1.7	0.76	199	79
Moderate Frequency Species																		
Band-tailed Pigeon		42	40	27	0.11	0.01	50.4	14.7	0.59	31	21	0.75	0.48	100.0	0.1	0.22	73	29
Brewer's Blackbird		13	12	11	0.32	0.09	15.9	5.3	0.79	41	28	3.45	0.85	32.4	7.3	0.80	54	21
Cassin's Vireo		50	48	45	0.16	0.02	70.2	11.3	0.72	30	20	0.37	0.05	67.2	21.6	0.51	80	32
Common Raven		37	35	14	0.08	0.01	40.6	20.3	0.41	13	9	1.00	n/a	100.0	0.9	0.12	50	20
Evening Grosbeak		72	69	46	0.40	0.07	52.4	6.0	0.92	45	30	1.17	0.23	68.6	15.8	0.62	117	46
Golden-crowned Kinglet		70	67	67	0.40	0.05	71.7	5.1	0.96	31	21	0.60	0.08	44.6	24.7	0.42	101	40

		Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
Common Name	Species Status[1]	# of Sites	% of Sites	% of Sites - L100	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites
Green-tailed Towhee		47	45	44	0.34	0.08	57.3	7.8	0.83	9	6	0.40	0.11	100.0	4.4	0.05	56	22
Hairy Woodpecker		75	71	70	0.16	0.02	93.7	8.7	0.81	47	32	0.41	0.04	55.6	8.2	0.82	122	48
Hermit Thrush		68	65	49	0.30	0.04	60.4	7.3	0.85	31	21	0.39	0.07	69.4	6.4	0.25	99	39
House Wren		27	26	26	0.22	0.03	40.0	9.2	0.72	45	30	0.46	0.05	64.9	15.0	0.63	72	28
Macgillivray's Warbler		67	64	61	0.30	0.04	71.7	6.3	0.91	55	37	0.58	0.07	81.5	21.2	0.55	122	48
Mountain Quail		62	59	35	0.17	0.03	70.8	17.0	0.57	18	12	0.50	0.14	100.0	8.9	0.02	80	32
Mourning Dove		46	44	36	0.18	0.02	45.6	6.8	0.86	29	20	0.70	0.08	27.2	7.3	0.77	75	30
Nashville Warbler		63	60	57	0.34	0.04	70.6	7.1	0.87	30	20	0.50	0.10	100.0	0.3	0.24	93	37
Pine Grosbeak		37	35	30	0.16	0.02	58.4	17.1	0.56	28	19	0.40	0.07	51.9	16.2	0.57	65	26
Pygmy Nuthatch		42	40	40	0.32	0.06	52.3	7.6	0.83	19	13	0.61	0.12	89.2	78.8	0.22	61	24
Red Crossbill		36	34	20	0.13	0.02	100.0	0.0	0.22	24	16	0.47	0.10	100.0	0.4	0.27	60	24
Red-breasted Sapsucker		32	30	26	0.13	0.02	58.5	21.8	0.49	18	12	0.43	0.11	100.0	0.9	0.12	50	20
Rufous Hummingbird		33	31	31	0.39	0.11	39.5	6.7	0.85	42	28	0.52	0.05	98.9	46.5	0.35	75	30
Song Sparrow		18	17	16	0.23	0.06	22.7	6.3	0.78	35	24	1.21	0.16	35.6	1.7	0.66	53	21
Williamson's Sapsucker		58	55	52	0.19	0.02	69.6	8.5	0.81	24	16	0.63	0.13	100.0	1.2	0.10	82	32
Wilson's Warbler		51	49	49	0.24	0.03	61.7	7.4	0.85	56	38	0.65	0.07	75.8	16.3	0.62	107	42
Low Frequency Species																		
American Kestrel		1	1						0.00							0.00	1	< 1
Anna's Hummingbird		5	5	5	0.06	0.01	100.0	3.6	0.06	1	1	0.17	n/a			0.00	6	2
Barn Swallow		3	3	1	0.76	n/a	1.1	1.1	0.94	7	5	1.72	0.58	5.6	2.9	0.89	10	4
Belted Kingfisher		1	1	1	0.24	n/a	1.1	1.1	0.94	11	7	0.32	0.05	14.8	5.8	0.75	12	5
Black-headed Grosbeak		21	20	20	0.11	0.02	50.0	20.4	0.46	7	5	0.43	0.15	100.0	3.5	0.06	28	11
Black Phoebe		1	1	1	0.07	n/a	100.0	37.9	0.01	1	1	0.25	n/a	100.0	17.9	0.01	2	1
Black-throated Gray Warbler		5	5	5	0.10	0.04	100.0	3.6	0.06							0.00	5	2
Blue-gray Gnatcatcher		3	3	3	0.10	0.03	100.0	5.8	0.03							0.00	3	1

		Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
Common Name	Species Status[1]	# of Sites	% of Sites	% of Sites - L100	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites
Brewer's Sparrow		1	1	1	0.05	n/a	100.0	14.9	0.01	2	1	1.25	n/a	2.8	2.5	0.89	3	1
Bushtit		5	5	5	0.17	0.09	100.0	1.7	0.06							0.00	5	2
Calliope Hummingbird		17	16	14	0.11	0.02	39.2	22.5	0.42	23	16	0.43	0.06	37.1	15.6	0.53	40	16
Canyon Wren		1	1	1	0.05	n/a	100.0	14.9	0.01	3	2	0.25	0.00	100.0	5.9	0.04	4	2
Chipping Sparrow		32	30	29	0.15	0.02	64.3	20.3	0.51	6	4	0.85	0.09	100.0	8.9	0.02	38	15
Cliff Swallow		8	8	2	0.52	0.24	2.4	1.8	0.87	15	10	1.57	0.45	100.0	0.9	0.13	23	9
Common Nighthawk		4	4						0.00	9	6	1.00	n/a	11.1	8.2	0.56	13	5
Common Poorwill		2	2	2	0.08	0.01	2.4	1.8	0.87							0.00	2	1
Cooper's Hawk		4	4	1	0.05	n/a	100.0	14.9	0.01	1	1			100.0	17.9	0.01	5	2
Downy Woodpecker		21	20	16	0.10	0.01	55.2	33.4	0.34	5	3	0.63	0.18	4.9	3.4	0.75	26	10
European Starling									0.00	6	4	2.03	1.26	100.0	17.9	0.01	6	2
Gray-crowned Rosy Finch		2	2	2	0.46	0.18	2.0	1.4	0.97	1	1			100.0	17.9	0.01	3	1
Hammond's Flycatcher		5	5	5	0.10	0.03	100.0	1.7	0.06	2	1	0.25	0.00	100.0	8.9	0.02	7	3
Hermit Warbler		32	30	30	0.20	0.03	69.0	21.5	0.50	17	11	0.40	0.05	100.0	0.2	0.18	49	19
House Finch		1	1	1	0.14	n/a	100.0	37.9	0.01	3	2	0.92	0.08	100.0	17.9	0.01	4	2
House Sparrow									0.00	2	1	0.50	0.17	100.0	17.9	0.01	2	1
Killdeer		4	4						0.00	6	4	0.31	0.07	1.2	1.2	1.00	10	4
Lark Sparrow		1	1	1	0.05	n/a	100.0	14.9	0.01							0.00	1	< 1
Lazuli Bunting		6	6	6	0.11	0.02	100.0	3.2	0.07	2	1	1.00	n/a			0.00	8	3
Lesser Goldfinch		2	2	1	0.05	n/a	100.0	14.9	0.01	4	3	0.42	0.20	4.9	3.4	0.75	6	2
Mountain Bluebird		11	10	10	0.15	0.03	14.4	5.6	0.73	5	3	0.56	0.16	100.0	8.9	0.02	16	6
Northern Harrier									0.00	1	1			100.0	17.9	0.01	1	< 1
Northern Rough-winged Swallow									0.00	3	2	2.50	2.00	4.9	3.4	0.75	3	1
Orange-crowned Warbler		16	15	14	0.12	0.03	63.2	55.0	0.26	10	7	0.56	0.16	25.0	2.4	0.40	26	10

Common Name	Species Status[1]	Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
		# of Sites	% of Sites	% of Sites - L100	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites
Ovenbird		1	1	1	0.05	n/a	100.0	14.9	0.01							0.00	1	< 1
Pacific-slope Flycatcher		5	5	5	0.07	0.01	100.0	1.7	0.06	6	4	0.23	0.02	100.0	4.4	0.05	11	4
Purple Finch		2	2	1	0.10	n/a	100.0	14.9	0.01	1	1	0.25	n/a	100.0	17.9	0.01	3	1
Red-tailed Hawk		16	15	7	0.05	0.00	100.0	1.2	0.08	7	5	0.17	0.00	100.0	3.5	0.06	23	9
Red-winged Blackbird		16	15	10	0.65	0.29	12.8	4.0	0.88	31	21	2.46	0.39	14.3	4.7	0.95	47	19
Rock Pigeon		1	1						0.00	3	2	1.17	0.17	2.8	2.5	0.89	4	2
Rock Wren		14	13	10	0.22	0.06	12.7	4.0	0.88	9	6	0.27	0.04	19.8	15.5	0.44	23	9
Ruby-crowned Kinglet		4	4	4	0.14	0.05	100.0	4.1	0.04	2	1	0.29	0.04	100.0	17.9	0.01	6	2
Savannah Sparrow		1	1	1	0.43	n/a	100.0	37.9	0.01	2	1					0.00	3	1
Sharp-shinned Hawk		2	2	2	0.06	0.01	100.0	9.8	0.02	4	3	0.20	0.03	100.0	4.4	0.05	6	2
Spotted Towhee		10	10	10	0.16	0.06	17.0	7.7	0.63	3	2	0.13	0.00			0.00	13	5
Swainson's Hawk									0.00	1	1					0.00	1	< 1
Swainson's Thrush		3	3	3	0.07	0.01	100.0	5.8	0.03							0.00	3	1
Townsend's Warbler		1	1	1	0.14	n/a	100.0	37.9	0.01							0.00	1	< 1
Tree Swallow		3	3	1	0.05	n/a	100.0	14.9	0.01	7	5	0.50	0.14	100.0	8.9	0.02	10	4
Turkey Vulture		2	2	2	0.07	0.00	100.0	18.9	0.02							0.00	2	1
Vesper Sparrow		1	1	1	0.07	n/a	100.0	37.9	0.01	1	1	0.25	n/a	100.0	17.9	0.01	2	1
Violet-green Swallow		4	4	3	0.19	0.12	100.0	4.9	0.03							0.00	4	2
Western Bluebird		11	10	10	0.13	0.02	52.3	47.8	0.24							0.00	11	4
White-crowned Sparrow		13	12	12	0.66	0.30	19.6	7.2	0.70	11	7	1.24	0.28	2.5	1.7	1.00	24	9
White-throated Swift		3	3						0.00							0.00	3	1
Winter Wren		13	12	11	0.16	0.04	16.6	5.7	0.76	1	1					0.00	14	6
Wrentit		1	1	1	0.19	n/a	100.0	14.9	0.01							0.00	1	< 1
Mammals																		
Douglas' squirrel		100					96.1	2.2	0.99	109				95.6	4.5	0.87	209	83

Common Name	Species Status[1]	Forestwide Sites (n = 105)								Lentic Sites (n = 148)							All Sites (n = 253)	
		Frequency of Detection[2]			Abundance[3]		Monitoring Metrics[4]			Frequency of Detection[2]		Abundance[3]		Monitoring Metrics[4]			Frequency of Detection	
		# of Sites	% of Sites	% of Sites - L100	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites	Abundance per count	Abundance s.e.	Estimated Site Occupancy (% of sites)	Occupancy s.e.	Probability of Detection	# of Sites	% of Sites
American pika		21					33.6	18.0	0.66	9				100.0	0.0	0.08	30	12
Yellow-bellied marmot		4					100.0	0.0	0.04	0						0.00	4	2

1 MIS = Management Indicator Species, FSS = Forest Service sensitive species, FT = Federally threatened under ESA, SOC = Pathway 2007 proposed species of concern (FSH 1900.12 section 43.22b), SOI = Pathway 2007 proposed species of interest (FSH 1900.12 section 43.22c), waterbird = Pathway 2007 proposed species group (FSH 1900.12 section 43.24).

2 Frequency of detection values represent the number or percent of sites with detections of the respective species, and are based on detections at any distance from the point count station, except when noted. L100 = based on detections within 100 meters of the count station.

3 Abundance estimates represent the average number of individuals detected per point count per survey visit per site, and reflect the average of sites where the respective species was detected. Abundance values are limited to detections within 100 meters of the count station and based on 10 minute point counts at forestwide sites and 20 minute counts at lentic sites. Species without abundance estimates were not detected within 100 meters of any count station.

4 Monitoring metric estimates for forest wide sites are based on detections within 100 meters of count stations, however, estimates for lentic sites are based on detections at any distance from count stations. Estimates require a minimum of 2 survey visits per site in order to allow for estimation of monitoring metrics; all 105 forestwide sites had at least 2 visits, however only 81 of the 145 lentic sites had 2 survey visits. Hence the sample size for lentic estimates was reduced and as a result some species were not detected at the 81 sites used for calculation of estimates and therefore have no associated estimates for monitoring metrics.

Appendix A-2. Bird species distribution (% of sites with detections), total species richness, and mean richness by sub-watershed (Hydrologic Unit Category Level 6) in the Lake Tahoe basin, based on detections at any distance from count stations and during all visits to forest wide (FW) and 145 lentic (LEN) monitoring sites sampled in 2002-2005. Values represent the percent of sites within each watershed with detections of the respective species. Distributions of 3 small mammal species detected vocally with point count sampling are also shown. The number of sites sampled within each sub-watershed are shown beneath the name of each respective sub-watershed.

	Burton Creek-Watson Creek-Tahoe Vista Frontal		Stateline Point-Third Creek-Incline Creek Frontal		Lake Tahoe - East Shore Frontal / North Half		Lake Tahoe - East Shore Frontal / South Half		Upper Truckee River - Trout Creek		Upper Truckee River		Cascade Creek-Tallac Creek-Taylor Creek Frontal		McKinney Creek-Bliss-Eagle Creek Frontal		Ward Creek-Blackwood Creek-Eagle Rock Frontal	
Common Name	*FW (n=8)*	*LEN (n=6)*	*FW (n=6)*	*LEN (n=5)*	*FW (n=4)*	*LEN (n=6)*	*FW (n=14)*	*LEN (n=7)*	*FW (n=14)*	*LEN (n=8)*	*FW (n=19)*	*LEN (n=46)*	*FW (n=12)*	*LEN (n=31)*	*FW (n=13)*	*LEN (n=26)*	*FW (n=11)*	*LEN (n=10)*
Birds																		
American Coot											5	7						
American Dipper [R]												4		13	8	8		
American Kestrel															8			
American Robin [M]	100	83	100	80	100	83	100	86	100	63	100	87	100	77	100	69	100	100
Anna's Hummingbird			17						7		5			3	15			
Bald Eagle						17												
Barn Swallow							7	43	7			4	8	6				
Black-backed Woodpecker	13						29		7		16	9	8	6	15	4		20
Black-crowned Night Heron								14										
Belted Kingfisher [M/R]									7			15		6				10
Blue-gray Gnatcatcher			17		25		7											
Brown-headed Cowbird	88	33	67	40	75	50	71	100	57	25	63	20	67	19	46	19	36	40
Black-headed Grosbeak [R]		33	17		25		43	14	36		11	4	17	3	8	4	9	
Blue Grouse	38		50	20	75	17	14		14		32	2	25	19	23	4	55	
Black Phoebe												2			8			
Brewer's Blackbird		50		40	25	17	7	71	14	13	21	26	17	39	15	12		10
Brown Creeper [OG]	88	83	50	60	75	50	93	29	93	50	74	52	75	39	85	62	100	60
Brewer's Sparrow			17									2		3				
Black-throated Gray Warbler											11				8		9	
Band-tailed Pigeon	25	33	67	20	25	33	71	29	14	13	32	13	33	35	46	15	36	20
Bufflehead												9		3		15		10
Bushtit							7		7		11				8			
Cassin's Finch [OG]	38	17	83	80	100	50	79	29	64	75	84	43	83	42	69	19	91	40
Canada Goose		17				33	7	29			11	9	17	6	8	8	9	
California Gull								14				2	8	6				
Calliope Hummingbird	25	50	33	20		17			7	13	26	9	33	23	23			40

Common Name	Burton Creek-Watson Creek-Tahoe Vista Frontal		Stateline Point-Third Creek-Incline Creek Frontal		Lake Tahoe - East Shore Frontal / North Half		Lake Tahoe - East Shore Frontal / South Half		Upper Truckee River - Trout Creek		Upper Truckee River		Cascade Creek-Tallac Creek-Taylor Creek Frontal		McKinney Creek-Bliss-Eagle Creek Frontal		Ward Creek-Blackwood Creek-Eagle Rock Frontal	
	FW (n=8)	*LEN (n=6)*	*FW (n=6)*	*LEN (n=5)*	*FW (n=4)*	*LEN (n=6)*	*FW (n=14)*	*LEN (n=7)*	*FW (n=14)*	*LEN (n=8)*	*FW (n=19)*	*LEN (n=46)*	*FW (n=12)*	*LEN (n=31)*	*FW (n=13)*	*LEN (n=26)*	*FW (n=11)*	*LEN (n=10)*
Caspian's Tern						17												
Cassin's Vireo	38	17	33		75	33	57		36	13	37	24	50	13	62	35	55	20
Canyon Wren							7							6		4		
Chipping Sparrow [M]	63		50		75	33	21		21		26	2	25	3	15		36	10
Clark's Grebe						17												
Clark's Nutcracker	75	17	100	80	75	50	93	14	93	63	84	43	75	58	85	69	45	40
Cliff Swallow		33			25		14	57	7		21	15		3		4		
Cooper's Hawk	13								7		5		8					10
Common Loon													8					
Common Merganser [R]	13					33					5	7	25	23	15	15		
Common Nighthawk									7		5	7	8	10	8	8		
Common Poorwill	13										5							
Common Raven	50	17	50	20	75	17	43	14	29	13	32	7	42	6	23	8	18	10
Dark-eyed Junco	100	83	100	80	100	100	100	43	100	100	100	91	100	90	100	85	100	80
Downy Woodpecker [R]	25	17			50	17	21		14		11	2	33		15		27	20
Dusky Flycatcher	100	50	83		100	100	86	14	79	88	95	30	83	35	85	35	100	80
Earred Grebe																4		
European Starling						17		43				2		3				
Evening Grosbeak [OG]	88	67	33	20	75		71	14	57	50	63	22	67	23	62	35	91	60
Fox Sparrow	100	50	83	40	75	33	93		64	25	89	39	92	45	85	50	91	50
Forster's Tern													8					
Gadwall								14				4		13				10
Great Blue Heron [R]												2	8					
Golden-crowned Kinglet	100	17	33		50	50	64	29	43	13	63	15	58	13	69	23	100	50
Gray-crowned Rosy Finch				20							5		8					
Green-tailed Towhee	25		100		75		50	14	29	25	42	2	42	13	31	4	64	
Green-winged Teal									7			4						
Hammond's Flycatcher									7		11			3	8	4	9	
Hairy Woodpecker	75	50	67	60	75	50	86	29	64	25	47	37	67	23	77	19	91	30
Hermit Thrush	63	50	50	20	100	17	36	14	57	50	74	15	42	10	77	12	100	70
Hermit Warbler [OG]	25	33	17				7	14	43	13	42	15	8	3	54	8	27	20
House Finch							7	29						3				

Common Name	Burton Creek-Watson Creek-Tahoe Vista Frontal		Stateline Point-Third Creek-Incline Creek Frontal		Lake Tahoe - East Shore Frontal / North Half		Lake Tahoe - East Shore Frontal / South Half		Upper Truckee River - Trout Creek		Upper Truckee River		Cascade Creek-Tallac Creek-Taylor Creek Frontal		McKinney Creek-Bliss-Eagle Creek Frontal		Ward Creek-Blackwood Creek-Eagle Rock Frontal	
	FW (n=8)	*LEN (n=6)*	*FW (n=6)*	*LEN (n=5)*	*FW (n=4)*	*LEN (n=6)*	*FW (n=14)*	*LEN (n=7)*	*FW (n=14)*	*LEN (n=8)*	*FW (n=19)*	*LEN (n=46)*	*FW (n=12)*	*LEN (n=31)*	*FW (n=13)*	*LEN (n=26)*	*FW (n=11)*	*LEN (n=10)*
House Sparrow								14						3				
House Wren [M/R]	13	17		20	50	17	21	43	21	38	37	28	33	32	15	31	18	40
Killdeer [R]					25	17		29			11	4	8					
Lark Sparrow									7									
Lazuli Bunting [M/R]			33				7				11			3			9	10
Lesser Goldfinch							7	29				2		3				
Lincoln's Sparrow [M]		17		60	25	17			7	38	21	15	25	19	15	35	27	40
Mallard		17				67		29	7		5	50	33	45	23	42	9	20
Macgillivray's Warbler [M/R]	13	50	67	20	75	50	71	14	43	38	79	33	50	42	62	31	100	50
Mountain Bluebird			33				21			25	5	2	8	3	15	4	18	
Mountain Chickadee	100	100	100	100	100	100	100	86	100	88	100	98	100	94	100	92	100	100
Mourning Dove	75	33	33	20	75	17	71	57	57		26	26	33	19	31		9	20
Mountain Quail	100	33	67		25	17	36		36	13	63	9	33	3	85	19	73	20
Nashville Warbler [M]	50	67	67	20	75	17	57		29		63	22	58	23	62	15	91	20
Northern Flicker	100	50	100	20	75	50	100	57	79	50	79	59	92	61	77	58	91	60
Northern Goshawk [OG]				20			7				5	4			8		9	
Northern Harrier												2						
Northern Pintail												2						
Northern Shoveler														3				
Northern Rough-winged Swallow [M/R]		17						14				2						
Orange-crowned Warbler [M]			33					14	7		11	4	33	13	23	8	27	10
Olive-sided Flycatcher	88	33	67	60	100	50	93	29	50	38	89	46	75	61	100	69	91	40
Osprey	13		17			17	14					7		6	8			
Ovenbird					25													
Pied-billed Grebe											5							
Pine Grosbeak	13	17	67	40	25	17	7	14	21	13	63	20	25	16	54	23	36	10
Pine Siskin	63	17	67	40	75		64	57	93	50	95	39	92	35	92	27	100	60
Pileated Woodpecker [OG]			17							13	11	2	25	3	8	4	27	10
Pacific-slope Flycatcher [R]			17	20			7					7	8		15			10
Purple Finch [OG]			17		25							2						
Pygmy Nuthatch [OG]	38	33			50	17	86	14	43		32	20	50	10	23	12	27	
Ring-billed Gull																	9	

	Burton Creek-Watson Creek-Tahoe Vista Frontal		Stateline Point-Third Creek-Incline Creek Frontal		Lake Tahoe - East Shore Frontal / North Half		Lake Tahoe - East Shore Frontal / South Half		Upper Truckee River - Trout Creek		Upper Truckee River		Cascade Creek-Tallac Creek-Taylor Creek Frontal		McKinney Creek-Bliss-Eagle Creek Frontal		Ward Creek-Blackwood Creek-Eagle Rock Frontal	
Common Name	*FW (n=8)*	*LEN (n=6)*	*FW (n=6)*	*LEN (n=5)*	*FW (n=4)*	*LEN (n=6)*	*FW (n=14)*	*LEN (n=7)*	*FW (n=14)*	*LEN (n=8)*	*FW (n=19)*	*LEN (n=46)*	*FW (n=12)*	*LEN (n=31)*	*FW (n=13)*	*LEN (n=26)*	*FW (n=11)*	*LEN (n=10)*
Red-breasted Nuthatch [OG]	100	83	100	60	100	67	93	29	93	75	95	76	92	68	92	81	100	70
Red-breasted Sapsucker [M]	38	33	50		50	17	21	29	29		16	11	25	10	38	12	36	20
Ruby-crowned Kinglet		17	17		25						5	2						
Red Crossbill	50	17	33		25	17	43	14	14	25	11	13	50	23	38	23	64	
Ring-necked Duck								14				2		3		4		
Rock Pigeon							7	29								4		
Rock Wren	13		33		25	17			7		16		17	16	15	4	18	20
Red-tailed Hawk	13		50			33	21	14	14		11		8	3	23	4		20
Ruddy Duck											5	2				4		
Rufous Hummingbird	13	17	67	20		33	7	14	21	38	53	24	42	35	31	27	45	50
Red-winged Blackbird		33		20	75	67	7	57	7		21	15	17	19	15	19	18	20
Savannah Sparrow								14			5							
Sora												2						
Song Sparrow [M/R]	13	33	17	20	75	83	7	57	14	25	26	13	8	13	15	19	18	60
Spotted Sandpiper [R]						17	7	29	7		11	24	8	10		15		10
Spotted Towhee	13			20			29		7		5		8	6			9	
Sharp-shinned Hawk							7							6	8			20
Steller's Jay	100	83	100	100	100	83	100	86	100	75	100	93	92	84	100	88	100	100
Swainson's Hawk												2						
Swainson's Thrush [M/R]											5						18	
Townsend's Solitaire	88	17	67	20	75	17	93		86		84	35	67	39	85	58	73	40
Townsend's Warbler															8			
Tree Swallow [M/R]						17		14			11	7		6	8			
Turkey Vulture							7						8					
Vesper Sparrow											5	2						
Violet-green Swallow							7				11						9	
Warbling Vireo [M/R]	50	67	50	40	100	100	79	57	71	13	63	35	58	19	85	35	64	50
White-breasted Nuthatch	100	33	67	60	100	50	100	29	86	63	68	43	92	45	77	35	73	40
White-crowned Sparrow [M]	13		33	40							32	7	17	16		4	18	
Western Bluebird	13				25		14		7		16		8		8		9	
Western Tanager	100	83	67	40	100	50	100	57	86	50	79	30	75	29	69	38	100	40
Western Wood-pewee	75	83	83	40	75	100	93	71	50	38	74	78	83	61	92	77	82	80

Common Name	Burton Creek-Watson Creek-Tahoe Vista Frontal *FW (n=8)*	*LEN (n=6)*	Stateline Point-Third Creek-Incline Creek Frontal *FW (n=6)*	*LEN (n=5)*	Lake Tahoe - East Shore Frontal / North Half *FW (n=4)*	*LEN (n=6)*	Lake Tahoe - East Shore Frontal / South Half *FW (n=14)*	*LEN (n=7)*	Upper Truckee River - Trout Creek *FW (n=14)*	*LEN (n=8)*	Upper Truckee River *FW (n=19)*	*LEN (n=46)*	Cascade Creek-Tallac Creek-Taylor Creek Frontal *FW (n=12)*	*LEN (n=31)*	McKinney Creek-Bliss-Eagle Creek Frontal *FW (n=13)*	*LEN (n=26)*	Ward Creek-Blackwood Creek-Eagle Rock Frontal *FW (n=11)*	*LEN (n=10)*
White-headed Woodpecker [OG]	63	50	67	40	50	50	43	29	57		42	11	50	16	38	19	73	10
Wilson's Phalarope											5							
Williamson's Sapsucker	88	50	67		25	17	64		64		32	22	58	10	62	15	36	30
Wilsons Snipe		17									5	2		6	8			
Wilson's Warbler [M/R]	13	67	67	20	75	83	43	43	43	25	42	28	42	32	46	27	82	80
Winter Wren [R, OG]					25		7		7		5				38	4	27	
Wood Duck [R]		17																
Wrentit											5							
White-throated Swift											5		8		8			
Yellow-headed Blackbird							7	14				4		3				
Yellow-rumped Warbler	100	33	83	60	100	67	100	57	100	100	100	63	100	58	100	58	100	90
Yellow Warbler [M/R]	13				25		7				5	7		3	23	4		
Total Bird Richness	**58**	**55**	**59**	**43**	**58**	**59**	**74**	**61**	**70**	**41**	**91**	**93**	**76**	**87**	**79**	**70**	**66**	**60**
Total Bird Richness per site	**7**	**9**	**10**	**9**	**15**	**10**	**5**	**9**	**5**	**5**	**5**	**2**	**6**	**3**	**6**	**3**	**6**	**6**
Beta Diversity (Total/mean richness)	**2.1**	**2.5**	**2.0**	**2.5**	**1.8**	**2.4**	**2.5**	**3.0**	**2.8**	**2.5**	**3.2**	**5.0**	**2.8**	**4.6**	**2.7**	**3.9**	**2.1**	**2.6**
Mean Bird Richness per site	**31.0**	**22.3**	**32.3**	**17.4**	**36.3**	**24.0**	**32.8**	**20.6**	**27.7**	**16.5**	**32.5**	**18.7**	**31.7**	**18.9**	**33.1**	**18.0**	**34.5**	**22.8**
std. dev.	6.0	9.0	5.5	6.5	7.1	10.7	4.7	9.5	7.4	6.7	6.7	7.8	4.2	8.3	7.6	8.0	3.5	9.2
Mammals																		
Douglas' Squirrel	100	83	100	40	50	83	100	29	79	75	100	93	100	81	100	77	100	70
Yellow-bellied Marmot											5		8		15			
American Pika	13		17								37	4	33	16	31	4	36	20

M, R, M/R, OG: Codes representing species dependency on various special habitats in the Sierra Nevada according to Siegel and DeSante (1999). Codes represent categories for species with part or all of life cycle dependent upon the indicated habitat type. M= Meadow dependent species, R = Riparian dependent species, M/R = Meadow and riparian dependent species, and OG = Late successional old growth habitat dependent species

Appendix B-1. Small mammal species detected during small mammal live trapping surveys at 105 sites sampled in the Lake Tahoe basin, CA and NV 2002, 2004 and 2005. Values reported per species are based on either all captures or only unique individuals. Observed site occupancy is the percent of site with detections of each species. Estimated site occupancy and probability of detection were determined based on methods in MacKenzie et al (2002). Species with standard error values of 0.0 were detected too infrequently to adequately estimate detection probabilities and site occupancy rates.

	All captures			Unique individual captures		Monitoring Metrics			
Common Name	**# of Sites**	**Relative Abundance**	**Abundancne s.d.**	**Relative Abundance**	**Abundance s.d.**	**% of Sites**	**Estimated Site Occupancy (%)**	**Occupancy s.e.**	**Probability of Detection**
Deer Mouse	105	58.1	38.6	42.8	29.5	100	100.0	0.0	1.00
Golden Mantled Ground Squirrel	85	17.7	19.1	12.3	12.1	81	81.0	3.8	1.00
Lodgepole Chipmunk	78	36.8	44.7	20.3	24.8	74	74.3	4.3	1.00
Long-eared Chipmunk	78	16.4	19.8	10.2	11.7	74	68.8	4.5	1.00
Yellow-Pine Chipmunk	76	45.1	55.2	23.8	28.0	72	72.4	4.4	1.00
Allen's / Shadow Chipmunk	72	19.5	24.4	10.9	13.8	69	74.4	4.3	1.00
California Ground Squirrel	33	8.6	12.7	6.2	8.4	31	31.9	4.6	0.98
Long-tailed Vole	29	3.3	2.9	2.4	1.8	28	29.4	4.7	0.94
Douglas' Squirrel[2]	27	2.1	1.9	2.0	1.7	95	96.1	2.2	1.00
Northern Flying Squirrel	17	1.6	0.9	1.5	0.6	16	27.7	8.7	0.58
Bushy-Tailed Woodrat	13	5.3	5.7	3.5	3.3	12	13.2	3.5	0.94
Trowbridge's Shrew[1]	12	1.3	0.6	1.3	0.6	11	27.0	13.4	0.42
Long-tailed Weasel	9	1.6	1.1	1.4	1.0	9	16.7	8.2	0.51
Brush Mouse	8	1.8	1.4	1.4	1.1	8	13.8	6.8	0.55
Montane Vole	7	3.7	3.4	3.0	2.6	7	7.0	2.6	0.95
Vagrant or Dusky Shrew	7	1.7	1.5	1.7	1.5	7	11.2	5.5	0.60
Western Jumping Mouse	6	2.0	2.4	2.0	2.4	6	11.1	6.7	0.51
Short-tailed Weasel / Ermine	4	1.0	0.0	1.0	0.0	4	100.0	3.9	0.04
Belding's Ground Squirrel	3	4.0	5.2	4.0	5.2	3	3.0	1.7	0.96
Desert Woodrat	3	1.3	0.6	1.3	0.6	3	5.6	4.8	0.51
American Pika[2]	2	5.0	5.7	2.5	2.1	20	33.6	18.0	0.66

Common Name	# of Sites	Relative Abundance	Abundancne s.d.	Relative Abundance	Abundance s.d.	% of Sites	Estimated Site Occupancy (%)	Occupancy s.e.	Probability of Detection
	All captures			Unique individual captures		Monitoring Metrics			
Great Basin pocket mouse	2	1.0	0.0	1.0	0.0	2	100.0	7.8	0.02
Western Gray Squirrel	2	1.0	0.0	1.0	0.0	2	100.0	7.8	0.02
Least Chipmunk	1	14.0	0.0	9.0	0.0	1	1.0	1.0	1.00
Mountain Pocket Gopher	1	1.0	0.0	1.0	0.0	1	100.0	15.6	0.01
Nuttall's Cottontail	1	1.0	0.0	1.0	0.0	1	100.0	15.6	0.01
Yellow-bellied Marmot[2]	0	0.0	n/a	0.0	n/a	4	100.0	0.0	0.10

1 Pathway 2007 proposed species of concern (FSH 1900.12 section 43.22b)

2 Species detected more effectively with bird point count methods than trapping methods, therefore, all monitoring metrics shown for these species in this table result from bird point count survey methods and include detections within 100 m of point count stations

Appendix B-2. Small mammal distribution, total species richness, mean richness and mean abundance per species by sub-watershed (HUC level 6) in the Lake Tahoe basin, based on MSIM Sherman live trapping methods employed at forestwide monitoring sites, 2002-2005. Values are the percent of sites within each watershed with detections. The number of sites sampled within each sub-watershed are shown beneath each sub-watershed name.

Common Name	**Burton Creek-Watson Creek-Tahoe Vista Frontal** *(n = 8)*	**Stateline Point-Third Creek-Incline Creek Frontal** *(n = 6)*	**Lake Tahoe - East Shore Frontal / North Half** *(n = 4)*	**Lake Tahoe - East Shore Frontal / South Half** *(n = 14)*	**Upper Truckee River - Trout Creek** *(n = 14)*	**Upper Truckee River** *(n = 19)*	**Cascade Creek-Tallac Creek-Taylor Creek Frontal** *(n = 12)*	**McKinney Creek-Bliss-Eagle Creek Frontal** *(n = 13)*	**Ward Creek-Blackwood Creek-Eagle Rock Frontal** *(n = 11)*
Allen's / Shadow Chipmunk	75	83	75	79	64	63	67	85	82
American Pika	13	17				37	33	31	36
Belding's Ground Squirrel		17		7			8		
Brush Mouse				14		11	8		27
Bushy-Tailed Woodrat		17	25	21	7	26	17		
California Ground Squirrel	50	67	25	36	7	26	67	23	9
Deer Mouse	100	100	100	100	100	100	100	100	100
Desert Woodrat			25	7	7				
Douglas' Squirrel	100	100	50	100	79	100	100	100	100
Golden Mantled Ground Squirrel	100	83	100	100	93	74	58	85	55
Great Basin pocket mouse						5			9
Least Chipmunk		17							
Lodgepole Chipmunk	75	100	75	79	86	79	67	69	55
Long-eared Chipmunk	63	50	75	57	14	74	83	100	91
Long-tailed Vole	38	17	25	7	21	53	33	23	9
Long-tailed Weasel	13					11	17	23	9
Montane Vole	13				7	16	8		
Mountain Pocket Gopher				7					
Northern Flying Squirrel		17		14	21	21	25		36
Nuttall's Cottontail			25						
Short-tailed Weasel / Ermine	13			7		11			
Trowbridge's Shrew		17			14	5	33	31	
Vagrant or Dusky Shrew	25		25			16	8		
Western Gray Squirrel					7			8	
Western Jumping Mouse	13		25		7		8	8	9

Common Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (*n* = 8)	Stateline Point-Third Creek-Incline Creek Frontal (*n* = 6)	Lake Tahoe - East Shore Frontal / North Half (*n* = 4)	Lake Tahoe - East Shore Frontal / South Half (*n* = 14)	Upper Truckee River - Trout Creek (*n* = 14)	Upper Truckee River (*n* = 19)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (*n* = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (*n* = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (*n* = 11)
Yellow-Pine Chipmunk	100	100	100	93	64	63	75	54	55
Yellow-bellied Marmot						5	8	15	
Total Small Mammal Richness	**13**	**14**	**12**	**15**	**14**	**18**	**17**	**12**	**13**
Total small mammal richness per site	**2**	**3**	**4**	**1**	**1**	**1**	**2**	**1**	**1**
Beta diversity (total/mean richness per site)	**1.9**	**1.9**	**1.9**	**2.2**	**2.7**	**2.5**	**2.4**	**2.0**	**2.2**
Mean small mammal richness per site	**7.9**	**8.0**	**7.5**	**7.3**	**6.0**	**7.9**	**8.3**	**7.5**	**6.8**
std.dev. (richness)	2.0	0.9	1.9	1.2	1.6	2.1	1.0	1.7	1.9
Mean abundance	**23.6**	**18.9**	**12.8**	**19.7**	**17.1**	**18.9**	**21.1**	**18.2**	**17.3**
std.dev. (abundance)	8.5	8.1	8.1	7.4	11.3	9.6	9.8	7.7	11.2

Appendix C-1. Site occupancy and detections per visit of target carnivore species from the MSIM trackplate and camera survey protocol. Observed site occupancy is the number or percent of sites with detections of each species at either trackplate or camera stations. Estimated site occupancy (Psi) and detection probability (Pd) were determined following maximum likelihood methods described by MacKenzie et al (2002). See Data Analysis Methods section for additional details on calculation of Pd.

				Detections per Visit		Detection Probability	Est. Site Occupancy (%)	
Common Name	**Legal Status**	**Obs. Site Occupancy (#)**	**Obs. Site Occupancy (%)**	**Mean**	**s.d.**	**Pd**	**Psi**	**s.e.**
Target Species								
American Marten	FSS,FSC	31	53.4	0.43	0.37	99.9	53.5	6.6
Black Bear	MIS	38	65.5	0.12	0.12	92.5	70.8	7.0
Bobcat		3	5.2	0.03	0.00	5.1	100.0	3.9
Coyote		18	31.0	0.05	0.03	54.1	57.3	18.3
Gray Fox		1	1.7	0.03	n/a	1.7	100.0	12.0
Long-tailed Weasel		2	3.4	0.05	0.02	68.1	5.1	4.3
Raccoon		2	3.4	0.05	0.02	68.1	5.1	4.3
Ringtail		1	1.7	0.10	n/a	98.9	1.7	1.7
Short-tailed Weasel / Ermine		1	1.7	0.13	n/a	100.0	1.7	1.7
Spotted Skunk		4	6.9	0.05	0.03	0.8	0.1	0.0
Non-target special interest species								
Mule Deer	MIS	13	22.4	0.05	0.03	65.4	34.3	11.1

FSS = US Forest Service LTBMU Sensitive Species, Regional Forester's Sensitive Species List, Amended May 2003
FSC = USFWS Federal Species of Concern
MIS = USFS LTBMU Management Indicator Species

Appendix C-2. Observed site occupancy, mean number of detections per visit, total species richness and mean richness per site for target carnivore species within sub-watersheds (HUC level 6) in the northern and eastern portions of the Lake Tahoe basin; as observed at Multi-Species Inventory and Monitoring camera and track plate stations during 2005. Observed site occupancy is the percentage of sites within the watershed at which each species was detected. Mean detections per visit is the average number of detections (photos and track plates combined) per station per visit per site.

	Burton Creek-Watson Creek-Tahoe Vista Frontal (N = 4)			**Stateline Point-Third Creek-Incline Creek Frontal (N = 3)**			**Lake Tahoe -East Shore Frontal / North Half (N = 1)**			**Lake Tahoe -East Shore Frontal / South Half (N = 7)**		
Common Name	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**
Target Species												
American Marten	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	29	0.55	0.07
Black Bear	75	0.10	0.07	0	0.00	n/a	100	0.03	n/a	100	0.11	0.13
Bobcat	0	0.00	n/a	33	0.03	n/a	0	0.00	n/a	14	0.03	n/a
Coyote	50	0.03	0.00	0	0.00	n/a	0	0.00	n/a	14	0.03	n/a
Gray Fox	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Long-tailed Weasel	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Raccoon	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Ringtail	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	14	0.10	n/a
Short-tailed Weasel / Ermine	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Spotted Skunk	25	0.03	n/a	0	0.00	n/a	0	0.00	n/a	29	0.08	0.07
Non-target Special Interest Species												
Mule Deer	25	0.03	n/a	33	0.03	n/a	0	0.00	n/a	71	0.06	0.03
Total Target species richness		**3**			**1**			**1**			**5**	
Total Target species richness per site		**0.8**			**0.3**			**1.0**			**0.7**	
Beta Diversity (Total/mean richness per site)		**1.7**			**0**			**2.0**			**3.3**	
Mean richness per site		**1.2**			**1.0**			**1.0**			**2.0**	

Appendix C-3. Observed site occupancy, mean number of detections per visit, total species richness and mean richness per site for target carnivore species within sub-watersheds (HUC level 6) in the southern and western portions of the Lake Tahoe basin; as observed at Multi-Species Inventory and Monitoring camera and track plate stations during 2005. Observed site occupancy is the percentage of sites within the watershed at which each species was detected. Mean detections per visit is the average number of detections (photos and track plates combined) per station per visit per site.

	Upper Truckee River - Trout Creek (N = 9)			**Upper Truckee River (N = 10)**			**Cascade Creek-Tallac Creek-Taylor Creek Frontal (N = 7)**			**McKinney Creek-Bliss-Eagle Creek Frontal (N = 5)**			**Ward Creek-Blackwood Creek-Eagle Rock Frontal (N = 7)**		
Common Name	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**	**Obs. Site Occupancy (%)**	**Mean detections per visit**	**s.d**
Target Species															
American Marten	67	0.23	0.13	80	0.22	0.17	71	0.19	0.20	80	0.40	0.41	100	0.80	0.44
Black Bear	78	0.12	0.07	40	0.06	0.03	71	0.11	0.08	60	0.17	0.13	86	0.19	0.21
Bobcat	0	0.00	n/a	0	0.00	n/a	14	0.03	n/a	0	0.00	n/a	0	0.00	n/a
Coyote	22	0.05	0.02	50	0.05	0.04	57	0.08	0.05	20	0.03	0.00	29	0.05	0.02
Gray Fox	11	0.03	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Long-tailed Weasel	0	0.00	n/a	10	0.07	n/a	0	0.00	n/a	0	0.03	n/a	0	0.00	n/a
Raccoon	0	0.00	n/a	10	0.03	n/a	14	0.07	n/a	0	0.00	n/a	0	0.00	n/a
Ringtail	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Short-tailed Weasel / Ermine	0	0.00	n/a	10	0.13	n/a	0	0.00	n/a	0	0.00	n/a	0	0.00	n/a
Spotted Skunk	0	0.00	n/a	0	0.00	n/a	14	0.03	n/a	0	0.00	n/a	0	0.00	n/a
Non-target Species of Interest															
Mule Deer	11	0.10	n/a	30	0.04	0.02	14			0	0.00	n/a	14	0.03	n/a
Total Target species richness	**4**			**6**			**6**			**4**			**3**		
Total Target species richness per site	**0.4**			**0.6**			**0.9**			**0.8**			**0.4**		
Beta Diversity (Total/mean richness per site)	**2.1**			**3.8**			**2.6**			**2.0**			**1.4**		
Mean richness per site	**1.8**			**1.8**			**2.4**			**2.0**			**2.1**		

Appendix D-1. Bat species detected during mist-netting surveys at 22 sites sampled in the Lake Tahoe basin, CA and NV in 2002. Observed site occupancy is the number (#) or percent (%) of sites with detections of each species. Estimated site occupancy, the per-visit probability of detection (p) and associated standard errors were determined based on methods in MacKenzie et al (2002). Protocol detection probabilities (Pd) per species were calculated based on per-visit detection probabilities and the number of survey visits to sites (see Data Analysis Methods section). Species with standard error values of 0.0 were detected too infrequently to adequately estimate detection probabilities and site occupancy rates.

Common Name	**Status[1]**	**Observed Site Occupancy (#)**	**Mean Frequency (all)**	**Mean Frequency (where present)**	**Observed Site Occupancy (%)**	**Estimated Site Occupancy (%)**	**Occupancy s.e.**	**Per-visit detection probability (p)**	**p s.e.**	**Protocol detection probability (Pd)**
Long-eared myotis	FSC, M	16	0.27	0.46	76	100.0	0.0	0.31	0.05	0.77
Big brown bat	M	13	0.22	0.49	62	94.1	22.1	0.27	0.08	0.72
Little brown bat	M	12	0.6	1.31	57	64.3	12.4	0.50	0.08	0.94
Silver-haired bat	M	11	0.27	0.65	52	62.6	13.8	0.42	0.08	0.89
Long-legged myotis	FSC, M	7	0.11	0.48	33	42.1	14.2	0.36	0.11	0.83
California myotis	L	6	0.05	0.19	29	52.2	27.9	0.19	0.11	0.57
Fringed myotis	FSC, M	4	0.05	0.33	19	30.2	17.5	0.24	0.13	0.66
Yuma myotis	L	4	0.02	0.13	19	47.2	39.9	0.13	0.11	0.42
Hoary bat	M	2	0.01	0.13	10	100.0	3.5	0.02	0.02	0.10
Pallid bat	CSC, FSS, M	-	-		-	-	-	-	-	
Mexican free-tailed bat	M	-	-		-	-	-	-	-	
Western pipistrelle	L	-	-		-	-	-	-	-	
Western red bat	FSS, H	-	-		-	-	-	-	-	

[1] FSC = Federal species of concern , CSC = California species of concern, FSS = Forest Service sensitive species, L = Western bat working group (WBWG) rating of low vulnerability , M = WBWG rating of moderate vulnerability, and H = WBWG rating of high vulnerability.

Appendix D-2. Bat species distribution, total species richness and mean richness per site per species by sub-watershed (HUC level 6) in the Lake Tahoe basin, based on mist-netting surveys at 22 forestwide monitoring sites in 2002. Values are the percent of sites within each watershed with detections. The number of sites sampled within each sub-watershed are shown beneath each sub-watershed name.

Common Name	**Burton Creek-Watson Creek-Tahoe Vista Frontal** *(n = 2)*	**Stateline Point-Third Creek-Incline Creek Frontal** *(n = 1)*	**Lake Tahoe - East Shore Frontal / North Half** *(n = 1)*	**Lake Tahoe - East Shore Frontal / South Half** *(n = 2)*	**Upper Truckee River - Trout Creek** *(n = 1)*	**Upper Truckee River** *(n = 6)*	**Cascade Creek-Tallac Creek-Taylor Creek Frontal** *(n = 4)*	**McKinney Creek-Bliss-Eagle Creek Frontal** *(n = 3)*	**Ward Creek-Blackwood Creek-Eagle Rock Frontal** *(n =2)*
Big brown bat	50	100	100	100		33		67	50
Silver-haired bat	50	100	100	50		17	25	67	50
Hoary bat				50			25		
California myotis	50	100	100	100				33	
Long-eared myotis	50	100	100	100		33	75	67	50
Little brown bat	50	100		50		33	50	67	50
Fringed myotis			100	50		17			
Long-legged myotis	50	100		50				67	
Yuma myotis	50			50			25		
Total Species Richness	**7**	**6**	**5**	**9**	**0**	**5**	**5**	**6**	**4**
Total Species Richness per site	**4**	**6**	**5**	**5**	**0**	**1**	**1**	**2**	**2**
Beta Diversity (Total/mean richness per site)	**2.0**	**1.0**	**1.0**	**1.5**	**0.0**	**3.8**	**2.5**	**1.6**	**2.0**
Mean Richness per site	**3.5**	**6.0**	**5.0**	**6.0**	**0.0**	**1.3**	**2.0**	**3.7**	**2.0**
s.d.	4.9	n/a	n/a	1.4	n/a	2.1	0.8	3.2	2.8

Appendix E-1. Detections of vertebrate species in pitfall trap arrays at each of 9 monitoring points surveyed within LTBMU and within each of the two life zones (lower and upper montane conifer) sampled during 2002. Values listed per species are the sum of all captures per species. Detection rates per point represent the average number of captures of all species per month of survey time. Basin orientation (N, S, E and W) is indicated by the leading letter of the site name.

	North		East		South			West	
Common Name	**N1**	**N14**	**E40**	**E36**	**S23**	**S5**	**S27**	**W8**	**W29**
Amphibians									
Long-toed salamander*						1			
Pacific tree frog		1							
Reptiles									
Western fence lizard			2	12			1		
Sagebrush lizard			2	1					
Northern/Sierra alligator lizard					1	1			
Mammals									
Mountain pocket gopher	1		2		4	4		1	
Trowbridge's shrew*	2				2	1		4	
Vagrant or dusky shrew						3		1	
Golden-mantled ground squirrel							1		1
Deer mouse								1	1
Long-tailed vole					4	2			
Lodgepole chipmunk			1						
Unknown shrew	3				1	2		2	
Unknown chipmunk			1						
Total # inds.	6	1	8	13	12	14	2	9	2
Detection rates (summer)	4.3	0.7	4	1.1	6	7.5	1.3	5	1.8
Detection rates (fall)	0	0	2	22	0	0	0	6	0
Species Richness per Site	1	1	4	2	4	6	2	4	2
Total Species Richness	**3**		**4**			**8**		**5**	

* P7 proposed special interest species

Appendix F-1. Detection frequency, abundance, detectability and estimated occupancy rates for amphibian and reptile species detected during visual encounter surveys at 148 lentic aquatic sites sampled in 2003 and 2004 in the Lake Tahoe basin.

		Frequency of Detection[2]		Abundance[3]								Monitoring Metrics[4]		
Common Name	**Species Status[1]**	**# of Sites**	**% of Sites**	**Adults**	**s.d.**	**Subadults**	**s.d.**	**Larvae**	**s.d.**	**Eggs**	**s.d.**	**Estimated Site Occupancy (% of sites)**	**Occupancy s.e.**	**Probability of Detection**
Long-toed salamander	SOI	32	21.1	-	-	1.8	1.0	23.5	47.0	5.5	4.9	16.5	17	67
Western toad	SOI	13	8.6	1.0	0.0	2501.0	3534.1	7265.8	8781.4	-	-	6.7	3.4	91[5]
Pacific treefrog		87	57.2	2.4	2.4	53.9	129.5	319.4	776.8	8.9	13.9	55.5	7.7	93
Bullfrog	SOI	8	5.3	8.2	8.7	3.0	2.8	3085.6	6662.4	1.0	-	6	2.6	99[5]
Sierra garter snake	garter snake	11	7.2	2.3	2.5	1.0	-	-	-	-	-	4.4	n/a	82[5]
Western terrestrial garter snake	garter snake	47	30.9	2.2	2.2	1.7	1.3	-	-	-	-	47.2	17.6	60
Common garter snake	garter snake	17	11.2	2.2	1.5	2.4	1.1	-	-	-	-	15.8	8.3	77

1 MIS = Management Indicator Species, FSS = Forest Service sensitive species, FT = Federally threatened under ESA, SOC = Pathway 2007 proposed species of concern (FSH 1900.12 section 43.22b), SOI = Pathway 2007 proposed species of interest (FSH 1900.12 section 43.22c), garter snake = Pathway 2007 proposed species group (FSH 1900.12 section 43.24).

2 Frequency of detection values represent the number or percent of sites with detections of the respective species.

3 Abundance estimates represent the average number of individuals detected per site, across sites where the respective species was detected. The number of individuals detected per site was represented by the maximum number of detections during any survey visit for each life stage.

4 Monitoring metric estimates are based on detections during 1-2 survey visits conducted per site.

5 Denotes potentially unreliable estimate due to very low frequency of detection, less than 15 sites with detections (i.e., number of sites with detections)

Appendix F-2. Amphibian and reptile distribution by sub-watershed (HUC level 6). Values represent the percent of sites with detections per sub-watershed. The number of sites sampled in each sub-watershed is shown beneath the respective sub-watershed name.

Species Name	**Burton Creek-Watson Creek-Tahoe Vista Frontal** *(n = 4)*	**Stateline Point-Third Creek-Incline Creek Frontal** *(n = 4)*	**Lake Tahoe - East Shore Frontal / North Half** *(n = 4)*	**Lake Tahoe - East Shore Frontal / South Half** *(n = 4)*	**Upper Truckee River - Trout Creek** *(n = 7)*	**Upper Truckee River** *(n = 32)*	**Cascade Creek-Tallac Creek-Taylor Creek Frontal** *(n = 22)*	**McKinney Creek-Bliss-Eagle Creek Frontal** *(n = 17)*	**Ward Creek-Blackwood Creek-Eagle Rock Frontal** *(n = 7)*
Long-toed salamander					57	41	27	18	57
Western toad	25		25			3	5	6	29
Alligator lizard							5		
Western skink							5		
Pacific tree frog	75	100	75	50	57	72	82	88	86
Bullfrog			25			13	14		
Sagebrush lizard							5		
Western fence lizard				25		3	5		
Sierra garter snake					14		23	6	
Western terrestrial garter snake	50	25	50	25		50	55	41	57
Common garter snake	50	25	25			9	14	18	71
Total Species Richness	**4**	**3**	**5**	**3**	**3**	**7**	**11**	**6**	**5**
Total Species Richness per site	**1.0**	**0.8**	**1.0**	**0.8**	**0.4**	**0.2**	**0.5**	**0.4**	**0.7**
Beta Diversity (Total/mean richness per site)	**3.3**	**2.5**	**3.3**	**5.0**	**2.7**	**5.0**	**6.3**	**5.0**	**2.4**
Mean Richness per Site	**2**	**2**	**2**	**1**	**1**	**2**	**2**	**2**	**3**
s.d.	1.4	1.0	1.4	0.0	0.8	1.1	1.0	1.1	1.2

Appendix G-1. Site occupancy status and cover of plant species detected with Multi Species Inventory and Monitoring plant and habitat sampling protocols at 105 forestwide monitoring sites. Observevd site occupancy is the number of sites with detections of each species by any sampling method (quadrats, subplots or transects) at any of the stations sampled within a site. Cover estimates were based on either quadrats or transects, depending on the species life form. Estimated site occupancy (Psi) and per-visit detection probability (p) were determined following maximum likelihood methods described by MacKenzie et al (2002). Protocol detection probabilities (Pd) for each species were calculated using the equation detailed in the "Data Analysis Methods" section.

			Cover where present (%)			Est. Site Occupancy (%)		Detection probability		
Species Name	**Obs. Site Occupancy (#)**	**Obs. Site Occupancy (%)**	**Mean**	**s.d.**	**N**	**Psi**	**s.e.**	**Per-visit (p)**	**s.e.**	**Protocol (Pd)**
Trees[1]										
Abies concolor	72	68.6	n/a	n/a	n/a	56.8	4.9	0.96	0.02	1.00
Abies magnifica	83	79.0	n/a	n/a	n/a	53.4	5.0	0.93	0.03	0.99
Calocedrus decurrens	13	12.4	n/a	n/a	n/a	8.1	2.8	0.81	0.13	-
Juniperus occidentalis	21	20.0	n/a	n/a	n/a	10.5	3.0	1.00	0.00	-
Pinus albicaulis	16	15.2	n/a	n/a	n/a	14.4	4.0	0.68	0.13	-
Pinus contorta	72	68.6	n/a	n/a	n/a	40.5	5.4	0.77	0.06	0.95
Pinus jeffreyi	84	80.0	n/a	n/a	n/a	52.6	5.1	0.87	0.04	0.98
Pinus lambertiana	21	20.0	n/a	n/a	n/a	13.6	5.7	0.49	0.20	-
Pinus monticola	64	61.0	n/a	n/a	n/a	31.6	4.7	0.87	0.05	0.98
Pinus ponderosa	2	1.9	n/a	n/a	n/a					-
Populus tremuloides	17	16.2	n/a	n/a	n/a	7.1	2.6	0.82	0.12	-
Tsuga mertensiana	34	32.4	n/a	n/a	n/a	17.7	3.8	0.89	0.06	-
Shrubs[2]										
Acer glabrum	15	14.3	1.6	0.6	2.0	14.6	3.5	0.92	0.06	-
Alnus incana	17	16.2	1.4	2.0	6.0	13.5	3.4	0.96	0.04	-
Alnus incana ssp. tenuifolia	1	1.0				1.0	0.9	1.00	0.00	-
Amelanchier alnifolia	1	1.0				100.0	18.4	0.01	0.01	-
Amelanchier utahensis	21	20.0	3.0		1.0	21.1	4.2	0.84	0.07	0.97
Arctostaphylos nevadensis	43	41.0	7.5	7.1	25.0	40.4	4.8	0.95	0.03	1.00
Arctostaphylos patula	27	25.7	3.1	2.6	4.0	25.0	4.3	0.95	0.04	1.00
Artemisia arbuscula	1	1.0				1.0	0.9	1.00	0.00	-

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Artemisia tridentata	20	19.0	4.9	4.0	6.0	18.2	3.8	0.97	0.03	1.00
Cassiope mertensiana	1	1.0				1.0	0.9	1.00	0.00	-
Ceanothus cordulatus	23	21.9	15.3	14.5	7.0	20.5	4.0	0.91	0.05	0.99
Ceanothus prostratus	18	17.1	8.1	6.4	8.0	17.3	3.7	0.96	0.04	1.00
Ceanothus velutinus	24	22.9	5.6	9.0	12.0	22.7	4.2	0.88	0.06	0.99
Cercocarpus ledifolius	2	1.9				2.3	1.8	0.64	0.32	-
Chrysolepis sempervirens	30	28.6	4.9	5.4	13.0	26.8	4.3	0.98	0.02	1.00
Chrysothamnus nauseosus*	2	1.9				100.0	18.4	0.01	0.01	-
Cornus sericea	1	1.0	0.6		1.0	1.0	0.9	1.00	0.00	-
Cornus sericea ssp. occidentalis	1	1.0								-
Cornus sericea ssp. sericea	2	1.9				1.9	1.3	1.00	0.00	-
Ericameria bloomeri	1	1.0	0.6		1.0	1.0	0.9	1.00	0.00	-
Ericameria discoidea	2	1.9				1.0	0.9	1.00	0.00	-
Ericameria suffruticosa	1	1.0	2.7		1.0	1.0	0.9	1.00	0.00	-
Holodiscus discolor	9	8.6	2.9	0.4	2.0	7.8	2.7	0.91	0.09	-
Holodiscus microphyllus	10	9.5	2.5	2.4	4.0	9.7	2.9	0.94	0.06	-
Juniperus communis	1	1.0				1.0	0.9	1.00	0.00	-
Kalmia polifolia	1	1.0				1.0	0.9	1.00	0.00	-
Ledum glandulosum	2	1.9				1.9	1.3	1.00	0.00	-
Lithocarpus densiflorus	1	1.0				1.0	0.9	1.00	0.00	-
Lonicera conjugialis	12	11.4	1.7	1.8	2.0	12.1	3.3	0.84	0.09	-
Lonicera involucrata var. involucrata	1	1.0				1.0	0.9	1.00	0.00	-
Phyllodoce breweri	6	5.7	2.0	1.4	2.0	6.1	3.3	0.58	0.28	-
Prunus emarginata	14	13.3	2.3	2.1	4.0	13.5	3.4	0.96	0.04	-
Purshia tridentata	15	14.3	5.4	3.5	6.0	14.3	3.4	1.00	0.00	-
Quercus vacciniifolia	33	31.4	14.3	9.7	14.0	31.5	4.8	0.82	0.06	0.97
Rhamnus rubra	1	1.0				100.0	18.4	0.01	0.01	-
Ribes cereum	23	21.9	2.6	1.8	5.0	20.5	4.0	0.91	0.05	0.99
Ribes lasianthum	3	2.9	0.9	0.6	2.0	3.1	1.8	0.78	0.21	-
Ribes montigenum	18	17.1	2.0	1.7	6.0	17.4	4.3	0.71	0.11	0.91

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Ribes nevadense	16	15.2	4.9	5.9	3.0	16.2	3.8	0.81	0.09	0.96
Ribes roezlii	19	18.1	1.7	2.2	3.0	19.7	4.2	0.79	0.08	0.96
Ribes roezlii var. roezlii	5	4.8	11.5		1.0	4.8	2.1	1.00	0.00	-
Ribes viscosissimum	21	20.0	1.1	0.6	3.0	20.8	4.1	0.88	0.06	0.99
Rosa woodsii	5	4.8	3.4		1.0	4.8	2.1	1.00	0.00	-
Rubus parviflorus	14	13.3	3.7	3.3	6.0	8.7	2.8	0.93	0.06	-
Salix eastwoodiae	1	1.0								-
Salix lasiolepis	1	1.0				1.0	0.9	1.00	0.00	-
Salix lemmonii	7	6.7	1.5		1.0	6.8	2.5	0.92	0.08	-
Salix orestera	5	4.8	4.2		1.0	5.0	2.2	0.83	0.17	-
Salix scouleriana	21	20.0	2.3	2.8	2.0	16.2	3.8	0.82	0.09	0.97
Sambucus mexicana	1	1.0				1.0	0.9	1.00	0.00	-
Sambucus racemosa	4	3.8	0.6		1.0	4.1	2.0	0.81	0.19	-
Sambucus racemosa var. racemosa	4	3.8				3.3	2.0	0.70	0.29	-
Sorbus	1	1.0								-
Sorbus californica	5	4.8				4.1	2.0	0.81	0.19	-
Spiraea densiflora	13	12.4	2.8	3.1	4.0	12.8	3.3	0.89	0.08	-
Symphoricarpos mollis	41	39.0	3.5	4.1	14.0	39.5	5.0	0.88	0.04	0.99
Symphoricarpos rotundifolius	25	23.8	1.6	0.9	6.0	22.4	4.1	0.92	0.05	0.99
Vaccinium cespitosum	2	1.9				1.9	1.3	1.00	0.00	-
Herbs [3]										
Achillea millefolium	10	9.5	0.7	0.6	3	3.1	1.8	0.78	0.21	-
Aconitum columbianum	3	2.9	0.4	0.5	2	2.3	1.8	0.64	0.32	-
Actaea rubra	3	2.9	0.3		1	1.0	0.9	1.00	0.00	-
Adenocaulon bicolor	1	1.0	4.0		1	1.0	0.9	1.00	0.00	-
Agastache urticifolia	4	3.8	1.3	0.8	3	3.1	1.8	0.78	0.21	-
Ageratina occidentalis	1	1.0								-
Agoseris glauca	3	2.9	0.3	0.2	2	1.9	1.3	1.00	0.00	-
Agoseris retrorsa	6	5.7	0.1	0.0	2	100.0	9.2	0.01	0.01	-
Allium campanulatum	30	28.6	0.2	0.2	16	16.6	3.9	0.79	0.09	0.95

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Allium obtusum	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Allium validum	2	1.9	1.3	1.8	2	2.3	1.8	0.64	0.32	-
Allophyllum gilioides	2	1.9	0.1	0.0	2	2.3	1.8	0.64	0.32	-
Allophyllum integrifolium	3	2.9	0.2		1	1.0	0.9	1.00	0.00	-
Allotropa virgata	2	1.9								-
Anaphalis	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Anemone	1	1.0								-
Angelica breweri	18	17.1	1.0	0.9	11	12.3	3.7	0.68	0.13	-
Antennaria media	2	1.9	0.2		1	1.0	0.9	1.00	0.00	-
Antennaria rosea	5	4.8	0.2	0.1	2	100.0	9.2	0.01	0.01	-
Apocynum androsaemifolium	27	25.7	0.5	0.9	12	13.8	4.2	0.64	0.15	-
Aquilegia formosa	21	20.0	0.7	0.5	12	12.1	3.4	0.82	0.10	-
Arabis drummondii	2	1.9				0.0	0.0			-
Arabis holboellii	12	11.4	0.1	0.0	3	2.9	1.6	1.00	0.00	-
Arabis lemmonii	4	3.8	0.0		1	100.0	18.4	0.01	0.01	-
Arabis platysperma	36	34.3	0.2	0.2	19	19.8	4.3	0.77	0.09	0.95
Arabis rectissima	1	1.0								-
Arabis repanda	1	1.0	0.0		1	100.0	18.4	0.01	0.01	-
Arceuthobium abietinum	2	1.9								-
Arenaria aculeata	3	2.9	0.3		1	100.0	18.4	0.01	0.01	-
Arenaria kingii	4	3.8	0.4	0.2	3	3.1	1.8	0.78	0.21	-
Arenaria kingii var. glabrescens	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Arnica cordifolia	4	3.8	0.2		1	100.0	18.4	0.01	0.01	-
Arnica latifolia	2	1.9								-
Arnica mollis	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Arnica nevadensis	1	1.0								-
Arnica parryi	1	1.0	0.8		1	100.0	18.4	0.01	0.01	-
Artemisia douglasiana	2	1.9	0.3		1	100.0	18.4	0.01	0.01	-
Aster ascendens	2	1.9	0.8	0.4	2	100.0	9.2	0.01	0.01	-
Aster breweri	26	24.8	1.1	1.0	17	16.8	3.7	0.88	0.07	0.99
Aster integrifolius	3	2.9	2.3		1	100.0	18.4	0.01	0.01	-

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Aster occidentalis	5	4.8	2.1	2.9	3	4.2	3.1	0.47	0.31	-
Astragalus bolanderi	1	1.0								-
Balsamorhiza sagittata	7	6.7	0.8	0.9	2	2.3	1.8	0.64	0.32	-
Barbarea	1	1.0								-
Botrychium multifidum	1	1.0								-
Brickellia	1	1.0								-
Calamagrostis	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Calochortus leichtlinii	11	10.5	0.2	0.2	4	4.6	2.5	0.64	0.23	-
Caltha leptosepala	1	1.0								-
Calyptridium umbellatum	11	10.5	0.2	0.1	7	6.8	2.5	0.91	0.09	-
Cardamine cordifolia	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Cardamine cordifolia var. lyallii	2	1.9								-
Castilleja applegatei	18	17.1	0.3	0.2	8	7.6	2.6	1.00	0.00	-
Castilleja miniata	9	8.6	0.4	0.3	4	4.0	2.0	0.84	0.15	-
Castilleja miniata ssp. miniata	6	5.7	0.6	0.5	5	4.9	2.2	0.88	0.12	-
Castilleja nana	7	6.7	0.1		1	100.0	18.4	0.01	0.01	-
Castilleja parviflora	1	1.0								-
Castilleja pilosa	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Castilleja tenuis	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Chaenactis douglasii	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Chaenactis douglasii var. douglasii	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Chenopodium incognitum	1	1.0								-
Chimaphila menziesii	20	19.0	0.1	0.1	12	13.0	3.7	0.71	0.12	-
Chimaphila umbellata	2	1.9	0.5	0.5	2	1.9	1.3	1.00	0.00	-
Circaea alpina ssp. pacifica	7	6.7	1.3	0.4	3	3.1	1.8	0.78	0.21	-
Cirsium andersonii	20	19.0	0.5	0.5	10	10.2	3.1	0.81	0.11	-
Cirsium scariosum	1	1.0								-
Claytonia lanceolata	1	1.0	0.0		1	100.0	18.4	0.01	0.01	-
Claytonia rubra	1	1.0								-
Collinsia parviflora	7	6.7	0.5	0.6	5	4.9	2.2	0.88	0.12	-

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Collinsia sparsiflora	1	1.0								-
Collinsia torreyi	22	21.0	0.2	0.3	14	14.8	3.8	0.75	0.11	-
Collomia grandiflora	5	4.8	0.1	0.0	3	4.2	3.1	0.47	0.31	-
Collomia linearis	1	1.0								-
Collomia tinctoria	3	2.9	0.4	0.1	2	2.3	1.8	0.64	0.32	-
Convolvulus arvensis[4, 5]	1	1.0								-
Corallorrhiza maculata	4	3.8	0.1		1	1.0	0.9	1.00	0.00	-
Cordylanthus tenuis	2	1.9	0.2		1	1.0	0.9	1.00	0.00	-
Crepis acuminata	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Cryptantha affinis	14	13.3	0.1	0.0	8	8.0	2.8	0.84	0.11	-
Cryptantha simulans	1	1.0								-
Cymopterus terebinthinus var. californicus	3	2.9								-
Delphinium glaucum	5	4.8	0.6	0.6	3	3.1	1.8	0.78	0.21	-
Delphinium nuttallianum	7	6.7	0.1	0.0	5	6.4	3.3	0.55	0.23	-
Descurainia incisa	2	1.9								-
Descurainia pinnata	1	1.0	0.4		1	100.0	18.4	0.01	0.01	-
Dicentra uniflora	4	3.8	0.1		1	100.0	18.4	0.01	0.01	-
Dodecatheon alpinum	3	2.9	0.2	0.1	2	100.0	29.7	0.01	0.01	-
Dodecatheon jeffreyi	1	1.0								-
Drosera rotundifolia	1	1.0	0.6		1	1.0	0.9	1.00	0.00	-
Epilobium angustifolium	4	3.8	0.5	0.4	4	4.0	2.0	0.84	0.15	-
Epilobium angustifolium ssp. circumvagum	14	13.3	0.3	0.4	5	5.0	2.2	0.83	0.17	-
Epilobium canum	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Epilobium ciliatum ssp. glandulosum	2	1.9	0.8		1	1.0	0.9	1.00	0.00	-
Epilobium glaberrimum	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Equisetum arvense	3	2.9	0.3		1	1.0	0.9	1.00	0.00	-
Erigeron breweri	11	10.5	0.3	0.3	6	6.9	3.0	0.64	0.19	-
Erigeron compositus	1	1.0								-
Erigeron coulteri	1	1.0	0.4		1	100.0	18.4	0.01	0.01	-
Erigeron divergens	1	1.0								-

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Erigeron peregrinus	14	13.3	0.5	0.5	8	7.8	2.7	0.92	0.08	-
Eriogonum incanum	7	6.7	0.1	0.0	5	6.1	3.3	0.58	0.28	-
Eriogonum lobbii	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Eriogonum marifolium	7	6.7	1.4	1.8	6	5.9	2.3	0.90	0.10	-
Eriogonum nudum	27	25.7	0.2	0.1	12	11.6	3.1	0.95	0.05	-
Eriogonum rosense	2	1.9	0.2		1	100.0	18.4	0.01	0.01	-
Eriogonum spergulinum	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Eriogonum umbellatum	14	13.3	1.0	0.9	7	7.2	2.7	0.80	0.14	-
Eriogonum ursinum	2	1.9	0.3		1	1.0	0.9	1.00	0.00	-
Eriogonum wrightii	6	5.7	0.3	0.2	5	5.6	2.6	0.68	0.22	-
Eriophyllum lanatum	2	1.9								-
Eriophyllum lanatum var. integrifolium	2	1.9								-
Erysimum capitatum	17	16.2	0.2	0.1	2	2.3	1.8	0.64	0.32	-
Fragaria virginiana	7	6.7	0.2	0.1	4	3.8	1.9	1.00	0.00	-
Fritillaria atropurpurea	2	1.9	0.2		1	1.0	0.9	1.00	0.00	-
Galium aparine	1	1.0				0.0	0.0			-
Galium bifolium	3	2.9	0.2		1	1.0	0.9	1.00	0.00	-
Galium trifidum	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Galium triflorum	4	3.8	0.2	0.1	4	3.8	1.9	1.00	0.00	-
Gayophytum diffusum	39	37.1	0.5	0.8	22	22.9	4.5	0.78	0.08	0.95
Gayophytum diffusum ssp. parviflorum	8	7.6	0.3	0.3	4	4.0	2.0	0.84	0.15	-
Gayophytum heterozygum	6	5.7	0.5	0.3	2	1.9	1.3	1.00	0.00	-
Gayophytum humile	2	1.9	0.3	0.1	2	100.0	9.2	0.01	0.01	-
Gentianopsis simplex	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Geranium richardsonii	2	1.9	0.7	0.4	2	2.3	1.8	0.64	0.32	-
Geum triflorum	1	1.0								-
Gilia capillaris	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Goodyera oblongifolia[4]	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Grindelia squarrosa[4, 5]	1	1.0								-
Hackelia floribunda	1	1.0								-
Hackelia micrantha	2	1.9	1.3		1	1.0	0.9	1.00	0.00	-

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Hackelia nervosa	13	12.4	1.8	2.5	7	7.1	2.6	0.82	0.12	-
Hackelia velutina	5	4.8	0.8		1	100.0	18.4	0.01	0.01	-
Heracleum lanatum	13	12.4	1.4	2.1	8	8.6	3.1	0.72	0.15	-
Heterotheca villosa	1	1.0	1.0		1	1.0	0.9	1.00	0.00	-
Heuchera micrantha	1	1.0								-
Heuchera rubescens	5	4.8								-
Hieracium albiflorum	21	20.0	1.0	2.4	13	14.8	4.2	0.65	0.13	-
Hieracium gracile	1	1.0								-
Hieracium horridum	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Horkelia fusca ssp. parviflora	2	1.9								-
Hypericum anagalloides	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Ipomopsis aggregata	3	2.9	0.4		1	1.0	0.9	1.00	0.00	-
Ivesia santolinoides	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-
Kelloggia galioides	33	31.4	0.5	0.5	11	11.9	3.6	0.72	0.13	-
Lactuca[5]	1	1.0								-
Lathyrus nevadensis	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Lepidium densiflorum	1	1.0								-
Leptodactylon pungens	3	2.9	0.1		1	100.0	18.4	0.01	0.01	-
Lewisia nevadensis	1	1.0								-
Lewisia triphylla	3	2.9	0.1	0.0	2	2.3	1.8	0.64	0.32	-
Ligusticum grayi	9	8.6	0.5	0.3	5	5.6	2.6	0.68	0.22	-
Lilium parvum	6	5.7	0.2	0.1	3	4.2	3.1	0.47	0.31	-
Lilium washingtonianum	1	1.0								-
Linanthus ciliatus	9	8.6	0.1	0.1	3	2.9	1.6	1.00	0.00	-
Linanthus nuttallii	5	4.8	0.3	0.2	2	2.3	1.8	0.64	0.32	-
Linanthus nuttallii ssp. pubescens[4]	2	1.9	0.2		1	1.0	0.9	1.00	0.00	-
Linum lewisii	1	1.0	0.7		1	1.0	0.9	1.00	0.00	-
Listera convallarioides	2	1.9	0.9	0.6	2	2.3	1.8	0.64	0.32	-
Lithophragma glabrum	1	1.0								-
Lomatium dissectum	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Lomatium nevadense	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Lotus nevadensis	3	2.9								-
Lotus purshianus	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Lupinus albicaulis	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Lupinus arbustus	21	20.0	1.1	0.9	17	17.1	3.8	0.84	0.08	0.97
Lupinus argenteus	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Lupinus breweri	5	4.8	1.5	2.4	4	5.2	3.3	0.53	0.30	-
Lupinus fulcratus	2	1.9	0.9	1.1	2	2.3	1.8	0.64	0.32	-
Lupinus grayi	2	1.9	2.9	0.1	2	1.9	1.3	1.00	0.00	-
Lupinus latifolius var. columbianus	1	1.0	0.3		1	1.0	0.9	1.00	0.00	-
Lupinus lepidus var. lobbii	1	1.0	0.0		1	1.0	0.9	1.00	0.00	-
Lupinus polyphyllus	5	4.8	4.1	4.7	2	100.0	29.7	0.01	0.01	-
Madia minima	2	1.9	0.2		1	1.0	0.9	1.00	0.00	-
Malacothrix floccifera	1	1.0								-
Malva neglecta	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Medicago sativa[4]	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Mentzelia dispersa	4	3.8	0.1		1	100.0	18.4	0.01	0.01	-
Menyanthes trifoliata	1	1.0	47.5		1	1.0	0.9	1.00	0.00	-
Mertensia ciliata	2	1.9	4.3	0.4	2	1.9	1.3	1.00	0.00	-
Microseris nutans	10	9.5	0.1	0.0	4	4.6	2.5	0.64	0.23	-
Mimulus breweri	8	7.6	0.1	0.1	4	4.6	2.5	0.64	0.23	-
Mimulus floribundus	1	1.0								-
Mimulus guttatus	13	12.4	1.4	3.1	9	11.0	4.0	0.59	0.16	-
Mimulus leptaleus	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Mimulus lewisii	2	1.9								-
Mimulus mephiticus	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Mimulus moschatus	3	2.9	0.4	0.4	2	2.3	1.8	0.64	0.32	-
Mimulus primuloides	3	2.9	0.8		1	1.0	0.9	1.00	0.00	-
Mimulus tilingii	2	1.9	0.3	0.1	2	1.9	1.3	1.00	0.00	-
Mimulus torreyi	2	1.9	0.1		1	1.0	0.9	1.00	0.00	-
Mitella breweri	8	7.6	0.5	0.4	5	5.4	2.4	0.73	0.18	-
Monardella odoratissima	26	24.8	2.5	1.9	14	13.5	3.4	0.96	0.04	-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Monardella odoratissima ssp. pallida	13	12.4	2.1	2.1	9	8.7	2.8	0.92	0.08	-
Montia linearis	1	1.0								-
Nemophila spatulata	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Nothocalais alpestris	2	1.9								-
Orobanche corymbosa	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Orthilia secunda	6	5.7	0.1		1	1.0	0.9	1.00	0.00	-
Orthocarpus cuspidatus ssp. cryptanthus	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Osmorhiza chilensis	19	18.1	0.4	0.4	13	13.9	3.8	0.74	0.11	-
Osmorhiza occidentalis	27	25.7	0.8	0.9	16	18.9	4.9	0.62	0.12	0.86
Paeonia brownii	6	5.7								-
Pedicularis attollens	2	1.9								-
Pedicularis groenlandica	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Pedicularis semibarbata	28	26.7	0.2	0.2	12	11.8	3.2	0.89	0.07	-
Penstemon deustus	4	3.8	0.3	0.3	2	1.9	1.3	1.00	0.00	-
Penstemon gracilentus	10	9.5	0.5	0.4	3	100.0	6.1	0.02	0.01	-
Penstemon heterodoxus	9	8.6	0.7	0.3	3	3.1	1.8	0.78	0.21	-
Penstemon newberryi	12	11.4	0.6	0.5	8	8.0	2.8	0.84	0.11	-
Penstemon newberryi ssp. newberryi	10	9.5	1.7	1.6	5	4.8	2.1	1.00	0.00	-
Penstemon rydbergii	1	1.0								-
Penstemon rydbergii var. oreocharis	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Penstemon speciosus	3	2.9								-
Perideridia lemmonii	3	2.9	1.2	1.6	3	3.3	2.0	0.70	0.29	-
Perideridia parishii	11	10.5	0.2	0.2	3	3.1	1.8	0.78	0.21	-
Perideridia parishii ssp. latifolia	2	1.9	0.3	0.0	2	100.0	9.2	0.01	0.01	-
Phacelia eisenii	1	1.0								-
Phacelia hastata	3	2.9	0.1	0.1	2	1.9	1.3	1.00	0.00	-
Phacelia hastata ssp. compacta	1	1.0								-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Phacelia hastata var. hastata	4	3.8	0.0		1	1.0	0.9	1.00	0.00	-
Phacelia heterophylla	5	4.8	0.8	1.3	4	4.0	2.0	0.84	0.15	-
Phacelia hydrophylloides	20	19.0	0.2	0.1	11	11.3	3.3	0.79	0.12	-
Phacelia mutabilis	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Phacelia ramosissima	3	2.9	0.6		1	1.0	0.9	1.00	0.00	-
Phacelia ramosissima var. eremophila	1	1.0								-
Phlox diffusa	29	27.6	0.5	0.8	22	21.3	4.0	0.94	0.04	1.00
Phoenicaulis cheiranthoides	2	1.9	0.3		1	100.0	18.4	0.01	0.01	-
Piperia leptopetala[4]	1	1.0								-
Piperia unalascensis	2	1.9								-
Platanthera leucostachys	4	3.8	0.3	0.1	2	1.9	1.3	1.00	0.00	-
Platanthera sparsiflora	3	2.9	0.1	0.0	3	100.0	6.1	0.02	0.01	-
Polemonium californicum	5	4.8	1.0	1.0	4	4.1	2.0	0.81	0.19	-
Polemonium occidentale	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Polygonum bistortoides	1	1.0								-
Polygonum douglasii	5	4.8	0.1		1	100.0	18.4	0.01	0.01	-
Polygonum minimum	3	2.9	0.2		1	1.0	0.9	1.00	0.00	-
Polygonum phytolaccifolium	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-
Polygonum polygaloides ssp. kelloggii	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Polygonum shastense	3	2.9	0.8	0.9	2	2.3	1.8	0.64	0.32	-
Potentilla drummondii ssp. breweri	1	1.0								-
Potentilla drummondii ssp. drummondii	1	1.0								-
Potentilla glandulosa	20	19.0	0.6	0.6	10	8.7	2.8	0.93	0.07	-
Potentilla glandulosa ssp. ashlandica	2	1.9	0.2		1	100.0	18.4	0.01	0.01	-
Potentilla gracilis	8	7.6	1.0	1.7	6	6.9	3.0	0.64	0.19	-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Potentilla palustris	2	1.9	1.4	1.9	2	1.9	1.3	1.00	0.00	-
Pseudostellaria jamesiana	2	1.9	0.3	0.3	2	1.9	1.3	1.00	0.00	-
Pterospora andromedea	4	3.8								-
Pyrola picta	31	29.5	0.2	0.1	7	7.3	2.8	0.77	0.16	-
Raillardella argentea	1	1.0								-
Raillardella scaposa	1	1.0	2.4		1	1.0	0.9	1.00	0.00	-
Ranunculus alismifolius	2	1.9	0.8	1.0	2	1.9	1.3	1.00	0.00	-
Ranunculus occidentalis	2	1.9								-
Rorippa nasturtium-aquaticum	2	1.9								-
Rumex acetosella	2	1.9								-
Sanicula tuberosa	1	1.0	0.4		1	1.0	0.9	1.00	0.00	-
Sarcodes sanguinea	4	3.8								-
Saxifraga bryophora	2	1.9								-
Saxifraga odontoloma	2	1.9	1.1	0.8	2	1.9	1.3	1.00	0.00	-
Saxifraga oregana	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Scrophularia	1	1.0								-
Sedum obtusatum	6	5.7	0.2	0.1	2	1.9	1.3	1.00	0.00	-
Sedum obtusatum ssp. Obtusatum	3	2.9	0.3	0.1	2	100.0	29.7	0.01	0.01	-
Sedum stenopetalum	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Selaginella watsonii	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Senecio integerrimus	30	28.6	0.4	0.3	13	13.0	3.4	0.86	0.08	-
Senecio triangularis	17	16.2	1.1	1.1	12	11.6	3.1	0.95	0.05	-
Sidalcea glaucescens	10	9.5	0.8	0.7	7	6.8	2.5	0.91	0.09	-
Sidalcea oregana	1	1.0	0.0		1	100.0	18.4	0.01	0.01	-
Sidalcea oregana ssp. spicata	2	1.9	0.3		1	100.0	18.4	0.01	0.01	-
Silene bernardina	1	1.0				0.0	0.0			-
Silene douglasii	7	6.7	0.4	0.4	4	5.2	3.3	0.53	0.30	-
Silene invisa	1	1.0								-
Silene lemmonii	10	9.5	0.4	0.5	3	100.0	6.1	0.02	0.01	-
Silene sargentii	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-

			Cover where present (%)			Est. Site Occupancy (%)		Detection probability		
Species Name	**Obs. Site Occupancy (#)**	**Obs. Site Occupancy (%)**	**Mean**	**s.d.**	**N**	**Psi**	**s.e.**	**Per-visit (p)**	**s.e.**	**Protocol (Pd)**
Sisymbrium altissimum[5]	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Smilacina racemosa var. amplexicaulis[4, **]	15	14.3	2.8	7.6	10	9.9	3.0	0.88	0.08	-
Smilacina racemosum**	1	1.0								-
Smilacina stellata**	8	7.6	0.6	0.4	4	4.0	2.0	0.84	0.15	-
Solidago californica	1	1.0	0.8		1	100.0	18.4	0.01	0.01	-
Sphenosciadium capitellatum	3	2.9	0.4		1	1.0	0.9	1.00	0.00	-
Spiranthes romanzoffiana	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Stachys ajugoides var. rigida	2	1.9	0.5	0.3	2	1.9	1.3	1.00	0.00	-
Stellaria longipes	1	1.0								-
Stephanomeria lactucina	7	6.7	0.2	0.2	3	4.2	3.1	0.47	0.31	-
Stephanomeria tenuifolia	3	2.9								-
Streptanthus tortuosus	2	1.9								-
Streptanthus tortuosus var. orbiculatus	3	2.9								-
Swertia radiata	2	1.9								-
Taraxacum[5]	1	1.0	0.4		1	100.0	18.4	0.01	0.01	-
Thalictrum fendleri	20	19.0	1.6	2.3	11	10.5	3.0	1.00	0.00	-
Thalictrum fendleri var. fendleri	10	9.5	1.6	1.2	8	8.6	3.1	0.72	0.15	-
Trichostema oblongum	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Trifolium longipes	3	2.9	0.4	0.5	2	2.3	1.8	0.64	0.32	-
Trifolium longipes var. nevadense[4]	1	1.0								-
Trifolium variegatum	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-
Triteleia ixioides	4	3.8	0.1	0.1	3	2.9	1.6	1.00	0.00	-
Triteleia ixioides ssp. anilina	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-
Triteleia montana	1	1.0								-
Valeriana californica	7	6.7	0.4	0.3	3	3.1	1.8	0.78	0.21	-
Veratrum californicum	13	12.4	2.1	2.2	7	6.7	2.4	1.00	0.00	-

			Cover where present (%)			Est. Site Occupancy (%)		Detection probability		
Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Mean	s.d.	N	Psi	s.e.	Per-visit (p)	s.e.	Protocol (Pd)
Veratrum californicum var. californicum	1	1.0								-
Vicia	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Viola adunca	1	1.0								-
Viola glabella	7	6.7	0.9	1.6	6	5.9	2.3	0.90	0.10	-
Viola macloskeyi	1	1.0								-
Viola pinetorum	2	1.9	0.6		1	1.0	0.9	1.00	0.00	-
Viola purpurea	18	17.1	0.3	0.3	10	10.2	3.1	0.81	0.11	-
Viola purpurea ssp. integrifolia	2	1.9	0.3		1	100.0	18.4	0.01	0.01	-
Wyethia mollis	17	16.2	5.3	7.7	10	9.7	2.9	0.94	0.06	-
Zigadenus venenosus	2	1.9	0.1	0.0	2	2.3	1.8	0.64	0.32	-
Undentified Herbaceous	49	46.7	-	-	-	-	-	-	-	-
Grass like plants [3]										
Achnatherum nelsonii	3	2.9								-
Achnatherum occidentale	9	8.6	2.1	3.8	7	14.6	10.9	0.29	0.22	-
Achnatherum thurberianum	17	16.2	0.7	1.4	9	11.0	4.0	0.59	0.16	-
Agrostis idahoensis	1	1.0	0.3		1	100.0	18.4	0.01	0.01	-
Agrostis thurberiana	5	4.8	1.2	1.4	2	100.0	9.2	0.01	0.01	-
Agrostis variabilis	2	1.9	1.3		1	100.0	18.4	0.01	0.01	-
Bromus carinatus	14	13.3	0.9	1.9	9	9.4	3.1	0.76	0.13	-
Bromus orcuttianus	1	1.0								-
Bromus suksdorfii	8	7.6	1.1	1.5	5	9.9	7.7	0.31	0.24	-
Bromus tectorum[5]	7	6.7	0.3	0.3	3	3.3	2.0	0.70	0.29	-
Carex amplifolia	3	2.9	4.0	3.0	3	2.9	1.6	1.00	0.00	-
Carex athrostachya	1	1.0								-
Carex bolanderi	1	1.0								-
Carex brainerdii	12	11.4	0.3	0.3	5	9.9	7.7	0.31	0.24	-
Carex disperma	1	1.0								-
Carex douglasii	1	1.0								-
Carex fracta	2	1.9								-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Carex hassei	1	1.0	2.1		1	1.0	0.9	1.00	0.00	-
Carex hoodii	1	1.0								-
Carex integra	3	2.9	0.6	1.0	3	4.2	3.1	0.47	0.31	-
Carex lenticularis	1	1.0								-
Carex multicostata	2	1.9								-
Carex nebrascensis	1	1.0	0.2		1	100.0	18.4	0.01	0.01	-
Carex nigricans	1	1.0	0.8		1	1.0	0.9	1.00	0.00	-
Carex pachystachya[4]	1	1.0								-
Carex raynoldsii	1	1.0	1.3		1	1.0	0.9	1.00	0.00	-
Carex rossii	5	4.8	0.2		1	100.0	18.4	0.01	0.01	-
Carex specifica	1	1.0								-
Carex spectabilis	1	1.0	5.8		1	1.0	0.9	1.00	0.00	-
Cinna latifolia	1	1.0	0.8		1	1.0	0.9	1.00	0.00	-
Dactylis glomerata[5]	3	2.9	0.3		1	100.0	18.4	0.01	0.01	-
Danthonia californica	1	1.0								-
Danthonia unispicata	4	3.8	0.2		1	1.0	0.9	1.00	0.00	-
Deschampsia	1	1.0	9.8		1	1.0	0.9	1.00	0.00	-
Elymus elymoides	42	40.0	0.7	1.7	22	24.0	4.8	0.72	0.09	0.92
Elymus elymoides ssp. elymoides	4	3.8	0.5	0.3	4	4.1	2.0	0.81	0.19	-
Elymus glaucus	7	6.7	0.3	0.4	2	100.0	9.2	0.01	0.01	-
Elymus glaucus ssp. glaucus	4	3.8	0.3	0.2	4	100.0	6.1	0.02	0.01	-
Elymus trachycaulus ssp. Subsecundus	1	1.0	1.3		1	1.0	0.9	1.00	0.00	-
Festuca idahoensis[4]	5	4.8	1.3	1.4	3	3.1	1.8	0.78	0.21	-
Festuca trachyphylla	1	1.0	1.6		1	100.0	18.4	0.01	0.01	-
Festuca viridula	1	1.0								-
Glyceria elata	1	1.0	10.1		1	1.0	0.9	1.00	0.00	-
Hordeum brachyantherum	2	1.9	12.6		1	1.0	0.9	1.00	0.00	-
Juncus balticus	4	3.8	1.2	1.7	4	4.6	2.5	0.64	0.23	-
Juncus drummondii	1	1.0	0.2		1	1.0	0.9	1.00	0.00	-
Juncus ensifolius	1	1.0								-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Juncus mertensianus	2	1.9	0.6	0.7	2	1.9	1.3	1.00	0.00	-
Juncus nevadensis	1	1.0	3.7		1	100.0	18.4	0.01	0.01	-
Juncus orthophyllus	4	3.8	0.8	0.9	2	2.3	1.8	0.64	0.32	-
Juncus parryi	7	6.7	0.9	1.3	6	5.9	2.4	0.87	0.13	-
Leymus cinereus	1	1.0	0.8		1	100.0	18.4	0.01	0.01	-
Leymus triticoides	1	1.0	0.7		1	100.0	18.4	0.01	0.01	-
Luzula comosa	1	1.0								-
Luzula subcongesta	2	1.9								-
Melica bulbosa	2	1.9								-
Melica fugax	2	1.9	0.1		1	100.0	18.4	0.01	0.01	-
Melica stricta	1	1.0	0.1		1	100.0	18.4	0.01	0.01	-
Melica subulata	1	1.0								-
Muhlenbergia filiformis	3	2.9	1.0	1.3	2	2.3	1.8	0.64	0.32	-
Poa bolanderi	1	1.0	0.6		1	100.0	18.4	0.01	0.01	-
Poa bulbosa[4, 5]	1	1.0								-
Poa cusickii	1	1.0	0.1		1	1.0	0.9	1.00	0.00	-
Poa pratensis[5]	4	3.8	0.3	0.2	2	2.3	1.8	0.64	0.32	-
Poa secunda	19	18.1	0.4	0.3	9	10.2	3.5	0.66	0.16	-
Poa wheeleri	5	4.8	2.1	3.4	4	100.0	4.5	0.02	0.01	-
Scirpus microcarpus	1	1.0								-
Trisetum canescens	1	1.0								-
Trisetum spicatum	3	2.9	0.3	0.1	2	100.0	29.7	0.01	0.01	-
Undentified grass-like plant	43	41.0	-	-	-	-	-	-	-	-
Ferns [3]										
Aspidotis densa	4	3.8	0.2	0.1	3	3.1	1.8	0.78	0.21	-
Athyrium alpestre	1	1.0	3.3		1	1.0	0.9	1.00	0.00	-
Athyrium alpestre ssp. americanum	1	1.0								-
Athyrium filix-femina	3	2.9	1.1	1.3	3	2.9	1.6	1.00	0.00	-
Cheilanthes gracillima	4	3.8	0.1		1	1.0	0.9	1.00	0.00	-

Species Name	Obs. Site Occupancy (#)	Obs. Site Occupancy (%)	Cover where present (%) Mean	s.d.	N	Est. Site Occupancy (%) Psi	s.e.	Detection probability Per-visit (p)	s.e.	Protocol (Pd)
Cryptogramma acrostichoides	11	10.5	0.4	0.3	2	1.9	1.3	1.00	0.00	-
Cystopteris fragilis	7	6.7	0.1	0.0	3	4.2	3.1	0.47	0.31	-
Dryopteris arguta	1	1.0								-
Pellaea breweri	1	1.0								-
Pellaea bridgesii	3	2.9	0.2		1	1.0	0.9	1.00	0.00	-
Pteridium aquilinum	11	10.5	4.6	2.7	6	5.7	2.3	1.00	0.00	-

1 No cover estimates were recorded for individual tree species in MSIM survey effort (2002-2005)

2 Shrub cover estimates were calculated based on data collected along vegetation composition line intercept transects only at each site. Values are the average across 2 survey visits to each site and the subsequent average across all sites where each species was present

3 Herb and Fern cover estimates were calculated based on data collected within quadrats only at each site, and values shown are the maximum cover value recorded for each species across 2 survey visits to each site; and the subsequen average across sites where the species was present

4 Unique species detected by MSIM surveys in LTBMU that were not recognized as occuring in the Tahoe basin according to a recent compilation, the Watershed Assessment (Murphy and Knopp, eds 2000). These species should be considered in addition to those listed in the Watershed Assessment as occuring in the Tahoe basin

5 Non-native species

* Genus recently updated to Ericameria (Plants database, USDA/NRCS 2000)

** Genus recently updated to Maianthemum (Plants database, USDA/NRCS 2000)

Appendix G-2. Plant detection frequencies (% of sites with detections) and species richness within each sub-watershed (Hydrologic Unit Category level 6) of the Lake Tahoe Basin, 2002-2005. Detections are based on all plant sampling methods utilized in the Multi species Inventory and Monitoring protocol at forestwide monitoring sites (quadrats, subplots, vegetation transects and tree plots). Total number of monitoring sites sampled in each sub-watershed are shown.

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Trees									
Abies									
Abies concolor	100	50	100	93	53	36	67	54	91
Abies magnifica	88	67	75	79	95	57	50	85	100
Calocedrus decurrens				14	5	7	33	23	
Juniperus occidentalis	25	17			42	7	33	38	
Pinus	13				5				
Pinus albicaulis		17			16	43	17	15	18
Pinus contorta	50	67	50	50	95	93	58	85	45
Pinus jeffreyi	100	67	100	100	63	71	92	85	55
Pinus lambertiana	38			14	16	14	25	8	27
Pinus monticola	38	50		43	84	57	58	77	73
Pinus ponderosa					5		8		
Populus tremuloides		17	50	14	26	14	25		18
Tsuga mertensiana	25		25	14	58	43	33	69	36
Tree Richness	***8***	***8***	***6***	***9***	***12***	***11***	***12***	***10***	***9***
Shrubs									
Acer glabrum					11	7	42		45
Alnus incana	13	17		14	11	29		31	27
Alnus incana ssp. tenuifolia							8		

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Amelanchier alnifolia							8		
Amelanchier utahensis	13			14	21	7	50	31	18
Arctostaphylos nevadensis	75			57	37	43	33	46	27
Arctostaphylos patula	50	17	50	43	26	7	25	31	
Artemisia				14					
Artemisia arbuscula				7					
Artemisia tridentata	13	33	75	7	26	29	17		18
Cassiope mertensiana								8	
Ceanothus cordulatus	38	17	50		11	14	17	23	55
Ceanothus prostratus	63		25	43	5	7	17		9
Ceanothus velutinus	63	33	75	64	11		8	8	
Cercocarpus ledifolius				7		7			
Chrysolepis sempervirens	25	17	50	71	16	14	33	23	
Chrysothamnus	13					7			
Chrysothamnus nauseosus			25	7					
Cornus sericea							8		
Cornus sericea ssp. occidentalis								8	
Cornus sericea				7				8	

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
ssp. sericea									
Ericameria bloomeri		17							
Ericameria discoidea					5			8	
Ericameria suffruticosa		17							
Holodiscus discolor				7	5		33	8	18
Holodiscus microphyllus					21	7	17	23	
Juniperus communis					5				
Kalmia polifolia								8	
Ledum glandulosum							17		
Lithocarpus densiflorus		17							
Lonicera conjugialis					21		8	15	45
Lonicera involucrata var. involucrata					5				
Phyllodoce breweri					5		25	8	9
Prunus emarginata	13	33	25		11		33	15	18
Purshia tridentata	13		50	50	11	14	8		
Quercus vacciniifolia	38	33		7	42		58	62	27
Rhamnus rubra							8		
Ribes	25				5			8	

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Ribes cereum	50	50	50	14	21	14	17		27
Ribes lasianthum	13	17							9
Ribes montigenum	13				37	14	17	15	36
Ribes nevadense		17		14	16	29	8	15	18
Ribes roezlii	25	33		7	16	7	33		45
Ribes roezlii var. roezlii	25							8	18
Ribes viscosissimum	13			7	21	7	33	38	36
Rosa woodsii				14	5		8		9
Rubus parviflorus				7	11	14	25	15	27
Salix						14			
Salix eastwoodiae					5				
Salix lasiolepis					5				
Salix lemmonii	13			7	11	7			18
Salix orestera					11		17	8	
Salix scouleriana			25	21	21	29	33	31	
Sambucus mexicana									9
Sambucus racemosa		17			5		8		9
Sambucus racemosa var. racemosa		17			5		8	8	
Sorbus					5				
Sorbus californica					11		17	8	
Spiraea densiflora					11		42	38	9
Symphoricarpos mollis	38	50	25	29	32	14	42	38	82

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Symphoricarpos rotundifolius	13	67	25	14	26	21	42	15	18
Vaccinium cespitosum							17		
Shrub Richness	***22***	***19***	***13***	***25***	***38***	***24***	***37***	***30***	***27***
Herbs									
Achillea millefolium	13		25	7	11		25	15	
Aconitum columbianum	13				5	7			
Actaea rubra				7		7		8	
Adenocaulon bicolor								8	
Agastache urticifolia					5				27
Ageratina occidentalis									9
Agoseris	13					7			9
Agoseris glauca					5		8		9
Agoseris retrorsa	38		25			7	8		
Allium	25	17		7		14	25		
Allium campanulatum	38	33	25	7	42	14	42	31	36
Allium obtusum					5				
Allium validum						7		8	
Allophyllum gilioides						7	8		
Allophyllum integrifolium	13						8		9
Allotropa virgata						14			

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Anaphalis							8	8	
Anemone									9
Angelica							8		
Angelica breweri	25	33	25		21	7	17		55
Antennaria							8	8	9
Antennaria media								15	
Antennaria rosea						7	17	8	9
Apocynum androsaemifolium	25	17	25	36	21	29	17	23	18
Aquilegia formosa		33		14	32	7	8	23	55
Arabis	25	50	25	36	37	21	25	15	36
Arabis drummondii		17						8	
Arabis holboellii	25	17	25	36			8		9
Arabis lemmonii				14	5	7			
Arabis platysperma	13	50	25	21	53	64	8	38	27
Arabis rectissima	13								
Arabis repanda				7					
Arceuthobium abietinum		17					8		
Arenaria							8		
Arenaria aculeata					5	7		8	
Arenaria kingii					11			8	9
Arenaria kingii var. glabrescens						7			
Arnica					5		8		
Arnica cordifolia					5		8		18
Arnica latifolia					11				
Arnica mollis							8		

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Arnica nevadensis					5				
Arnica parryi	13								
Artemisia douglasiana				7		7			
Aster							8	8	18
Aster ascendens	13			7					
Aster breweri		17			32	21	17	46	73
Aster integrifolius					16				
Aster occidentalis				7			8	15	9
Astragalus				7			8		
Astragalus bolanderi					5				
Balsamorhiza sagittata	25	17			5		17		9
Barbarea									9
Botrychium multifidum							8		
Brickellia									9
Calamagrostis								8	
Calochortus					5		8		
Calochortus leichtlinii	13						25	23	36
Caltha leptosepala							8		
Calyptridium umbellatum	13	33		7	11	21		15	
Cardamine cordifolia		17							
Cardamine cordifolia var. lyallii	13			7					

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Castilleja					5			8	18
Castilleja applegatei	25	50	25		21	7	25		36
Castilleja miniata		17			11		8	15	27
Castilleja miniata ssp. miniata	13				5			15	18
Castilleja nana					16		8	23	
Castilleja parviflora								8	
Castilleja pilosa								8	
Castilleja tenuis								8	
Chaenactis douglasii							8		9
Chaenactis douglasii var. douglasii		17							
Chenopodium				7		7			
Chenopodium incognitum		17							
Chimaphila menziesii				7	5	7	25	23	64
Chimaphila umbellata								8	
Circaea alpina ssp. pacifica		17		7	5	7		15	9
Cirsium	13				5				
Cirsium andersonii	25	17			26	14	8	15	64
Cirsium scariosum							8		
Claytonia					5				
Claytonia									9

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lanceolata									
Claytonia rubra				7					
Collinsia			25		11	7			
Collinsia parviflora					5		17	8	27
Collinsia sparsiflora			25						
Collinsia torreyi	38	33	25	29	16	7	25	23	18
Collomia						7			9
Collomia grandiflora	13		25			7	8	8	
Collomia linearis					5				
Collomia tinctoria	13								18
Convolvulus arvensis							8		
Corallorrhiza maculata						7			9
Cordylanthus tenuis					5		8		
Crepis	13	17							9
Crepis acuminata	13								
Cryptantha	25		50	14	5	14	17		9
Cryptantha affinis	50		75	29	5		8		9
Cryptantha simulans					5				
Cymopterus terebinthinus var. californicus					5			8	9
Delphinium	13					7			18
Delphinium glaucum		17			11				18

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Delphinium nuttallianum					5		8	8	36
Descurainia incisa			25		5				
Descurainia pinnata				7					
Dicentra uniflora	13				5				18
Dodecatheon alpinum	13				5		8		
Dodecatheon jeffreyi							8		
Drosera rotundifolia					5				
Epilobium	13	17				14		15	
Epilobium angustifolium								23	9
Epilobium angustifolium ssp. circumvagum	13	17		7	16	7	25	15	18
Epilobium canum								8	
Epilobium ciliatum ssp. glandulosum	13					7			
Epilobium glaberrimum		17						8	
Equisetum arvense				14		7			
Erigeron		17			5	7	8	8	27
Erigeron breweri		17	25		26		8	15	9
Erigeron compositus							8		
Erigeron coulteri	13								
Erigeron								8	

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divergens									
Erigeron peregrinus	13	17			21		17	31	18
Eriogonum	13	33				14	17		9
Eriogonum incanum					5	14	17	15	
Eriogonum lobbii						7			
Eriogonum marifolium					11	21	17		
Eriogonum nudum	38		25	14	32	7	33	38	45
Eriogonum rosense					5	7			
Eriogonum spergulinum		17				7			
Eriogonum umbellatum	13	50	25		16	14	8	23	
Eriogonum ursinum						7			9
Eriogonum wrightii				7	16	7	8		
Eriophyllum lanatum					11				
Eriophyllum lanatum var. integrifolium					5		8		
Erysimum capitatum	25	33	25	36	16	7	8		18
Fragaria virginiana					5	14	8	15	9
Fritillaria atropurpurea	13						8		

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Galium		17				7	8	15	
Galium aparine						7			
Galium bifolium				7		7			9
Galium trifidum						7			
Galium triflorum				7	5				18
Gayophytum		17		14	11	7			
Gayophytum diffusum	38	67	75	71	21	21	25	31	45
Gayophytum diffusum ssp. parviflorum	25		25	7	5	7	8	8	
Gayophytum heterozygum	13				11		8	15	
Gayophytum humile	13					7			
Gentianopsis simplex	13								
Geranium richardsonii	13			7					
Geum triflorum					5				
Gilia				7	5				
Gilia capillaris								8	9
Goodyera oblongifolia								8	
Grindelia squarrosa			25						
Hackelia	13			7		7	8		18
Hackelia floribunda		17							
Hackelia micrantha							8	8	
Hackelia nervosa	25	50		7	16			8	27

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Hackelia velutina		33			5				18
Heracleum lanatum	13	17		7	16	21		15	18
Heterotheca villosa									9
Heuchera					5				
Heuchera micrantha				7					
Heuchera rubescens				7	11		8		9
Hieracium								8	
Hieracium albiflorum		17		7	26	14	25	23	55
Hieracium gracile									9
Hieracium horridum							8		
Horkelia									9
Horkelia fusca ssp. parviflora					5			8	
Hypericum anagalloides		17						8	
Ipomopsis aggregata		17			5	7			
Ivesia santolinoides						7			
Kelloggia galioides	38		25	21	26	21	50	23	82
Lactuca			25						
Lathyrus				7			8		
Lathyrus nevadensis						7			
Lepidium							8		

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
densiflorum									
Leptodactylon pungens				7			17		
Lewisia nevadensis								8	
Lewisia triphylla								15	9
Ligusticum					5				
Ligusticum grayi					21			8	36
Lilium						14	8		
Lilium parvum		17		7	5	14			9
Lilium washingtonianum							8		
Linanthus	13					7			
Linanthus ciliatus	13		25	14	5		8	23	
Linanthus nuttallii				21		14			
Linanthus nuttallii ssp. pubescens				7				8	
Linum lewisii		17							
Listera convallarioides						14			
Lithophragma glabrum									9
Lomatium	13								
Lomatium dissectum	13								
Lomatium nevadense	13								
Lotus					5		8		
Lotus nevadensis			25			7			9

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Lotus purshianus									9
Lupinus	25	17	25		21	7	8	15	55
Lupinus albicaulis									9
Lupinus arbustus	25	17			16	14	8	38	64
Lupinus argenteus						7			
Lupinus breweri		33			11	7			
Lupinus fulcratus					5			8	
Lupinus grayi						7	8		
Lupinus latifolius var. columbianus					5				
Lupinus lepidus var. lobbii								8	
Lupinus polyphyllus	13				16	7			
Madia					5	7			
Madia minima			25					8	
Malacothrix floccifera				7					
Malva				7					
Malva neglecta				7					
Medicago sativa			25						
Mentzelia dispersa	13		25		5	7			
Menyanthes trifoliata					5				
Mertensia ciliata					11				
Microseris nutans					11	14	25		27
Mimulus					5	7		8	9
Mimulus breweri					16	7		15	18
Mimulus					5				

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floribundus									
Mimulus guttatus	13	17		7	16	14	8	8	27
Mimulus leptaleus		17							
Mimulus lewisii								15	
Mimulus mephiticus					5		8		
Mimulus moschatus					11				9
Mimulus primuloides					5		8		9
Mimulus tilingii							8	8	
Mimulus torreyi						7	8		
Mitella breweri					16	14		15	9
Monardella odoratissima	38	67	25	7	16	29	8	8	64
Monardella odoratissima ssp. pallida	13	17	25		16		8	23	27
Montia linearis									9
Nemophila									9
Nemophila spatulata									9
Nothocalais alpestris								8	9
Orobanche corymbosa					5				
Orthilia secunda					11	7	17	8	
Orthocarpus cuspidatus ssp. cryptanthus					5				
Osmorhiza						14	8		9

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Osmorhiza chilensis	13				16	14	17	23	55
Osmorhiza occidentalis	25	50		7	32	29	8	23	64
Paeonia brownii	13	17		7	5				18
Pedicularis attollens							8	8	
Pedicularis groenlandica							17		
Pedicularis semibarbata	25	33			37	21	25	31	55
Penstemon	25	17	50	21	11	7	17	15	27
Penstemon deustus					11		8	8	
Penstemon gracilentus	25	33	25	7	5	14		8	
Penstemon heterodoxus			25		5	21		23	9
Penstemon newberryi				7	16		25	23	9
Penstemon newberryi ssp. newberryi		17			11	21	17	15	
Penstemon rydbergii									9
Penstemon rydbergii var. oreocharis					5				
Penstemon speciosus	13				5	7			
Perideridia	13						8	8	9
Perideridia					5			8	9

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lemmonii									
Perideridia parishii		17			26		8	15	18
Perideridia parishii ssp. latifolia					5				9
Phacelia	50	33		7	5	14	8		18
Phacelia eisenii					5				
Phacelia hastata		17	25				8		
Phacelia hastata ssp. compacta									9
Phacelia hastata var. hastata		17	25	7					9
Phacelia heterophylla	25	17	25						9
Phacelia hydrophylloides	75	17			32			15	45
Phacelia mutabilis					5				
Phacelia ramosissima		17			5				9
Phacelia ramosissima var. eremophila				7					
Phlox diffusa	13	17	25		42	43	25	54	18
Phoenicaulis cheiranthoides					5			8	
Piperia	13								
Piperia leptopetala									9
Piperia unalascensis	13								9
Platanthera	13			7	5	7			

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leucostachys									
Platanthera sparsiflora					5	14			
Polemonium californicum	13				21				
Polemonium occidentale						7			
Polygonum			25	7			8		27
Polygonum bistortoides					5				
Polygonum douglasii			25		11		8		9
Polygonum minimum							8	8	9
Polygonum phytolaccifolium					5				
Polygonum polygaloides ssp. kelloggii					5				
Polygonum shastense		17				7		8	
Potentilla							8		
Potentilla drummondii ssp. breweri							8		
Potentilla drummondii ssp. drummondii					5				
Potentilla glandulosa		17		21	26		33	23	36
Potentilla glandulosa ssp.					5		8		

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ashlandica									
Potentilla gracilis	13			7	16			8	18
Potentilla palustris					11				
Pseudostellaria jamesiana					11				
Pterospora andromedea						7		23	
Pyrola						7			
Pyrola picta	50	17		29	16	36	25	8	64
Raillardella argentea		17							
Raillardella scaposa		17							
Ranunculus					5	7			
Ranunculus alismifolius					5				9
Ranunculus occidentalis							8		9
Rorippa nasturtium-aquaticum						14			
Rumex				7					
Rumex acetosella					5		8		
Sanicula tuberosa								8	
Sarcodes sanguinea					5	7	17		
Saxifraga bryophora								15	
Saxifraga odontoloma	13							8	

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Saxifraga oregana	13								
Scrophularia								8	
Sedum obtusatum					16		17	8	
Sedum obtusatum ssp. Obtusatum					5		8	8	
Sedum stenopetalum					5				
Selaginella							8		
Selaginella watsonii							8		
Senecio						7			9
Senecio integerrimus	13	33	25	7	32	21	33	38	64
Senecio triangularis	13	17		7	32	21		31	9
Sidalcea	13								18
Sidalcea glaucescens								23	64
Sidalcea oregana					5				
Sidalcea oregana ssp. spicata	13								9
Silene					5				
Silene bernardina									9
Silene douglasii					5		17	23	9
Silene invisa								8	
Silene lemmonii					26	7	17	15	
Silene sargentii					5				
Sisymbrium altissimum			25			7			
Smilacina racemosa							8		

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Smilacina racemosa var. amplexicaulis	13				16	21	8	23	36
Smilacina stellata				7		14	25	8	9
Solidago californica								8	
Sphenosciadium capitellatum	13				11				
Spiranthes romanzoffiana					5				
Stachys ajugoides var. rigida	13			7					
Stellaria							8		
Stellaria longipes							8		
Stephanomeria lactucina	25	33				7			18
Stephanomeria tenuifolia			25			14			
Streptanthus tortuosus							17		
Streptanthus tortuosus var. orbiculatus							17	8	
Swertia radiata					11				
Taraxacum				7					
Thalictrum fendleri		17		7	26	21	17	8	64
Thalictrum fendleri var. fendleri				7	16		8	23	18
Trichostema oblongum								8	

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Trifolium				7	5				9
Trifolium longipes					5	7			9
Trifolium longipes var. nevadense	13								
Trifolium variegatum	13								
Triteleia					11				
Triteleia ixioides					5		8	15	
Triteleia ixioides ssp. anilina								8	
Triteleia montana								8	
Valeriana californica	13	17			16				18
Veratrum californicum	13	17			16	14	25	8	18
Veratrum californicum var. californicum	13								
Vicia				7					
Viola		17	25		11				18
Viola adunca					5				
Viola glabella				7		14		8	27
Viola macloskeyi		17							
Viola pinetorum									18
Viola purpurea	38	67			21	14	8	8	27
Viola purpurea ssp. integrifolia	13						8		
Wyethia mollis	50	50		7	16	7	8		36
Zigadenus								15	

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
venenosus									
Undentified Herbaceous	63	50	75	43	53	36	33	31	64
Herbacious Richness	***86***	***71***	***41***	***72***	***155***	***107***	***118***	***122***	***121***
Grass-like Plants									
Achnatherum	13	50	25	21	37	29	8	23	9
Achnatherum nelsonii			25				8	8	
Achnatherum occidentale			25		21	7	8	8	9
Achnatherum thurberianum		33	50	14	16	29	17	15	
Agrostis					16		8		9
Agrostis idahoensis								8	
Agrostis thurberiana						14		8	18
Agrostis variabilis							8	8	
Bromus	38	50	25	7	16	14	17	8	45
Bromus carinatus	13	17	75	7	26		8		18
Bromus orcuttianus							8		
Bromus suksdorfii		50	25					15	18
Bromus tectorum			50	21		7	8		
Carex	50	50	25	50	58	64	58	46	64
Carex amplifolia				7			8	8	
Carex athrostachya									9

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Carex bolanderi						7			
Carex brainerdii	25				21		25	23	
Carex disperma						7			
Carex douglasii						7			
Carex fracta			25					8	
Carex hassei				7					
Carex hoodii						7			
Carex integra		17			5		8		
Carex lenticularis									9
Carex multicostata					5				9
Carex nebrascensis					5				
Carex nigricans								8	
Carex pachystachya									9
Carex raynoldsii								8	
Carex rossii	25			7	5	7			
Carex specifica		17							
Carex spectabilis					5				
Cinna latifolia					5				
Dactylis glomerata						14	8		
Danthonia californica							8		
Danthonia unispicata					11		17		
Deschampsia							8		
Elymus					11	7		23	
Elymus elymoides	50	67	75	36	32	43	33	38	45

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Elymus elymoides ssp. elymoides			25	14	5				
Elymus glaucus	13			7	5		17	8	9
Elymus glaucus ssp. glaucus	13			14			8		
Elymus trachycaulus ssp. Subsecundus					5				
Festuca			50	7	37	14	8	15	27
Festuca idahoensis				7	5		17	8	
Festuca trachyphylla				7					
Festuca viridula								8	
Glyceria elata	13								
Hordeum brachyantherum	13	17							
Juncus	13	17		7	21		17	15	9
Juncus balticus					5	7	17		
Juncus drummondii								8	
Juncus ensifolius		17							
Juncus mertensianus					5		8		
Juncus nevadensis	13								
Juncus orthophyllus								23	9
Juncus parryi					11	7		23	9
Leymus cinereus						7			
Leymus				7					

Scientific Name	**Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)**	**Stateline Point-Third Creek-Incline Creek Frontal (n = 6)**	**Lake Tahoe -East Shore Frontal / North Half (n = 4)**	**Lake Tahoe -East Shore Frontal / South Half (n = 14)**	**Upper Truckee River (n = 19)**	**Upper Truckee River - Trout Creek (n = 14)**	**Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)**	**McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)**	**Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)**
triticoides									
Luzula comosa					5				
Luzula subcongesta						7	8		
Melica								8	
Melica bulbosa								8	9
Melica fugax					11				
Melica stricta							8		
Melica subulata					5				
Muhlenbergia					5				
Muhlenbergia filiformis		17			5	7			
Poa	13			7	16	29	17	23	9
Poa bolanderi						7			
Poa bulbosa							8		
Poa cusickii						7			
Poa pratensis			25	7	5		8		
Poa secunda	13		25	7	21	14	25	38	18
Poa wheeleri			25		11	14			
Scirpus microcarpus				7					
Trisetum canescens				7					
Trisetum spicatum						7	8		9
Undentified Grass	25	33	50	50	58	36	25	46	45
Unidentified juncus							8		9
Grass-like plant Richness	***11***	***9***	***13***	***18***	***27***	***22***	***26***	***21***	***16***

Scientific Name	Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe -East Shore Frontal / North Half (n = 4)	Lake Tahoe -East Shore Frontal / South Half (n = 14)	Upper Truckee River (n = 19)	Upper Truckee River - Trout Creek (n = 14)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
Ferns									
Aspidotis densa					11			15	
Athyrium alpestre					5				
Athyrium alpestre ssp. americanum					5				
Athyrium filix-femina						14			9
Cheilanthes gracillima							33		
Cryptogramma acrostichoides					5		33	31	18
Cystopteris fragilis				7	16	7			18
Dryopteris arguta		17							
Pellaea breweri									9
Pellaea bridgesii					5		17		
Pteridium aquilinum		17		7	5	7	17	38	
Fern Richness	***0***	***2***	***0***	***2***	***7***	***3***	***4***	***3***	***4***
Total species Richness	**127**	**109**	**73**	**126**	**239**	**167**	**197**	**186**	**177**
Total species richness per site	**16**	**18**	**18**	**9**	**13**	**12**	**16**	**14**	**16**
Beta Diversity (Total/mean richness per site)	**4.1**	**3.6**	**2.7**	**5.9**	**6.6**	**6.9**	**5.5**	**5.4**	**4.1**

Appendix G-3. Plant species detected sufficiently to be able to detect changes of 20% or more in frequency of occurrence (% of quadrats with detections) per site with 80% confidence and power.

Species	N_{min} Frequency	# Sites Occupied
Shrubs		
Amelanchier utahensis	13	21
Arctostaphylos nevadensis	23	43
Arctostaphylos patula	9	27
Holodiscus discolor	8	9
Lonicera conjugialis	7	12
Prunus emarginata	10	14
Quercus vacciniifolia*	27	33
Ribes cereum*	16	23
Ribes montigenum	11	18
Ribes nevadense	12	16
Ribes roezlii	17	19
Ribes viscosissimum	19	21
Salix scouleriana	10	21
Spiraea densiflora	6	13
Symphoricarpos mollis	23	41
Symphoricarpos rotundifolius	23	25
Herbs		
Allium campanulatum*	16	30
Angelica breweri	12	18
Apocynum androsaemifolium*	13	27
Aquilegia formosa	19	21
Arabis holboellii	4	12
Arabis platysperma*	19	36
Aster breweri	22	26
Calyptridium umbellatum*	6	11
Castilleja applegatei	8	18
Chimaphila menziesii*	8	20
Chimaphila umbellata	2	2
Cirsium andersonii	6	20
Collinsia parviflora	7	7
Collinsia torreyi	13	22

Species	N_{min} Frequency	# Sites Occupied
Collomia tinctoria	2	3
Cryptantha affinis*	5	14
Delphinium nuttallianum*	6	7
Epilobium angustifolium ssp. circumvagum*	6	14
Erigeron peregrinus	9	14
Eriogonum incanum*	6	7
Eriogonum nudum*	12	27
Eriogonum umbellatum	8	14
Erysimum capitatum	5	17
Gayophytum diffusum	15	39
Hackelia nervosa	11	13
Kelloggia galioides*	15	33
Linanthus ciliatus*	4	9
Lupinus arbustus*	8	21
Mertensia ciliata*	2	2
Microseris nutans	4	10
Mitella breweri	8	8
Osmorhiza chilensis	18	19
Osmorhiza occidentalis	13	27
Pedicularis semibarbata*	13	28
Penstemon newberryi	7	12
Perideridia parishii*	8	11
Phacelia hydrophylloides*	5	20
Phlox diffusa	26	29
Platanthera leucostachys	4	4
Potentilla glandulosa	10	20
Pyrola picta*	12	31
Senecio integerrimus*	17	30
Senecio triangularis	12	17
Thalictrum fendleri var. fendleri	10	10
Valeriana californica	7	7
Veratrum californicum	12	13
Viola glabella	6	7
Viola purpurea	17	18
Grasse-like Plants		

Species	N_{min} Frequency	# Sites Occupied
Bromus carinatus	13	14
Carex brainerdii	7	12
Elymus elymoides	28	42

* species also adequately sampled for % cover metric

Appendix G-4. Plant species detected sufficiently to be able to detect changes of 20% or more in % cover per site with 80% confidence and power.

Species	N_{min} Cover	# Sites Occupied
Shrubs		
Quercus vacciniifolia*	20	33
Ribes montigenum*	9	18
Vaccinium cespitosum	2	2
Herbs		
Allium campanulatum*	10	30
Apocynum androsaemifolium*	10	27
Arabis platysperma*	16	36
Balsamorhiza sagittata	5	7
Calyptridium umbellatum*	6	11
Chimaphila menziesii*	8	20
Cryptantha affinis*	6	14
Delphinium nuttallianum*	7	7
Epilobium angustifolium ssp. circumvagum*	7	14
Eriogonum incanum*	2	7
Eriogonum nudum*	12	27
Fragaria virginiana	7	7
Gayophytum heterozygum	6	6
Kelloggia galioides*	23	33
Linanthus ciliatus*	7	9
Lupinus arbustus*	21	21
Lupinus grayi	2	2
Mertensia ciliata*	2	2
Pedicularis semibarbata*	10	28
Perideridia parishii*	8	11
Phacelia hydrophylloides*	14	20

Species	N_{min} Cover	# Sites Occupied
Pyrola picta*	14	31
Senecio integerrimus*	21	30
Grasse-like Plants		
Achnatherum thurberianum	5	17
Ferns		
Cystopteris fragilis	4	7

* species also adequately sampled for % frequency metric

Appendix H-1. Description of CWHR classification methods for MSIM monitoring sites.

Classification of CWHR habitat types for each of the 4 stations sampled at each site involved 2 main steps: 1) classification of the major habitat subdivision based on cover of various life forms (tree, shrub, herbaceous, aquatic or urban dominated community), 2) classification of specific individual habitat types based on relative cover of individual species.

Classification into major habitat subdivisions (e.g., tree, shrub, herbaceous or aquatic-dominated community) was determined at each station per site based on mean cover values; ≥10% tree canopy cover indicated tree-dominated habitat, <10% tree canopy cover, but ≥ 10 % shrub cover indicated shrub-dominated habitat, and <10% tree canopy and shrub cover and ≥ 2% total herbaceous cover indicated herbaceous-dominated habitat, <10% tree canopy and shrub cover and < 2% total herbaceous cover indicated either aquatic or developed (i.e., urban) habitat types dependent upon the relative cover of open water or impervious surfaces within the 24 ft subplot at each individual station.

Tree canopy cover values were based on the average of 16 canopy cover measurements from a convex densitometer taken at each station. Shrub cover values (for sites with < 10% tree canopy cover) were based on mean shrub cover values taken along vegetation transects at each station. Herbacious cover values were also based on mean values taken along vegetation transects at each station.

Specific CWHR habitat types within each major subdivision were then determined based on relative cover of individual species of trees, shrubs or herbaceous cover (depending on major subdivision type) indicative of the individual habitat types as described in CWHR (CDFG 2005b).

For tree-dominated habitat types, estimates of total crown diameter per tree species were calculated from diameter at breast height (DBH) measurements of each tree using the following linear model (USDA 2002) and summing crown diameter estimates across species:

Crown width per tree = a * (b * DBH)

a = intercept specific to individual tree species (USDA 2002)
b = linear coefficient specific to individual tree species (USDA 2002)
DBH = Diameter at breast height in inches

The resultant relative % cover of each species was compared to the CWHR habitat descriptions in Mayer and Laudenslayer (1988) to determine ultimate habitat classification of each station.

For shrub dominated habitat types, mean % cover of individual shrub species based on quadrat and subplot sampling at the central station (PC1) and frequency of detection of various species at point intercepts along vegetation transects at outlying stations (PC2, PC4 and PC6) when available were compared to the habitat type descriptions (Mayer and Laudenslayer 1988) to determine the likely habitat type.

For urban and aquatic habitat types, the proportion of cover of impervious surfaces, or open water, respectively was compared to that of herbaceous cover in quadrats (when available – at the central station PC1) or in subplots for all other stations. Cover values greater than 98% for impervious surfaces or open water were considered urban or aquatic habitat types, respectively. No aquatic habitat types were defined in this dataset, and only a single urban type was defined. For herbaceous types, the specific habitat type was determined using species composition and relative cover values per species from quadrat data at the central station (PC1) as compared to habitat type descriptions (Mayer and Laudenslayer 1988). Only one herbaceous type (wet meadow) was classified in this dataset.

Appendix H-2. Distribution of CWHR (California Wildlife Habitat Relationship v.2005) habitat types sampled at forestwide monitoring sites by sub-watershed (HUC level 6) within the Lake Tahoe Basin Management Unit, 2002-2005. Values represent the number of sites with at least one station in each habitat type within each sub-watershed. Some sites contain stations in multiple watersheds, allowing those sites to contribute data to more than one watershed. Size class values of 6 (Multi-layered tree canopy) and density cover class values of 60-100% indicate monitoring sites contributing most to late seral/old growth stages of development.

			North		East		South			West	
Habitat Type[a]	**Size Class[a]**	**Density Cover Class[a]**	**Burton-Watson-Tahoe Vista**	**Stateline Point-Third-Incline**	**East Shore North**	**East Shore South**	**Upper Truckee River**	**Upper Truckee-Trout**	**Cascade-Tallac-Taylor**	**McKinney-Bliss-Eagle**	**Ward-Blackwood-Eagle Rock**
Alpine Dwarf-Shrub				1			2	2	3	1	
Aspen	2	40-59%		1							
	3	10-24%		1							
		40-59%					1				
		60-100%							1		
Jeffrey Pine	3	10-24%					1				
		25-39%			1						
		40-59%								1	
		60-100%				1	1				
	4	10-24%				1				1	
		25-39%				3	2			1	
		40-59%			2	3	2	1	2		
		60-100%	2	1	3	5	3	2	3		
	5	10-24%						1		1	
		25-39%			1						
		40-59%								1	
		60-100%				2					
	6	10-24%								1	
		25-39%				2					
		40-59%						1	1		
		60-100%				**2**					
Juniper	4	25-39%	1				1				
	5	10-24%					1				
	6	10-24%							1		
		25-39%					1				
Lodgepole Pine	4	10-24%		1			4	1		1	
		25-39%						1	2	1	1
		40-59%					3	2			

Habitat Type[a]	Size Class[a]	Density Cover Class[a]	North: Burton-Watson-Tahoe Vista	North: Stateline Point-Third-Incline	East: East Shore North	East: East Shore South	South: Upper Truckee River	South: Upper Truckee-Trout	South: Cascade-Tallac-Taylor	West: McKinney-Bliss-Eagle	West: Ward-Blackwood-Eagle Rock
		60-100%	1				5	1	1	1	1
	6	10-24%					1				
		25-39%							1		
		40-59%					1				
		60-100%					**1**	**1**			
Montane Chaparral			2	2		2	1		3	1	1
Montane Riparian	2	60-100%					1				
	4	10-24%				1					
		25-39%									1
Red Fir	4	10-24%		1	1		1			1	
		25-39%	1	1			1	1	1		1
		40-59%	3		1		3	3		2	3
		60-100%	2	2	1	1	6	4	1	2	5
	5	10-24%									
		60-100%									1
	6	10-24%						1			
		25-39%	1				1			2	
		40-59%				2	1	2			
		60-100%		**1**				**1**		**1**	**5**
Sagebrush	3						1				
Sierran Mixed Conifer	4	25-39%	1			1	1				
		40-59%			1	1	2	1		1	1
		60-100%	1	1	1	2	2	1	2	1	2
	5	25-39%				1					
	6	10-24%				1					1
		25-39%									1
		40-59%									1
		60-100%	**1**			**2**					
Subalpine Conifer	3	10-24%						1	1		
		25-39%						2			
		60-100%					1				
	4	10-24%						1	1	2	

Habitat Type[a]	Size Class[a]	Density Cover Class[a]	North		East		South			West	
			Burton-Watson-Tahoe Vista	Stateline Point-Third-Incline	East Shore North	East Shore South	Upper Truckee River	Upper Truckee-Trout	Cascade-Tallac-Taylor	McKinney-Bliss-Eagle	Ward-Blackwood-Eagle Rock
		25-39%					1	3		1	
		40-59%					2	1		3	1
		60-100%					2	1	1	2	
	5	10-24%							1	1	
		25-39%				1					
		60-100%		1							
	6	10-24%					1		1	2	
		25-39%					1			1	
		40-59%						1			
		60-100%						**1**		**1**	
Wet Meadow					1	1	2	1			
White Fir	3	10-24%								1	
		40-59%									
		60-100%						1			
	4	25-39%	1	1					1	1	2
		40-59%	4	1		1	1		5	1	1
		60-100%	4	2	1	6	2	4	3	2	4
	5	25-39%								1	
		40-59%							1		
	6	25-39%									1
		40-59%	1			1					
		60-100%				**1**		**1**			**1**
Urban						1					

a Habitat types, size classes and density classes are defined according to the California Wildlife Habitat Relationship System (CDFG 2005).

Appendix H-3. Vegetation structural characteristics of each CWHR (California Wildlife Habitat Relationship v.2005) habitat type sampled at forestwide monitoring sites in the Lake Tahoe Basin Management Unit, 2002-2005. The number of sites sampled in each habitat type is shown beneath each respective habitat type.

Habitat Variables		Alpine Dwarf-Shrub (n = 9)	Aspen (n = 3)	Jeffrey Pine (n = 30)	Juniper (n =4)	Lodgepole Pine (n = 25)	Montane Chaparral (n = 12)	Montane Riparian (n = 3)	Red Fir (n =40)	Sierran Mixed Conifer (n = 25)	Subalpine Conifer (n = 25)	Wet Meadow (n = 5)	White Fir (n = 43)
Coarse Woody Debris biomass (tons/acre)[1]													
Large (Hard/Soft)	**Average**	**1.2**	**5.0**	**14.2**	**0.0**	**11.7**	**1.7**	**3.4**	**19.5**	**18.7**	**15.5**	**0.9**	**16.5**
	s.d.	3.3	5.3	33.2	0.0	20.0	4.0	4.2	20.8	28.1	28.3	1.9	18.4
Large Hard	**Average**	**0.0**	**1.6**	**4.8**	**0.0**	**1.6**	**0.0**	**2.7**	**0.6**	**1.8**	**3.4**	**0.0**	**4.9**
	s.d.	0.0	2.7	15.9	0.0	5.2	0.0	4.6	1.8	4.0	10.9	0.0	14.5
Large Soft	**Average**	**1.2**	**3.5**	**9.4**	**0.0**	**10.1**	**1.7**	**0.7**	**18.9**	**16.9**	**12.1**	**0.9**	**11.6**
	s.d.	3.3	3.1	25.5	0.0	17.1	4.0	1.2	20.9	27.7	20.8	1.9	13.1
Small (Hard/Soft)	**Average**	**0.4**	**3.3**	**1.0**	**0.0**	**0.7**	**0.4**	**0.5**	**1.1**	**2.0**	**1.1**	**0.0**	**2.1**
	s.d.	1.0	3.1	1.1	0.0	0.9	0.9	0.9	1.2	2.7	1.9	0.1	2.3
Small Hard	**Average**	**0.0**	**1.4**	**0.5**	**0.0**	**0.2**	**0.0**	**0.4**	**0.3**	**0.6**	**0.1**	**0.0**	**0.7**
	s.d.	0.0	2.5	0.8	0.0	0.4	0.0	0.7	0.5	1.2	0.3	0.0	1.4
Small Soft	**Average**	**0.4**	**1.9**	**0.5**	**0.0**	**0.5**	**0.4**	**0.1**	**0.8**	**1.4**	**1.0**	**0.0**	**1.5**
	s.d.	1.0	1.7	0.6	0.0	0.7	0.9	0.2	0.9	1.7	1.9	0.1	1.3
Total Volume - All Logs	**Average**	**1.6**	**8.4**	**15.2**	**0.0**	**12.4**	**2.1**	**3.9**	**20.6**	**20.7**	**16.6**	**0.9**	**18.6**
	s.d.	4.2	8.3	33.4	0.0	20.6	4.1	5.1	20.7	28.5	29.3	2.0	18.8
1000 hr Fuel Load (tons/acre)*	**Average**	**1.6**	**8.4**	**15.2**	**0.0**	**12.4**	**2.1**	**3.9**	**20.6**	**20.7**	**16.6**	**0.9**	**18.6**
	s.d.	4.2	8.3	33.4	0.0	20.6	4.1	5.1	20.7	28.5	29.3	2.0	18.8
Vertical Vegetation Structure (proportion of height interval occupied by vegetation)													
0 - 3 ft	**Average**	**0.441**	**0.678**	**0.440**	**0.389**	**0.454**	**0.501**	**0.705**	**0.408**	**0.369**	**0.370**	**0.822**	**0.415**

Habitat Variables		Alpine Dwarf-Shrub (n = 9)	Aspen (n = 3)	Jeffrey Pine (n = 30)	Juniper (n =4)	Lodgepole Pine (n = 25)	Montane Chaparral (n = 12)	Montane Riparian (n = 3)	Red Fir (n =40)	Sierran Mixed Conifer (n = 25)	Subalpine Conifer (n = 25)	Wet Meadow (n = 5)	White Fir (n = 43)
	s.d.	0.229	0.458	0.216	0.206	0.243	0.248	0.080	0.218	0.242	0.220	0.184	0.243
3 - 16 ft	**Average**	**0.097**	**0.313**	**0.251**	**0.058**	**0.253**	**0.072**	**0.551**	**0.250**	**0.287**	**0.144**	**0.015**	**0.366**
	s.d.	0.117	0.108	0.162	0.067	0.170	0.101	0.080	0.157	0.173	0.103	0.016	0.176
16 - 33 ft	**Average**	**0.036**	**0.236**	**0.245**	**0.019**	**0.201**	**0.027**	**0.244**	**0.234**	**0.287**	**0.122**	**0.012**	**0.313**
	s.d.	0.075	0.209	0.170	0.022	0.155	0.057	0.212	0.144	0.165	0.118	0.026	0.144
33 - 82 ft	**Average**	**0.000**	**0.000**	**0.029**	**0.000**	**0.012**	**0.000**	**0.231**	**0.042**	**0.023**	**0.001**	**0.000**	**0.032**
	s.d.	0.000	0.000	0.048	0.000	0.042	0.000	0.252	0.121	0.055	0.004	0.000	0.057
82 - 131 ft	**Average**	**0.000**	**0.000**	**0.029**	**0.000**	**0.012**	**0.000**	**0.231**	**0.042**	**0.023**	**0.001**	**0.000**	**0.032**
	s.d.	0.000	0.000	0.048	0.000	0.042	0.000	0.252	0.121	0.055	0.004	0.000	0.057
>33 ft	**Average**	**0.003**	**0.146**	**0.195**	**0.000**	**0.161**	**0.004**	**0.372**	**0.258**	**0.292**	**0.087**	**0.004**	**0.251**
	s.d.	0.006	0.221	0.174	0.000	0.235	0.011	0.459	0.205	0.173	0.124	0.009	0.152
Snag Density by Size Class (#/acre)													
5-11 in dbh	**Average**	**0.5**	**5.5**	**1.6**	**0.5**	**4.8**	**0.2**	**1.4**	**3.5**	**8.0**	**2.8**	**0.0**	**5.9**
	s.d.	1.4	6.4	3.3	1.0	8.5	0.6	2.4	5.8	13.7	4.4	0.0	10.4
11-24 in dbh	**Average**	**0.4**	**0.5**	**2.4**	**0.2**	**5.2**	**0.3**	**0.9**	**4.4**	**5.8**	**2.6**	**1.2**	**7.9**
	s.d.	0.5	0.3	3.0	0.2	6.1	0.6	1.0	5.9	5.9	3.0	2.2	6.6
24-30 in dbh	**Average**	**0.1**	**0.0**	**0.5**	**0.0**	**1.0**	**0.1**	**1.2**	**1.3**	**1.2**	**0.9**	**0.3**	**1.6**
	s.d.	0.2	0.0	0.4	0.0	1.1	0.2	1.1	1.0	0.9	1.1	0.5	1.2
>30 in dbh	**Average**	**0.2**	**0.0**	**0.8**	**0.0**	**1.3**	**0.2**	**0.8**	**2.2**	**2.4**	**1.1**	**0.3**	**2.1**
	s.d.	0.2	0.0	0.8	0.0	1.4	0.3	0.8	1.8	2.2	1.0	0.4	2.2
Snag Density by Hardness Class(#/acre)[2]													
Hard < 24 in dbh	**Average**	**0.2**	**5.1**	**2.4**	**0.0**	**4.0**	**0.3**	**0.4**	**4.3**	**7.4**	**2.2**	**0.8**	**6.8**
	s.d.	0.4	6.9	3.8	0.0	6.2	0.7	0.7	7.7	12.7	3.3	1.7	8.8
Soft < 24 in dbh	**Average**	**0.6**	**1.0**	**1.5**	**0.7**	**6.1**	**0.2**	**1.9**	**3.6**	**6.4**	**3.2**	**0.4**	**7.0**
	s.d.	1.3	1.0	2.0	1.1	9.5	0.3	2.7	5.0	8.3	4.7	0.5	7.6
Hard > 24 in dbh	**Average**	**0.1**	**0.0**	**0.5**	**0.0**	**1.0**	**0.0**	**0.9**	**1.1**	**1.2**	**0.8**	**0.5**	**1.3**
	s.d.	0.2	0.0	0.5	0.0	1.3	0.0	1.0	0.9	1.2	1.7	0.7	1.7

Habitat Variables		**Alpine Dwarf-Shrub** (n = 9)	**Aspen** (n = 3)	**Jeffrey Pine** (n = 30)	**Juniper** (n =4)	**Lodgepole Pine** (n = 25)	**Montane Chaparral** (n = 12)	**Montane Riparian** (n = 3)	**Red Fir** (n =40)	**Sierran Mixed Conifer** (n = 25)	**Subalpine Conifer** (n = 25)	**Wet Meadow** (n = 5)	**White Fir** (n = 43)
Soft > 24 in dbh	**Average**	**0.2**	**0.0**	**0.8**	**0.0**	**1.3**	**0.3**	**1.1**	**2.4**	**2.4**	**1.2**	**0.1**	**2.5**
	s.d.	0.3	0.0	0.9	0.0	1.4	0.5	1.5	1.8	2.3	0.9	0.2	2.0
Tree Density (#/acre)													
5-11 in dbh	**Average**	**10.7**	**64.4**	**57.2**	**9.1**	**48.8**	**6.4**	**40.3**	**60.1**	**51.5**	**60.6**	**0.0**	**57.4**
	s.d.	21.3	13.9	56.1	11.6	79.4	9.9	36.9	67.0	62.6	66.8	0.0	57.5
11-24 in dbh	**Average**	**2.7**	**46.4**	**33.7**	**4.2**	**40.2**	**3.0**	**16.6**	**37.0**	**43.0**	**33.0**	**0.0**	**45.0**
	s.d.	4.3	55.1	29.0	3.4	28.0	4.4	19.1	27.2	32.2	27.5	0.0	22.9
24-30 in dbh	**Average**	**0.7**	**0.3**	**4.2**	**1.1**	**4.9**	**1.3**	**3.2**	**5.8**	**4.8**	**3.5**	**0.4**	**4.7**
	s.d.	1.0	0.4	3.0	0.7	3.5	1.4	4.3	2.6	3.0	2.6	0.6	3.0
>30 in dbh	**Average**	**0.5**	**0.3**	**4.1**	**2.8**	**4.6**	**1.2**	**3.9**	**8.1**	**5.9**	**4.1**	**0.6**	**5.3**
	s.d.	0.6	0.2	2.7	1.8	3.8	1.2	5.4	4.9	3.6	2.8	0.6	4.1
Basal Area (ft2/acre)	**Average**	**14.9**	**75.0**	**118.3**	**65.0**	**137.4**	**21.8**	**85.2**	**171.7**	**150.9**	**122.7**	**7.2**	**150.9**
	s.d.	16.2	63.9	53.2	51.2	96.1	18.8	88.1	73.9	76.5	68.5	5.5	61.5
Canopy Cover (%)	**Average**	**1.3**	**53.0**	**55.7**	**25.2**	**46.6**	**4.1**	**32.6**	**58.3**	**61.1**	**42.1**	**1.9**	**65.0**
	s.d.	1.4	25.4	17.3	9.8	23.5	2.7	27.5	16.3	19.2	23.3	2.4	15.1
Litter Depth (in)	**Average**	**0.3**	**0.8**	**1.4**	**0.4**	**1.0**	**0.4**	**1.8**	**1.7**	**1.6**	**0.9**	**1.0**	**1.6**
	s.d.	0.3	0.1	0.7	0.2	0.8	0.4	1.2	1.8	0.9	1.9	0.7	0.7
Ground Cover (%)		(n = 4)	(n = 1)	(n = 19)	(n = 3)	(n = 10)	(n = 2)	(n = 1)	(n = 21)	(n = 7)	(n = 13)	(n = 1)	(n = 21)
Shrub	**Average**	**0.085**	**0.203**	**0.184**	**0.133**	**0.092**	**0.217**	**0.090**	**0.130**	**0.130**	**0.075**	**0.068**	**0.174**
	s.d.	0.076	0.203	0.164	0.138	0.119	0.245	0.063	0.134	0.188	0.084	0.083	0.155
Herb	**Average**	**0.053**	**0.189**	**0.018**	**0.021**	**0.102**	**0.043**	**0.199**	**0.045**	**0.067**	**0.044**	**0.186**	**0.032**
	s.d.	0.065	0.177	0.031	0.022	0.114	0.059	0.147	0.055	0.092	0.048	0.130	0.054
Grass	**Average**	**0.034**	**0.137**	**0.010**	**0.014**	**0.061**	**0.011**	**0.057**	**0.016**	**0.012**	**0.030**	**0.334**	**0.005**
	s.d.	0.065	0.211	0.017	0.016	0.079	0.024	0.050	0.046	0.026	0.057	0.213	0.011
Rock	**Average**	**0.407**	**0.012**	**0.077**	**0.553**	**0.185**	**0.291**	**0.027**	**0.073**	**0.105**	**0.182**	**0.049**	**0.066**
	s.d.	0.286	0.021	0.102	0.317	0.203	0.318	0.046	0.077	0.134	0.122	0.110	0.080
Litter	**Average**	**0.154**	**0.193**	**0.567**	**0.196**	**0.391**	**0.206**	**0.524**	**0.575**	**0.559**	**0.435**	**0.191**	**0.585**
	s.d.	0.120	0.025	0.199	0.230	0.231	0.179	0.262	0.199	0.220	0.185	0.159	0.175
Bare Ground	**Average**	**0.233**	**0.158**	**0.100**	**0.073**	**0.127**	**0.196**	**0.079**	**0.093**	**0.057**	**0.165**	**0.169**	**0.070**
	s.d.	0.302	0.160	0.099	0.091	0.183	0.168	0.114	0.126	0.062	0.185	0.119	0.096

Habitat Variables		Alpine Dwarf-Shrub (n = 9)	Aspen (n = 3)	Jeffrey Pine (n = 30)	Juniper (n =4)	Lodgepole Pine (n = 25)	Montane Chaparral (n = 12)	Montane Riparian (n = 3)	Red Fir (n =40)	Sierran Mixed Conifer (n = 25)	Subalpine Conifer (n = 25)	Wet Meadow (n = 5)	White Fir (n = 43)
Quadratic Mean Diameter (in)	**Average**	**16.8**	**8.1**	**18.7**	**39.8**	**18.2**	**25.1**	**10.2**	**20.6**	**19.7**	**19.3**	**21.7**	**17.9**
	s.d.	13.9	3.8	6.7	25.4	4.0	11.3	9.1	6.7	6.2	6.9	12.6	4.4
Stand Density Index (English)	**Average**	**21.6**	**107.4**	**191.8**	**75.5**	**206.5**	**33.8**	**130.0**	**249.7**	**222.0**	**186.2**	**7.8**	**226.1**
	s.d.	25.9	63.1	110.4	57.3	155.4	27.9	128.8	119.3	124.0	111.6	6.2	97.2

1 Large = logs >12 in diameter at large end, Small = logs < 12 in diameter at large end; Hard = Decay class 1 and 2 (Thomas (1979)); Soft = decay class 3-5 (Thomas (1979)).
2 1000 hour fuels include all logs > 3 inches in diameter at the small end.
3 Hard = decay class 1 and 2, Soft = decay class 3-5 according to Thomas (1979).

Appendix H-4. Vegetation structural characteristics of each sub-watershed (HUC level 6) sampled at forestwide monitoring sites in the Lake Tahoe Basin Management Unit, 2002-2005. The number of sites sampled in each sub-watershed is shown beneath each respective sub-watershed name.

Habitat Variables		**Burton Creek-Watson Creek-Tahoe Vista Frontal** (n = 8)	**Stateline Point-Third Creek-Incline Creek Frontal** (n = 6)	**Lake Tahoe - East Shore Frontal / North Half** (n = 4)	**Lake Tahoe - East Shore Frontal / South Half** (n =14)	**Upper Truckee River - Trout Creek** (n =16)	**Upper Truckee River** (n = 20)	**Cascade Creek-Tallac Creek-Taylor Creek Frontal** (n = 12)	**McKinney Creek-Bliss-Eagle Creek Frontal** (n = 13)	**Ward Creek-Blackwood Creek-Eagle Rock Frontal** (n = 11)
Coarse Woody Debris Volume (tons/acre)[1]										
Large (Hard/Soft)	**Average**	**17.5**	**6.4**	**4.9**	**23.6**	**17.8**	**8.8**	**11.8**	**9.9**	**16.9**
	s.d.	14.5	11.3	6.7	29.9	24.4	11.3	16.4	8.1	13.5
Large Hard	**Average**	**0.6**	**0.5**	**4.1**	**9.4**	**3.3**	**1.4**	**4.5**	**0.9**	**1.3**
	s.d.	1.0	0.9	6.6	22.3	8.1	3.0	12.3	2.4	2.2
Large Soft	**Average**	**16.9**	**5.9**	**0.8**	**14.3**	**14.4**	**7.4**	**7.3**	**9.0**	**15.6**
	s.d.	14.9	10.5	1.2	16.4	18.4	9.8	9.0	7.7	12.1
Small (Hard/Soft)	**Average**	**1.6**	**0.2**	**1.2**	**1.5**	**1.8**	**0.8**	**1.8**	**0.6**	**1.5**
	s.d.	1.4	0.3	1.1	1.3	2.3	0.8	2.1	0.4	1.3
Small Hard	**Average**	**0.6**	**0.1**	**0.4**	**0.5**	**0.7**	**0.2**	**0.6**	**0.1**	**0.5**
	s.d.	1.0	0.2	0.5	0.6	1.6	0.3	1.2	0.2	0.5
Small Soft	**Average**	**1.0**	**0.1**	**0.8**	**1.0**	**1.2**	**0.5**	**1.2**	**0.5**	**1.0**
	s.d.	0.8	0.1	0.6	0.9	1.0	0.6	1.2	0.4	0.9
Total Volume - All Logs	**Average**	**19.1**	**6.7**	**6.2**	**25.2**	**19.6**	**9.5**	**13.6**	**10.4**	**18.4**
	s.d.	14.6	11.4	7.8	30.4	24.3	11.6	17.6	8.3	13.9
1000 hr Fuel Load (tons/acre)[2]	**Average**	**19.1**	**6.7**	**6.2**	**25.2**	**19.6**	**9.5**	**13.6**	**10.4**	**18.4**
	s.d.	14.6	11.4	7.8	30.4	24.3	11.6	17.6	8.3	13.9
Vertical Vegetation Structure (proportion of height interval occupied by vegetation)										
0 - 3 ft	**Average**	**0.504**	**0.545**	**0.341**	**0.345**	**0.249**	**0.472**	**0.454**	**0.439**	**0.476**
	s.d.	0.148	0.184	0.170	0.166	0.115	0.182	0.138	0.162	0.158

Habitat Variables		Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe - East Shore Frontal / North Half (n = 4)	Lake Tahoe - East Shore Frontal / South Half (n =14)	Upper Truckee River - Trout Creek (n =16)	Upper Truckee River (n = 20)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
3 - 16 ft	**Average**	**0.286**	**0.255**	**0.215**	**0.228**	**0.206**	**0.250**	**0.226**	**0.178**	**0.261**
	s.d.	0.199	0.156	0.086	0.093	0.111	0.147	0.180	0.083	0.122
16 - 33 ft	**Average**	**0.246**	**0.157**	**0.222**	**0.248**	**0.223**	**0.217**	**0.171**	**0.149**	**0.262**
	s.d.	0.116	0.129	0.067	0.115	0.134	0.194	0.126	0.105	0.090
33 - 82 ft	**Average**	**0.205**	**0.098**	**0.188**	**0.232**	**0.227**	**0.180**	**0.135**	**0.119**	**0.255**
	s.d.	0.105	0.116	0.140	0.115	0.175	0.160	0.123	0.108	0.114
82 - 131 ft	**Average**	**0.026**	**0.011**	**0.024**	**0.032**	**0.032**	**0.011**	**0.012**	**0.004**	**0.059**
	s.d.	0.043	0.027	0.048	0.048	0.051	0.020	0.013	0.008	0.075
>33 ft	**Average**	**0.205**	**0.103**	**0.188**	**0.236**	**0.233**	**0.181**	**0.138**	**0.119**	**0.272**
	s.d.	0.105	0.115	0.140	0.117	0.178	0.161	0.123	0.108	0.114
Snag Density by size class (#/acre)										
5-11 in dbh	**Average**	**2.3**	**6.4**	**2.6**	**3.9**	**6.8**	**2.0**	**4.9**	**2.8**	**3.7**
	s.d.	2.6	11.5	3.2	5.5	14.1	1.8	7.3	3.8	3.6
11-24 in dbh	**Average**	**4.9**	**4.3**	**3.9**	**5.2**	**4.2**	**2.9**	**4.0**	**3.2**	**6.0**
	s.d.	3.4	9.1	2.9	5.7	4.5	3.6	4.0	2.1	6.1
24-30 in dbh	**Average**	**0.8**	**0.9**	**0.8**	**1.4**	**0.9**	**0.8**	**0.8**	**0.9**	**1.7**
	s.d.	0.8	1.4	0.7	0.8	0.7	0.7	0.7	0.6	0.9
>30 in dbh	**Average**	**1.0**	**0.5**	**0.4**	**2.6**	**1.3**	**1.6**	**0.8**	**1.1**	**2.4**
	s.d.	1.1	0.5	0.4	2.1	1.2	1.2	0.9	0.8	2.1
Snag Density by Hardness Class(#/acre)[3]										
Hard < 24 in dbh	**Average**	**3.3**	**8.7**	**2.6**	**5.2**	**5.3**	**2.5**	**4.1**	**2.8**	**4.9**
	s.d.	3.1	16.7	2.3	7.3	10.5	2.6	5.9	2.6	4.4
Soft < 24 in dbh	**Average**	**3.9**	**2.0**	**3.9**	**3.8**	**5.7**	**2.4**	**4.8**	**3.2**	**4.8**

Habitat Variables		Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe - East Shore Frontal / North Half (n = 4)	Lake Tahoe - East Shore Frontal / South Half (n =14)	Upper Truckee River - Trout Creek (n =16)	Upper Truckee River (n = 20)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
	s.d.	3.7	3.9	3.9	4.2	8.8	2.6	6.5	3.3	5.4
Hard > 24 in dbh	**Average**	**0.2**	**0.8**	**0.7**	**1.5**	**0.8**	**0.8**	**0.6**	**0.6**	**1.3**
	s.d.	0.2	1.5	0.6	1.6	0.8	0.7	0.4	0.6	0.7
Soft > 24 in dbh	**Average**	**1.5**	**0.6**	**0.5**	**2.5**	**1.3**	**1.5**	**1.0**	**1.4**	**2.9**
	s.d.	1.5	0.7	0.2	2.0	1.2	1.3	1.3	0.9	1.9
Tree Density (#/acre)										
5-11 in dbh	**Average**	**32.5**	**31.2**	**37.7**	**31.6**	**67.6**	**67.5**	**36.6**	**32.1**	**55.6**
	s.d.	20.4	28.9	33.9	31.8	63.3	52.9	29.0	28.8	40.6
11-24 in dbh	**Average**	**43.4**	**21.5**	**26.8**	**36.5**	**34.7**	**34.5**	**34.7**	**26.8**	**40.0**
	s.d.	16.2	19.2	16.6	26.5	22.7	23.1	28.5	18.1	24.0
24-30 in dbh	**Average**	**4.6**	**3.2**	**4.5**	**3.4**	**6.2**	**4.3**	**3.3**	**2.9**	**5.8**
	s.d.	2.3	3.7	1.3	1.2	2.7	2.4	1.9	1.4	2.5
>30 in dbh	**Average**	**3.7**	**2.1**	**3.8**	**4.6**	**7.4**	**5.7**	**3.0**	**4.6**	**8.2**
	s.d.	1.9	1.9	2.4	2.2	5.1	3.7	1.5	2.2	5.5
Basal Area (ft2/acre)	**Average**	**126.3**	**71.3**	**97.4**	**113.3**	**165.1**	**143.4**	**105.3**	**106.4**	**169.2**
	s.d.	36.9	62.2	36.2	38.3	69.4	74.4	60.8	62.1	56.2
Canopy Cover (%)	**Average**	**53.5**	**41.5**	**51.0**	**56.3**	**51.8**	**50.4**	**42.0**	**40.8**	**59.5**
	s.d.	16.2	19.9	7.4	16.8	21.0	20.3	27.8	20.2	17.7
Litter Depth (in)	**Average**	**1.5**	**1.0**	**1.4**	**1.5**	**1.2**	**1.4**	**0.9**	**1.2**	**1.4**
	s.d.	0.6	0.9	0.3	0.7	0.8	1.6	0.7	1.2	0.4
Ground Cover (%)		(n = 8)	(n = 6)	(n = 4)	(n =14)	(n =14)	(n = 19)	(n = 12)	(n = 13)	(n = 10)
Shrub	**Average**	**0.232**	**0.149**	**0.089**	**0.094**	**0.047**	**0.134**	**0.163**	**0.174**	**0.104**
	s.d.	0.136	0.136	0.063	0.052	0.048	0.108	0.152	0.179	0.098
Herb	**Average**	**0.054**	**0.105**	**0.030**	**0.018**	**0.014**	**0.079**	**0.032**	**0.042**	**0.084**
	s.d.	0.074	0.060	0.037	0.020	0.017	0.097	0.042	0.030	0.058
Grass	**Average**	**0.008**	**0.009**	**0.044**	**0.012**	**0.048**	**0.045**	**0.033**	**0.016**	**0.030**

Habitat Variables		Burton Creek-Watson Creek-Tahoe Vista Frontal (n = 8)	Stateline Point-Third Creek-Incline Creek Frontal (n = 6)	Lake Tahoe - East Shore Frontal / North Half (n = 4)	Lake Tahoe - East Shore Frontal / South Half (n =14)	Upper Truckee River - Trout Creek (n =16)	Upper Truckee River (n = 20)	Cascade Creek-Tallac Creek-Taylor Creek Frontal (n = 12)	McKinney Creek-Bliss-Eagle Creek Frontal (n = 13)	Ward Creek-Blackwood Creek-Eagle Rock Frontal (n = 11)
	s.d.	0.014	0.019	0.065	0.022	0.081	0.074	0.035	0.021	0.060
Rock	**Average**	**0.053**	**0.082**	**0.063**	**0.099**	**0.093**	**0.153**	**0.238**	**0.189**	**0.087**
	s.d.	0.065	0.103	0.037	0.112	0.078	0.142	0.242	0.178	0.090
Litter	**Average**	**0.513**	**0.323**	**0.577**	**0.612**	**0.574**	**0.452**	**0.393**	**0.446**	**0.576**
	s.d.	0.158	0.216	0.018	0.152	0.163	0.209	0.194	0.165	0.172
Bare Ground	**Average**	**0.103**	**0.287**	**0.132**	**0.108**	**0.162**	**0.092**	**0.074**	**0.089**	**0.049**
	s.d.	0.075	0.255	0.034	0.110	0.144	0.113	0.081	0.067	0.048
Quadratic Mean Diameter (in)	**Average**	**18.5**	**15.3**	**19.7**	**22.2**	**19.6**	**19.4**	**18.5**	**21.5**	**20.4**
	s.d.	3.4	3.0	1.8	6.8	6.1	6.4	6.3	4.7	5.4
Stand Density Index (English)	**Average**	**186.6**	**109.6**	**144.9**	**183.4**	**239.3**	**216.0**	**156.1**	**153.4**	**247.8**
	s.d.	55.3	96.5	53.0	106.6	103.1	114.2	94.8	91.5	76.6

1 Large = logs >12 in diameter at large end, Small = logs < 12 in diameter at large end; Hard = Decay class 1 and 2 (Thomas (1979)); Soft = decay class 3-5 (Thomas (1979)).
2 1000 hour fuels include all logs > 3 inches in diameter at the small end.
3 Hard = decay class 1 and 2, Soft = decay class 3-5 according to Thomas (1979).

Appendix H-5. Vegetation structural characteristics of each wildfire threat zone sampled at forestwide monitoring sites in the Lake Tahoe Basin Management Unit, 2002-2005. wildfire threat zone. The number of sites sampled in each threat zone is shown beneath each respective threat zone.

Habitat Variables		**Defense Zone** (n = 36)	**Threat Zone** (n = 23)	**Outside WUI** (n = 71)
Coarse Woody Debris Volume (tons/acre)[1]				
Large (hard/soft)	**Average**	**11.9**	**24.0**	**13.3**
	s.d.	14.0	40.9	18.7
Large Hard	**Average**	**2.0**	**8.5**	**3.2**
	s.d.	3.4	34.8	10.4
Large Soft	**Average**	**10.0**	**15.5**	**10.2**
	s.d.	13.1	15.0	12.9
Small (hard/soft)	**Average**	**1.2**	**2.1**	**1.0**
	s.d.	1.4	2.2	1.1
Small Hard	**Average**	**0.4**	**0.9**	**0.3**
	s.d.	0.7	1.4	0.7
Small Soft	**Average**	**0.8**	**1.2**	**0.7**
	s.d.	0.9	1.2	0.7
Total Volume - All Logs	**Average**	**13.1**	**26.0**	**14.3**
	s.d.	14.7	41.2	19.1
1000 hr Fuel Load (tons/acre)[2]	**Average**	**13.1**	**26.0**	**14.3**
	s.d.	14.7	41.2	19.1
Vertical Vegetation Structure (proportion of height interval occupied by vegetation)				
0 - 3 ft	**Average**	**0.462**	**0.385**	**0.424**
	s.d.	0.163	0.182	0.194
3 - 16 ft	**Average**	**0.276**	**0.277**	**0.220**
	s.d.	0.142	0.147	0.157
16 - 33 ft	**Average**	**0.238**	**0.256**	**0.181**
	s.d.	0.122	0.142	0.136
33 - 82 ft	**Average**	**0.228**	**0.208**	**0.169**
	s.d.	0.141	0.136	0.153
82 - 131 ft	**Average**	**0.023**	**0.027**	**0.024**
	s.d.	0.038	0.045	0.053
>33 ft	**Average**	**0.230**	**0.211**	**0.174**
	s.d.	0.141	0.136	0.158
Snag Density by Size Class (#/acre)				
5-11 in dbh	**Average**	**4.6**	**8.2**	**2.4**
	s.d.	7.1	13.8	3.4

Habitat Variables		Defense Zone (n = 36)	Threat Zone (n = 23)	Outside WUI (n = 71)
11-24 in dbh	**Average**	**4.8**	**7.8**	**3.1**
	s.d.	4.8	6.9	3.2
24-30 in dbh	**Average**	**1.3**	**1.6**	**0.9**
	s.d.	1.6	1.1	0.8
>30 in dbh	**Average**	**1.3**	**2.0**	**1.5**
	s.d.	1.3	1.5	1.6
Snag Density by Hardness Class(#/acre)[3]				
Hard < 24 in dbh	**Average**	**5.0**	**8.9**	**2.6**
	s.d.	7.8	13.1	2.8
Soft < 24 in dbh	**Average**	**4.4**	**7.2**	**2.9**
	s.d.	4.9	7.4	4.1
Hard > 24 in dbh	**Average**	**0.9**	**1.1**	**0.8**
	s.d.	1.4	1.3	0.8
Soft > 24 in dbh	**Average**	**1.7**	**2.5**	**1.6**
	s.d.	1.8	1.9	1.6
Tree Density (#/acre)				
5-11 in dbh	**Average**	**52.7**	**54.8**	**41.9**
	s.d.	45.7	61.7	40.1
11-24 in dbh	**Average**	**37.9**	**43.1**	**30.4**
	s.d.	20.6	26.9	22.5
24-30 in dbh	**Average**	**4.6**	**4.5**	**4.4**
	s.d.	2.1	2.5	3.0
>30 in dbh	**Average**	**4.9**	**4.2**	**5.6**
	s.d.	2.4	2.8	4.3
Basal Area (ft^2/acre)	**Average**	**132.8**	**133.0**	**128.0**
	s.d.	43.9	60.2	75.7
Canopy Cover (%)	**Average**	**58.0**	**56.2**	**46.4**
	s.d.	14.9	18.6	22.5
Litter Depth (in)	**Average**	**1.5**	**1.8**	**1.1**
	s.d.	0.6	1.7	0.8
Ground Cover (%)			(n = 46)	(n = 58)
Shrub	**Average**	**0.161**	**0.136**	**0.135**
	s.d.	0.149	0.109	0.145
Herb	**Average**	**0.053**	**0.025**	**0.057**
	s.d.	0.070	0.038	0.072
Grass	**Average**	**0.040**	**0.005**	**0.021**

Habitat Variables		Defense Zone (n = 36)	Threat Zone (n = 23)	Outside WUI (n = 71)
	s.d.	0.068	0.013	0.045
Rock	**Average**	**0.073**	**0.075**	**0.163**
	s.d.	0.114	0.097	0.165
Litter	**Average**	**0.540**	**0.593**	**0.461**
	s.d.	0.137	0.168	0.217
Bare Ground	**Average**	**0.084**	**0.093**	**0.105**
	s.d.	0.074	0.115	0.124
	Average	**19.0**	**18.2**	**20.5**
Quadratic Mean Diameter (in)	s.d.	6.2	5.4	6.7
	Average	**212.4**	**202.5**	**184.8**
Stand Density Index (English)	s.d.	107.9	101.7	110.0

1 Large = logs >12 in diameter at large end, Small = logs < 12 in diameter at large end; Hard = Decay class 1 and 2 (Thomas (1979)); Soft = decay class 3-5 (Thomas (1979)).
2 1000 hour fuels include all logs > 3 inches in diameter at the small end.
3 Hard = decay class 1 and 2, Soft = decay class 3-5 according to Thomas (1979).

Appendix H-6. List of habitat variables evaluated in species-habitat covariate analyses and associated habitat variable groups used for summary and interpretation.

Variable Tested	Species Groups tested	Assigned Variable Group
Number of lake stations per site	bats	Lentic habitat availability
Number of meadow stations per site	bats	Lentic habitat availability
Number of pond stations per site	bats	Lentic habitat availability
Number of stream stations per site	bats	Lentic habitat availability
Number of trail stations per site	bats	Lentic habitat availability
Percent slope	carnivores	Slope
Basal Area of Conifers	carnivores	Basal Area
Basal Area of Fir	carnivores	Basal Area
Basal Area of Hardwoods	carnivores	Basal Area
Basal Area of Pine	carnivores	Basal Area
Basal Area of Snags	carnivores	Basal Area
Basal Area of Trees	carnivores	Basal Area
Cosine Transformed Slope (in radians)	carnivores	Slope
Distance to nearest water from station	carnivores	Distance to water
Total length of large coarse woody debris (>12 in diameter)	carnivores	Coarse woody debris
Total length of small coarse woody debris (<12 in diameter)	carnivores	Coarse woody debris
Volume of Large coarse woody debris (> 12 in diameter)	small mammals and carnivores	Coarse woody debris
Volume of Large hard coarse woody debris	small mammals and carnivores	Coarse woody debris
Volume of Large soft coarse woody debris	small mammals and carnivores	Coarse woody debris
Volume of small coarse woody debris (< 12 in diameter)	small mammals	Coarse woody debris
Total volume of coarse woody debris	small mammals and plants	Coarse woody debris
Canopy cover per station (Field collected)	birds, small mammals, carnivores, bats and plants	Canopy cover
Canopy cover per station (GIS generated; IKONOS v.4)	birds, and small mammals	Canopy cover
Snag density per size class (5-11in, 11-24in, 24-30in and >30in dbh)	birds, small mammals, carnivores and bats	Tree/snag Density
Total snag density	birds, small mammals, carnivores and bats	Tree/snag Density
Soft snag density per size class (<24in, >24 in dbh)	birds and small mammals	Tree/snag Density
Tree density per size class (5-11in, 11-24in, 24-30in and >30in dbh)	birds, small mammals, carnivores and bats	Tree/snag Density
Total tree density	birds, small mammals, carnivores and bats	Tree/snag Density
Stand Density Index	carnivores	Tree/snag Density
Quadratic Mean Diameter (field based data)	birds, small mammals and carnivores	Tree size
Mean dbh within 200 meters of station (GIS generated; IKONOS v.4)	bats	Tree size
Mean dbh within 50 meters of station (GIS generated; IKONOS v.4)	bats	Tree size
Mean dbh within 500 meters of station (GIS generated; IKONOS v.4)	bats	Tree size
Number of stations with roads within 150 meters	birds and small mammals	Disturbance

Variable Tested	Species Groups tested	Assigned Variable Group
Area of ground within 30 meters of stations with roads/trails	birds and small mammals	Disturbance
Disturbance index value within 300 meters of station (Parks …)	birds, small mammals and plants	Disturbance
HUC level 6 watershed location	birds, small mammals, carnivores, bats and plants	Spatial
Elevation	birds, small mammals, carnivores and plants	Spatial
Portion of basin where located (north, south, east, west)	birds, small mammals and plants	Spatial
Portion of basin where located (eastside or westside)	birds and small mammals	Spatial
Number of trees with loose bark within 1 hectare surrounding station	bats	Tree Decadence
Number of trees with cavities within 1 hectare surrounding station	bats	Tree Decadence
Litter Cover estimate within 24 ft diameter subplot	small mammals	Amount of Litter
Litter cover estimate along line intercept transects	small mammals	Amount of Litter
Litter depth	small mammals and plants	Amount of Litter
Proportion of area within 50 meters of station with various soil types (Rock outcrop; Soil F/G/D/<F33; Soil F/G/S; Soil F/G/VD/C,JP; Soil F/G/VD/T,SP; Soil F/L/MD), based on TEUI layer (Slaton et al 2006)	plants	Soil Type
Intensity of trap effort (103 extra long traps versus 79 extra long and extra large traps)	small mammals	Protocol intensity
Ground Cover for various cover types along line transects (Bare ground, grass, herbs, and shrubs)	birds and small mammals	Ground Cover
UTM Zone 10 easting value	carnivores	Spatial
UTM Zone 10 northing value	carnivores	Spatial
Proportion of various height intervals with presence of live vegetation (0-1 meter, 1-5 meters, 5-10 meters, 10-25meters, 25-40 meters)	birds, small mammals and bats	Vertical Structure
Year of survey	birds, small mammals, bats and plants	Year
Field generated CWHR habitat type per site (e.g., number of stations with each habitat type per site, Dominant habitat type per site)	birds and small mammals	Field habitat
GIS generated CWHR habitat type per site (e.g., habitat type at centerpoint location, proportion of area within 50, 200, 300 or 500 meters of each site with each habitat type)	birds, small mammals and bats	GIS habitat