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BIOMASS TO ENERGY:

FOREST MANAGEMENT FOR WILDFIRE REDUCTION, ENERGY PRODUCTION, AND OTHER BENEFITS

APPENDIX 5

PIER FINAL PROJECT REPORT

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APPENDIX 5:

BIOMASS TO ENERGY PROJECT:WILDLIFE HABITAT EVALUATION

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Notice of Change in Scenario Naming Conventions

Key assumptions, modeling structures and terminology were altered and refined to accommodate new thinking during the course of this study. The reader will observe in the appendices that the scenarios are referred to as "Scenarios 1, 2 and 3" or "S1, S2 and S3."

In both the main text of the Final Report and in the Life Cycle Assessment appendix (Appendix 4), the former Scenario 1 (S1) was renamed to the "Reference Case." Scenario 3 (S3) has been renamed the "Test Scenario." Scenario 2 (S2), focused on the relative contributions and impact of Industrial Private Forestry (IPF) has been eliminated from most of the analyses that make up the entire study. These changes better reflect the focus of the study, which is fundamentally about the landscape level changes in wildfire, habitat, and other dynamics. The modification of terminology do not substantively affect the findings or recommendations of the study.

2. APPROACH

We evaluated vegetation conditions, along with environmental variables (e.g., elevation, slope, precipitation) to evaluate how habitat conditions for wildlife species are expected to change as a result of different fuels management scenarios. We evaluated the potential effects of biomass removal scenarios on biological diversity by evaluating changes in habitat suitability from five perspectives: habitat element specialists, aquatic species, service-providing units, indicator species, and individual species of special interest. Each of the five perspectives address concerns regarding the direct and indirect effects of management on biological diversity and the services it provides.

- Habitat element specialist guilds (HEGs) represent the effects of forest management on vegetation structure, and in turn, habitat conditions for wildlife species.
- Service providing units (SPUs) represent the effects of forest management on ecosystem services by affecting the diversity of service providers and biological diversity as a whole.
- Aquatic species use upland habitats to meet a variety of life history needs, including foraging, cover, estivation, and dispersal. Upland conditions and activities can also affect aquatic habitats.

- Indicator species are those species that meet criteria for one or more of five key types of indicators, and their fate reflects core conditions of associated ecological systems.
- Species of special interest are those that are of particular interest or concern based on their current population status or their vulnerability to forest management practices.

Ecosystem Services

The maintenance of native biological diversity is the ultimate objective of this evaluation. Biological diversity is essential to maintenance of ecosystem processes and their associated services (Daily 1997; Hughes et al. 1997; Naheem & Li 1997; Tilman et al. 1997; Peterson et al. 1998; Luck et al. 2003; Dobson et al. 2006), which together help to maintain the resilience of dynamic ecosystems subjected to disturbance in both natural and urbanizing landscapes (Chapin et al. 1997; Loreau et al. 2002; Kinzig et al. 2002; Luck et al. 2003). Resilience is the capacity of a system to absorb disturbance so as to retain the same function, structure, and services (Folk et al. 2004, Walker et al. 2004). Ecosystem services, such as nutrient cycling, seed dispsersal, water infiltration, carbon sequestration, and climate regulation, are provided by the biotic and abiotic components of ecosystems and are considered critical for human well-being (Daily 1997).

Forest management can have a diversity of effects on biological diversity, both positive and negative. Little attention has been directed towards identifying linkages between forest management and corresponding changes in ecosystem services. As human populations increase, wildlands are increasingly affected directly and indirectly through actions such as forest management to generate products, manage risk (e.g., fire), recreational use, water allocation, and climate change. The conservation of biodiversity and ecosystem services is important in working landscapes because the full scope of those services cannot be captured in parks and nature reserves, which amount to less than an eighth of Earth's land surface (Groom et al. 2006; Pyke 2007).

Ecosystem services can be transformed by altering the diversity of species with particular functional roles (Frost et al. 1995; Ives et al. 1999; Cottingham et al. 2001; Elmqvist et al. 2003; Norburg 2004; Folk et al. 2004; Dobson et al. 2006,). Suites of species that share a particular functional role or niche in the ecosystem and together provide a discrete set of ecosystem services have been termed functional groups (Walker et al. 1999; Elmqvist et al. 2003) or "service-providing units" (SPUs; sensu Luck et al. 2003). Diversity within SPUs maintains or more swiftly restores processes in the face of environmental perturbations because associated species have different tolerances and sensitivities, known as response diversity (Elmqvist et al. 2003). Thus, biological diversity within and among SPUs is central to maintaining the ecosystem services that they regulate and support (Naeem & Li 1997; Folk et al. 2004; Balvanera et al. 2006).

B2E STUDY AREA

Vegetation and Physical Characteristics

The study area is located area is located in northeastern California in Lassen and Plumas counties, where the northern Sierra Nevada meets the Southern Cascades. The area encompasses most of the Plumas National Forest and the eastern portion of the Lassen National Forest, and includes portions of the Southern Cascades, Sierra Nevada, Modoc Plateau, and Sierra Foothills ecoregions. It is comprised of 65% public lands, with 48 percentage points in multiple use (Figure 1). The remainder of the landscape is 17% private industrial forest lands, 14% private non-industrial forest lands, and 4% of a variety of other elements (including urban).

The study area is topographically complex, ranging from rugged mountain ranges on the eastern side, to moderately sloping foothills on the western side. Elevations range from 200 ft in the western foothills to 10,457 ft on the top of Mt. Lassen. The northern portion is dominated by volcanic plateaus, and there are canyons and riparian areas associated with the Feather River in the southern portion. The landscape contains several lakes and reservoirs. Most of the soils are derived from volcanic material and are well drained. They tend to be deeper, moister, and more productive on the west side of the mountain ranges and on north slopes, and shallower, drier, and less productive on the east side of the mountain ranges and on south slopes (Miles and Goudy 1997).

Climate is highly variable in this region. On the western side, the marine influence of the Pacific Ocean carries moisture up the western slopes of the Sierra Nevada and Cascade ranges, generating precipitation mostly in the form of snow. Thus, the west side experiences a Mediterranean climate with wet winters (approximately 40 – 90 inches of precipitation) and dry summers. On the eastern sides of the ranges, the air masses lose most of their moisture, resulting in lower precipitation (approximately 10 – 40 inches), and a greater range of seasonal and daily temperatures. Temperatures range from hot (mean annual temperature of 56-64 degrees F) in the western foothills to very cold (mean annual temperature of 30-45 degrees F) around Mt. Lassen (Miles and Goudy 1997).

A summary of the types and amounts of vegetative cover occurring in the study area is provided in Table 1. The vegetation is largely dominated by conifers (78%; Figure 2), and Sierran mixed conifer specifically (40%; Figure 2). Lower montane elevations support mixed conifer forest and white fir, while red fir is found at higher elevations. Jeffrey pine tends to occur in the dry eastern and northern portions of the study area. Lodgepole pine may be found in cold basins and around lakes at higher elevations. In the mid- to lower elevations, common hardwoods include California black oak, blue oak, and canyon live oak. The most common riparian hardwoods are black cottonwood at the lower elevations, and mountain alder at the high elevations. Wet basins support sedge meadows. In the Southern Cascades ecoregion, sagebrush, grassland, and western juniper may be found on the volcanic plateaus (Miles and Goudy 1997).

Because of its unique location, the Plumas-Lassen area experiences diverse geological, topographical, and climatic conditions that interact to generate a wide variety of habitats. Furthermore, unique features of the landscape, such as hydrothermal areas, serpentine soils, canyons, lakes, and vernal pools support the presence of many specialized habitats. Such a heterogeneous landscape is expected to foster biodiversity by providing a greater variety of microhabitats for rare and endemic species. For example, of 140 plant taxa located in the Feather River basin, 79 are endemic to the Sierra Nevada and 95 are rare (Shevock 1996). Since

Species in the B2E Study Area

The study area is located at the intersection of two ecoregions. The result is two fold: high species diversity, and a large proportion of species at the edge of their geographic range. Individuals at the edge of their ranges are apt to be less tolerant and/or more vulnerable to environmental stress or change because they near the limits of their physiological tolerance in one or more ways. The Plumas-Lassen area is subject to increasing pressure from logging and recreation, as well as from natural disturbances like wildfire and climate change. This suggests that the area must be managed carefully, to avoid accelerating the decline of populations that may be more vulnerable to decline at their edges than they would be at the centers of their geographical ranges.

The CWHR database (CDFG 2002) was used to derive a species list for the study area (Appendix A). The species list was based primarily on species range maps, without consideration for the amount of suitable habitat within the bounds of the study area (i.e., the ability of the landscape to support a self-sustaining population). The study area is within the geographic ranges of 307 vertebrate species, including 17 amphibians, 19 reptiles, 196 birds, and 76 mammals (Appendix A). Of these 307 species, 79 are strongly associated with aquatic habitats.

METHODS

Treatments

A brief description of treatments is provided here. A more detailed description is provided in the vegetation modeling domain report. Scenario 1 entailed no mechanical treatments – only wildfire. Scenario 2 entailed treatment of private timber lands, which comprised 31% of the landscape (847,000 ac), and associated wildfire across the landscape. Scenario 3 entailed treatment of private lands (as per Scenario 2) and multiple use National Forest System (NFS) lands (48% of the landscape; 1,311,500 ac), and associated wildfire across the landscape.

Treatments and fire varied among scenarios. In Scenario 233,100 ac are treated in the first decade on private timber lands using primarily selective harvest, with a minor amount of other silvicultural prescriptions (Figure 3). The following decade, an additional 295,000 ac are treated, for a total of approximately 627,000 ac treated (75% of private timber lands). Then this treatment pattern is repeated in the subsequent two decades, both in terms of the acreage, prescription, and location of treatments. In Scenario 3, public lands are treated with just one prescription – restricted thinning which results in a post-treatment canopy cover of 40%. In the first decade, 203,000 ac are treated on public lands in the form of defensible fuel profile zones (DFPZ), and in the second decade an additional 163,000 ac are treated to create the SPLAT configuration. In decades 3 and 4, these harvest patterns are repeated in terms of acreage, prescription, and location, for a total of 28% of multiple use lands. Wildfire varied by scenario, ranging from approximately 74,000 ac per decade in Scenario 1, to 69,000 ac per decade in Scenario 2, to 57,000 ac per decade in Scenario 3 (Figure 4).

Current vegetation conditions across the landscape were generated from existing FIA data (see SFA documentation), and future vegetation conditions were modeled based on current FIA-based vegetation, FVS growth models, and a set array of

disturbance events (see vegetation modeling domain). There were three scenarios and eight time steps (pre and post treatment for each of four decades), with one shared starting condition, for a total of 25 landscape condition snap-shots. Vegetation conditions for each landscape were provided by the vegetation modeling group.

Biodiversity Measures

Habitat Guilds

Species associations with primary habitat features that are likely to change as a result of biomass harvesting were identified to create five habitat element guilds (HEG): old forests, early seral conditions, snags, logs, and oaks (Appendix A). Membership of each of the five HEGs developed for this analysis was determined based on multiple sources. The old growth associates were derived from Graber (1996) old growth conifer dependent species for the Sierra Nevada, and included old growth dependent and associated species. Early seral species were those which early seral stages (open, seedling, or sapling stages) were considered high quality habitat for reproduction, feeding, and cover in the CWHR database. Oak guild membership reflects a combination of species dependent upon oak foothill habitats (Graber 1996), a five additional species for which the CWHR database identified acorns as secondarily essential or essential. Snag and log associates were identified using the CWHR database; species for which snags or logs (large and medium diameter) were considered an essential or secondarily essential were selected.

Each of the terrestrial habitat element guilds consisted of representatives of multiple vertebrate classes. We identified a total of 63 old growth associates, including 2 amphibians, 3 reptiles, 36 birds, and 22 mammals (two of which are currently extirpated). Seventy-nine species were identified as early seral associates, including 9 reptiles, 37 birds, and 33 mammals. Forty-four species were associated with oaks or acorns, including 1 amphibian, 3 reptiles, 30 birds, and 10 mammals. Thirty-four species were associated with snags, including 24 birds and 10 mammals (one extirpated); and 16 species were associated with logs, including 1 amphibian, 3 reptiles, 2 birds, and 10 mammals (one extirpated). We did not analyze the effects of treatment scenarios on the snag or log guilds because of uncertainties regarding the reliability of forest modeling for these elements.

Service-providing Units

We identified seven service-providing units (sensu Luck 2003) to evaluate the effects of forest management on ecosystem services provided by vertebrate species: insect regulators, seed dispersers, decomposition aides, and herbivore regulators. Insectivorous animals serve to keep populations of herbivorous insects in check, limiting

a variety of undesirable damages associated with outbreaks of these insects, such as stress to native plant species including trees (e.g., bark beetles). With an emphasis on aerial insects, we identified 93 members of the insectivorous service-providing unit, including birds and bats. Seed dispersal is a key service in any ecosystem that is provided by vertebrates, as well as invertebrates (e.g., ants). Many species eat and transport seeds; we targeted two groups of species (22 species total): conifer seed dispersers (small mammals), and fruit-bearing plant seed dispersers (frugivorous birds and mammalian omnivores). Snags and logs contribute significantly to soil nutrient availability and nutrient cycling in forested ecosystems. Although other biota, such as bacteria, fungi, and ants, serve the primary role in decomposition, the 13 species of woodpeckers and secondary cavity nesters in the study area contribute to decomposition in an ecologically significant manner by exposing trees to disease through sapsucker feeding holes, and speeding the breakdown of snags and logs through the creation of cavities for feeding and nesting. Carnivores serve a regulatory function in ecosystems, keeping populations of lower trophic level species (primarily herbivorous mammals) in check. We identified two tiers of herbivore regulators: primary (top carnivores; n = 21) and secondary (n = 9).

Species of Special Interest

We considered species with special status, exotic species, and aquatic species to be of special interest. There were 5 exotic vertebrate species in the study area: 3 birds, 1 amphibian, and 1 mammal. We analyzed the richness of exotic species as a group. We identified Forest Service Sensitive species and Management Indicator Species for the Plumas and Lassen National Forests as species of special interest (Appendix A), which included 23 extant species: 8 aquatic species (4 amphibians, 3 birds, 1 reptile), and 16 terrestrial associates (6 birds, 9 mammals). The wolverine was also identified as a FSS/MIS species, but it is considered extirpated in the Sierra Nevada and Southern Cascades.

We evaluated the individual responses of one FSS/MIS species, the American marten, as a demonstration of the type of analysis that can be conducted in any landscape where systematic surveys have been conducted. For the American marten, we developed a predictive model for probability of occurrence based on GIS-based environmental data associated with survey data (detection, non-detection) collected in the study area and adjacent landscapes. In 1999 to 2002, USDA Forest Service, Pacific Southwest Research Station (PSW) conducted a survey for mammalian carnivores in the Greater Southern Cascades Region (GSCR) of northeastern California using baited trackplate and camera stations (Barrett 1983, Kirk 2007). The GSCR landscape overlaps the B2E landscape, extending far to the north but not as far east as the B2E project area (Figure 5). Nonetheless, the GSCR landscape is comprised of vegetation and other environmental conditions typical of the B2E landscape, so it was determined that predictive models developed for the GSCR landscape could be reliably applied to the B2E project area.

We identified 79 non-fish aquatic species that were primarily dependent on aquatic habitats, including 15 amphibians, 58 birds, 4 mammals, and 2 reptiles (Appendix A). In addition, 38 species of fish were identified as confirmed or likely to occur in the B2E landscape (Appendix B). Aquatic species were only included in the aquatic guild, and

were excluded from other habitat element guilds because of their unique considerations relative to changes in upland conditions. Aquatic species were not analyzed in this analysis.

Response Modeling

The landscapes were represented by 1 ha grid cells, and each grid cell was attributed with values for 17 vegetation variables (Table 2). We converted average diameter and canopy cover estimates into CWHR size and density classes (Mayer and Laudenslayer 1988). Non-forested habitat types were not modeled by the vegetation modeling group, meaning that size and density information for these types was not provided for the existing landscape, nor did they change over time. We made the following assumptions in evaluating non-forested habitat types. We gave all herbaceous types a size of 1 (short herb; less than 12" high) and a density of M (moderate cover; 40-59% cover). Our rationale was that most herbaceous areas are probably lightly grazed, causing the herb height to be less than 12" and cover about 50%. We gave all shrub and chaparral types a size of 4 (decadent shrub; > 25% crown decadence) and a density class of M (moderate COVER; 40-59% cover). Our rationale was that most shrub dominated areas are decadent, although there are most likely exceptions to this rule. These are the primary assumptions made in the translation of vegetation modeling data into interpretations of habitat condition for wildlife. A number of secondary assumptions also needed to be made; they are documented in Appendix B.

Habitat Guilds and Exotic Species

We evaluated the existing and modeled future landscape conditions to determine how the amount and location of suitable habitat changes for each species within each guild, and then we evaluated how richness (number of species with suitable habitat in each sample unit) changes over time among scenarios. We used the suitability ratings for feeding, cover, and reproduction to represent habitat suitability: if 2 types were rated as moderate or high, then the cell was assigned a 1, otherwise the cell was assigned a 0. We considered this to be a fairly inclusive interpretation of suitability; cells that were rated moderate or high for all 3 uses also could be considered in future analyses to represent high quality habitat. For snag and log associates, we were going to apply a minimum of 12 snags > 12 in dbh and 50 logs > 12 in average diameter (and > 3 m long) per ha grid cell, respectively. The snag density threshold was based on relationships observed in the Lake Tahoe basin between bird species richness and snag density (Manley et al. 2007), and the log density threshold was based on the low end of the range of log density values observed in the field in the Lake Tahoe basin (Manley and McIntyre 2007). These thresholds, however, were not applied because the reliability of the snag and log data was in question.

The count of values >0 indicate richness, the sum of values represent a mix of species richness and potential species abundance. Changes in the proportion of the landscape able to support various levels of species richness for HEGs represents the ability of the landscape to support native biological diversity and identify the limiting factors (i.e., declining elements), and therefore represents a significant segment of native vertebrate biological diversity. The output of this analysis is a map of richness for pre and post treatment for each time step (n = 9) maps for each measure) in each scenario (n = 3 scenarios). The summary of each measure was depicted as a histogram that tallies the proportion of the landscape in each richness class

Service-providing Units

The functional diversity of each SPU is a function of species richness and abundance. We did not have a measure of abundance, so we based this evaluation on richness alone. For the woodpecker SPU, the minimum snag and log densities established for snag and log dependent species also needed to be met for cells to receive a value of >0. The count of values >0 indicate richness. We evaluate patterns of ratings among species and their summed values to provide insights into how each scenario might affect the resilience, and therefore ecosystem services, by affecting the functional diversity of the SPU. Summaries of richness were created in the same manner for SPUs as for HEGs.

American Marten

Model Development

The development of the predictive model for marten within the GSCR landscape and its application within the B2E landscape were conducted by Thomas A. Kirk, Pacific Southwest Research Station. The model developed predicted the probability of occurrence of marten based on habitat characteristics at the home range scale (1 km radius circle). Habitat suitable for reproduction was determined based on a modified version of the California Wildlife-Habitat Relationships (CWHR) system. The CWHR marten model was modified to account for differences in marten use of some forest types in this portion of the state, as evidenced by survey results (Kirk 2007). The survey data, suitable habitat definitions, and environmental characteristics of each survey site (n = 184) were used to develop a predictive model of marten occurrence for the GSCR landscape (Figure 5). Multiple approaches were tested in the course of developing the final models presented here, including models of habitat at larger scales and the inclusion of other variables.

A two-stage modeling approach was used to first identify areas with a probability of occurrence > 0, and then to estimate the probability of occurrence where it can occur. The first stage of the modeling process involved determining an elevational cut-off for the inclusion of data points used in the development of the 1 km-scale model. Elevations of survey locations ranged from 1280 – 7580 ft. The marten's preference for higher elevation coniferous forests in the mountains of northeastern California is well documented in natural history accounts (Grinnell et al. 1937) and more recent studies (Simon 1980, Spencer et al. 1983, Ellis 1998, Zielinski et al. 2005). Logistic regression models accounting for imperfect detection probability included elevation as the sole predictor variable, with sample sites classified into 500 ft. elevation increments. We then used only those sites above the elevation threshold in the second stage of modeling to predict the probability of occurrence based on habitat characteristics.

For the second analysis stage, we included an array of vegetation and environmental variables in a multivariate logistic regression accounting for imperfect detection probability (Table 3). Habitat suitable for reproduction was limited to conifer and riparian types, and the inclusion of size classes to 4 (11-24 in dbh) and 5 (> 24 in dbh) and canopy cover classes M (40-60%) and D (>60%). Red fir, White fir, and Lodgepole pine habitats were the only exceptions, where size class 6 was also included as suitable reproductive habitat based on CWHR. Vegetation characteristics were represented as the percent of the area within a 1 km radius circle. Four non-vegetative variables were included in the second stage regression model: elevation, precipitation, road density, and stream density. These variables were represented as densities or averages within a 1 km radius circle.

Model Application to B2E Study Area

Landscape predictions in the B2E landscape were based on habitat data provided by B2E modelers, with all other variables generated using the same approaches used to generate variables on the GSCR sample study area. The forests of size class 5 variable, (SZ_5), was created with SQL statements using B2E modeled vegetation data. Moving window grids were computed for ROAD, STREAM, and SZ_5 variables using FRAGSTATS for the B2E project area. All lakes were reclassified as NoData, effectively removing them from consideration as habitat.

RESULTS

Forest Structure

Changes in forest structure are measured by the two variables, canopy closure and average tree diameter, individually and in combination with each other. Prior to treatment, the landscape was predominantly in a high canopy closure condition, with approximately 45% of the landscape with > 60% (D) canopy closure, and another approximately 25% of the landscape with 40 – 60% (M) canopy closure (Figure 6). Scenario 1 resulted in an increase in the proportion of the landscape with D canopy closure to nearly 70% and a concomitant decrease to approximately 5%. In contrast, Scenario 3, existing conditions remained largely unchanged over the duration of the 40 year treatment period. Scenario 2 had an intermediate effect, with the final landscape increasing to 55% D and decreasing to 15% M canopy cover. There was a significant difference in the three higher canopy cover classes, with 25-40 and 40-60% canopy closure classes declining in scenario 1 and an increase in > 60% class in scenario 1, with no change or variability in scenario 3 (Table 4).

Prior to treatment, approximately half of the landscape and two-thirds of forested habitats were occupied by small-diameter (mature) stands with an average diameter of 12 to 24 inches dbh (diameter class 4), with an additional 20% of the landscape (~ 35% of the remaining forested habitat) the occupied by medium to large diameter (old forest) stands (average diameter > 24 in dbh; diameter class 5 and 6; Figure 7). Smaller diameter stands (diameter class 3) occupied < 3% of the landscape, with the remaining landscape occupied by non-forested habitat conditions. This characterization of stand diameter is a function of how average diameters are calculated, specifically, it was based on the quadratic mean diameter of the largest 75% of all trees (QMD75). The use of QMD75 to determine diameter class is the reason so little of the landscape was classified as size class 3. It is also likely to reduce the magnitude of changes observed as a result of biomass removal, which primarily consists of removing smaller diameter understory trees. For example if primarily the smaller diameter trees are removed, then 75% of the remaining trees will consist of fewer trees with a resulting larger average diameter.

In scenario 1, the proportion of the landscape in mature and old forest conditions switched in dominance, such that at the end of the treatment period, 60% of the forested habitat was occupied by old forest stands (5/6 diameter), and 30% occupied by mature stands (Figure 7). Virtually no change occurred in diameter class 3. In scenario 3, the proportion of the landscape in pole and mature stands equalized to where they both occupied approximately 35% of the landscape. No change occurred in the amount of size class 3 forests. Scenario 2 effected a similar level of equalization between size class 4 and 5/6 as observed in scenario 3, with 40% in size class 5/6 and 30% in size class 4. Size class 5/6 was nearly significantly different among the scenarios, with scenario 1 being higher that the other two scenarios.

The combination of canopy closure and diameter defines the CWHR habitat type. Prior to treatment, nearly 50% of the landscape was occupied by pole stands with higher canopy closure (4MD), with the most of the remaining forests (20% of the landscape) were mature stands with higher canopy closure (56MD), typically considered a representation of old growth conditions (Figure 8). The predominant difference among the scenarios was driven by changes in average diameter, as depicted in the diameter class evaluation, where the proportion of the landscape in 4MD and 5/6MD switched

position in terms of their dominance (old forests increased from ¼ to ½ of the landscape), whereas in scenario 3 they equalized by the end of the treatment period. In addition, habitat type 4SP increased slightly to 5 to 10% in scenarios 2 and 3. Only old forest conditions different significantly among scenarios, with significantly higher values in scenario 1 (Table 4).

When we look at patterns of change within mature and old forest conditions (larger diameter and higher canopy closure conditions), we see that approximately half of size class 4 was M and half D, whereas almost all of size class 5/6 was D (Figure 9a). Thus, prior to treatment, old forest conditions were approximately 1/3 4M, 1/3 4D, and 1/3 56D. In scenario 1, these three conditions diverged over the course of the treatment period, with the end result of old forests increasing from 25% to 50% of the landscape, 4D declining slightly, and 4M nearly declining to zero. In scenario 3, there three conditions diverge only slightly, with a slight increase in 5M. Scenario 2 showed an intermediate outcome. We also observed that within old forests alone, prior to treatment none of the landscape was typed as size class 5, and only a limited amount of size class 5 occurred on the landscape in any scenario by the end of the treatment period (Figure 9b). This indicates that the assumption is that as size class 4 stands grow, they become multi-layered size class 6. In scenarios 2 and 3, it appears that as size class 6 is treated, it is assumed that on private lands the majority become size class 4 with a canopy closure > 40%, and on public land, some become size class 5 with canopy closure >40%.

Forest Structure Associates

Habitat guilds showed limited responses to changes in forest structure. Prior to treatment, the nearly 70% of the landscape was occupied by 21 to 40 old forest (OF) associated species, followed by approximately 30% of the landscape occupied by 1 to 20 OF species (Figure 10). With every scenario, the proportion of the landscape with 21 to 40 OF species declined by around 10%; however, they faired better in scenario 3 than scenario 1, where the proportion of the landscape with > 40 sp increased slightly. We found that, in CWHR, size class 6 was considered to have lower suitability for a number of old forest associates. Thus, as size class 6 was replaced by other conditions (4 and 5), the interpretation based on CWHR was that habitat conditions improved for some old forest associates. It is most likely that harvest treatments that change stands from size class 6 to primarily size class 4 M (private land) and 5 M (public land) reduce the suitability of habitat for old forest associates. Only the highest richness category varied significantly among scenarios, showing an increase with increased treatment (Table 4).

We evaluated patterns for old forest dependent species to see if they provided any additional information about the potential effects of harvest treatments on old forest associates. Prior to treatment, nearly 40% of the landscape was occupied by the highest richness class (> 10 sp), with the remaining landscape occupied equivalently (~ 20% each) by the other three richness classes (0, 1-5, 6-10; Figure 11). In scenario 1, an increasing proportion of the landscape was supported high numbers of old forest dependent species, following the trajectory of size class 6 habitat. In scenario 3, overall the proportion of the landscape occupied by each of the richenss classes did not change, but the treatments reduced richness of highest richness class (>10 sp) to the lower richness class (6-10 sp) just following treatment, then appearing to recover at the end of the 10 year growth period. Significant declines in richness with treatment was demonstrated by analysis of richness classes among scenarios (Table 4).

The richness of early seral associated species followed the same pattern as the conversion of size class 6 to 4M (Figures 9a and 12). Prior to treatment, there was a similar proportion (40 to 50%) of the landscape supporting 1 to 20 and 20 to 40 species. In scenario 1, approximately half of the sites supporting 20 to 40 species were reduced to supporting only 1 to 20 species; little change was observed in highest and lowest richness classes (Figure 9a). In scenario 3, the richness classes remained relatively constant, and scenario 2 was intermediate. Early seral species were significantly more speciose with each increment of treatment (i.e., scenario 2 and 3; Table 4).

The final habitat guild we evaluated was the oak and acorn associates. Prior to treatment, nearly 50% of the landscape supported 1 to 5 species, and nearly 30% of the landscape supported 5 to 10 sp

(Figure 13). In scenario 1, an increasing proportion of the landscape (~ 10%) supported fewer oak associates (1 to 5 sp) and a concomitant decreasing proportion supported the highest richness class (>10 sp). Scenario 2 had appeared to have limited effect on oak associates, whereas scenario 3 appeared to slightly improve conditions for oak associates. Increases in oak associates were significant with each increment of increasing treatment across the scenarios (Table 4). The indications of these results would be strengthened if the presence of oaks in conifer forests could have been considered; however, data on the density of oaks was not available at the time of this analysis.

The analysis of exotic species richness was not very informative (Figure 14). It simply showed that that proportion of the landscape with one or more exotic species started low (~10%) and did not change over time under any of the treatment scenarios.

Service-providing Units

Seed dispersers and bioturbers had similar patterns of response within and among scenarios as early seral associates – they declined over time in scenario 1, but remained at similar or higher levels over time in scenario 3 (Figure 15 and 16). The differences among the scenarios were significant (Table 4).

Prior to treatment, less than 10% of the landscape had one or more pollinators (Figure 17). We did not see directional changes in pollinators among the scenarios, but scenario 1 was significantly different than the other two scenarios for all three richness levels because of the temporal variability created by the treatments in scenarios 2 and 3. Similarly, decomposers showed no change within or among scenarios (Figure 18, Table 4).

Prior to treatment, almost 60% of the landscape supported 21 to 40 insect regulators, the second to the highest richness class for this guild, with an additional 20% of the landscape supporting 1 to 20 sp (Figure 19). In scenario 1, there was a 5-10% increase in the proportion of the landscape occupied by the two lowest richness classes (0 and 1 to 20 sp) and a concomitant decrease in the higher richness classes. Response in scenarios 2 was not substantially different than scenario 1, but in scenario 3, the shifts among the richness classes were largely compensatory, resulting in no overall change. There was a significant increase in the highest richness class and decline in the second highest richness class from scenario 1 to 3.

Over 70% of the landscape supported habitat suitable for one or more herbivore regulators (top carnivores), with 50% of the landscape providing habitat for 3 or more species (Figure 20a). In scenario 1, the proportion of the landscape supporting the highest richness declined significantly relative to scenario 2 and 3 (Table 4), and in scenario 3 they benefited slightly. We observed no patterned response in the richness of secondary herbivore regulators within or among scenarios (Figure 20b; Table 4).

We evaluated the potential magnitude of the effects of treatments that reduced canopy to 40% (m treatments) implemented on public lands. We evaluated old forest dependent species and early seral species. For old forest dependent species, we found that the proportion of the landscape in the higher richness classes only decreased by a few percentage points post treatment (Figure 21a). For early seral associated species, the proportion of the landscape in the higher richness classes increased by around 5 percentage points post treatment (Figure 21b).

American Marten Home Range Occupancy

The logistic regression of marten occurrence and elevation indicted that survey sites above 5000 ft. had a greater correct classification of marten detections than those below 5000 ft. Probability of occurrence was calculated for sites above and below 5000 ft using maximum likelihood methods in a SAS program (J. Baldwin, USDA Forest Service, unpublished data) which resembles the method advocated by MacKenzie et al. (2002). The probability of occurrence > 4500 ft = 0.24 > 5500 = -0.21- > 5000 = 0.3, > 6000 = -0.08 for marten at a sample unit under 5000 ft was 65.6 %, compared to 99.3 % for sample units above 5000 ft (P = 0.0015, t = 3.68, df = 20). Of the 184 sample sites in the GCSR study area, 100 were > 5000 ft in elevation; only two of the 20 marten detections in the original dataset were below 5000 ft,

leaving 18 sites with detections in the second stage of analysis. This essentially resulted in the removal of small amounts of what would have otherwise been classified as low-to-moderate suitability reproductive habitat primarily near Sierraville.

Based on the 100 sample sites > 5000 ft elevation, the second stage regression model had relatively high model selection uncertainty (Burnham and Anderson 1998); five models had an AIC_c difference of < 2 (Table 5). The first and fifth models were very similar in composition and overall model performance; both models contained elevation, stream density, and road density, with the only difference being tree size class (size class 4 or 5 and 6). These two models also had very similar kappa statistics (the proportion of predictions that were accurate based on the sample data): the model based on size class 4 (> 28 cm dbh; > 11 in dbh) had a kappa statistic of 0.43, and the model based on size class 5 (> 61 cm dbh; 24 in) was = 0.43. The model including size class 5 and 6 with canopy cover >40% (SZ_5) was chosen as the final model to represent marten *reproductive habitat* based on the importance of older forests in providing essential maternal dens and rest sites. Forest size class, elevation, and stream were all positively associated with marten occurrence; road was negatively associated.

The predicted values for the B2E project area show only a small amount (3%) of highly suitable habitat (Figure 22). The majority of the B2E project area (89.9%) was occupied by habitat with a low or no probability of occupancy (≤ 30%), with the majority of this habitat unsuitable for marten reproduction (probability of occupancy ≤ 10%). The predictive model indicated that the western portion of the B2E project area, south of Lake Almanor, contained relatively little reproductive habitat (Figure 23). This is consistent with the lack of marten detections by PSW surveys in this region and the small number of detections obtained by surveys conducted by the Lassen National Forest in recent years. Moreover, the existing suitable reproductive habitat is highly fragmented along the western boundary. The west side is the most likely region to be used by dispersing martens as a corridor between known population centers located to the north and south. Maintaining habitat connectivity in this 'gap' may require special planning and restoration. The Storrie Fire adversely affected forest connectivity in this region, where a natural break in higher elevation forests occurs due to the deeply incised canyon of the North Fork of the Feather River.

Management scenarios had no appreciable effect on the amount of habitat suitable for marten (Figure 24). The only variable in the model that can be affected by forest management was the combined amount of 5M, 5D, and 6 habitat. The amount of these habitat types increased much more in scenario 1 than scenario 3; however, those increases were likely to be at the lower elevations, below the modeled elevational limit (< 5000 ft) of marten habitat.

DISCUSSION

Forest Structure Associates

It is likely that the CWHR-based responses in the richness of habitat guilds are under estimated for a number of reasons. Management typically simplifies forest structure and composition by removing various elements and disturbing the understory in the process. We were unable to account for many of the changes expected to occur as a result of harvest treatments, such as reductions in canopy density, reduction in vertical complexity of vegetation, reductions in snags and logs, reductions in special habitat elements such as large oaks and granary trees, and potential reductions in ground cover of vegetation, increases in bare mineral soil, and introductions of exotic plant species. All of these effects, combined with the disturbance of the actual harvest activities, are likely to negatively affect the suitability of sites for species associated with later seral conditions. The resulting vegetation conditions are not necessarily more suitable for early seral associates because of the disturbance to the understory and retention of an overstory of larger diameter trees. For example, the vertical layering of canopy is altered by the thinning

prescriptions modeled in this study, but we were unable to consider this important change in our analysis because we could not generate a variable to represent canopy layering, and if we had, we would only be able to use it to evaluate habitat for individual species for which we had appropriate survey data within the study area. CWHR habitat suitability ratings are based essentially on unmanaged vegetation conditions, thus they reflect the diversity and complexity that exists in unmanaged conditions. The simplification that results from management cannot be accounted for using CWHR alone.

Based on the vegetation variables available for this analysis, the primary changes in forest conditions resulting from biomass harvest treatments were limited largely to shifts between moderate and high canopy closure and shifts between medium and large average tree diameter. Implementation of harvest treatments designed to reduce biomass maintained canopy closure conditions close to the initial conditions in terms of the proportion of the landscape occupied by each canopy closure class (S, P, M, and D). The let-grow landscape (scenario 1) showed an increase in the proportion of the landscape in high canopy cover and a decline in moderate canopy cover. Scenario 3 showed no directional change in canopy cover. Harvest activities did change the character of conditions in one important manner – the proportion of the landscape in high the canopy closure class oscillated within each decadal period, frequently changing by 5 to nearly 10%. The oscillation of high canopy cover was matched by an opposing oscillation in low (SP) canopy closure, which suggests that in these stands canopy closure is reduced to below 40% and then recovers to over 60% in the course of 10 years. This oscillation would be amplified in terms of habitat suitability if we reduced suitability of M stands that were just harvested. Recovery of these stands to full suitability within 10 years was a simple assumption that we did not test and may be an under estimate.

In terms of average diameter, the let-grow alternative showed that 30 percentage points of size class 4 being converted to size class 6 over the course of the 40 year assessment period. Stands with average diameters of >24 in were almost all considered to be multi-layered, and therefore size class 4 stands primarily grew into size class 6 stands as opposed to size class 5. Harvest activities slowed this conversion such that only 15 percentage points of size class 4 were converted to size class 6 in the 40 year period.

The combined look at canopy closure and diameter showed that changes in forest structure resulting from biomass harvest were primarily a function of approximately 15 percentage points of the existing size class 4, all with moderate canopy cover, being converted to size class 6 (with some growth in the amount of size class 4 with low canopy cover), whereas in the let-grow scenario, 30 percentage points are converted to size class 6. This outcome seems suspect, given that biomass removal tends to homogenize the age structure of stands by removing the understory, making it less likely that stands will be multilayered. It seems more likely that size class 4 would become size class 5. Second, there seems to be an assumption that existing high canopy cover size class 4 stands will grow into the next diameter class in 40 years and that they will all be multi-layered stands. It is difficult to ascertain to what degree the calculation of QMD75 is contributing to this rapid conversion of stands from size class 4 to size class 5/6 (i.e., removing the understory alone will increase the average diameter, perhaps to the degree that, combined with growth, they move into the higher diameter class in a few decades). Assuming that the vegetation modeling results are representative, the responses observed for seral associates seemed reasonable – specifically, that old forest associated species richness stayed fairly unaffected by treatments, old forest dependent species were negatively affected by increasing treatment, and early seral associates benefited because of the reduction in canopy closure from D to M in treated stands. Nearly 80% of the landscape is forested, and approximately 20% of the forests were harvested in scenario 3. If the harvest treatments did not reduce average diameter to under 12 inches dbh, then the majority of old forest associates would be likely to be able to find suitable habitat in the resulting stands. The list of old forest associates consists largely of secondary associates, of which most can tolerate a wide range of forest conditions. Old forest dependent species provided a more sensitive indication of old forest conditions, given that they closely tracked the status of size class 5 and 6 stands.

Early seral associates were responsive to changes in size class 4 stands with moderate canopy cover, even though they reached their highest richness in the more open canopy conditions. Over 100

species were considered early seral associates, so it is plausible that converting 20% of the landscape to <40 % canopy cover would be a benefit to early seral associates, even though larger diameter trees are retained on the majority of the landscape. Further, many early seral associates are tolerant of environmental disturbance, so they are likely to be more competitive in recently harvested forests compared to old forest associates. It is likely that identifying the subset of these species that are truly dependent on early seral conditions would provide a more sensitive measure of response, and we predict that early seral dependent species would not show an appreciable positive response to harvest treatments. The ecological implications of shifts in community composition across a large proportion of the landscape form primarily mature and old forest associates to highly interspersed mix of thinned and unthinned forest are difficult to speculate. It is likely, however, that alterations in interspecific interactions resulting from a greater prevalence of early seral associates would have additional negative effects on old forest dependents and associates beyond changes in vegetation. For example, among the beneficiaries of more open canopies is the brown-headed cowbird, a species that parasitizes the nests of many native bird species, thereby reducing their productivity.

Our evaluation of oak and acorn associates showed that the highest richness classes faired better with increased harvest treatments. We were not able to consider changes in the density of large diameter oaks in this evaluation, and harvest is likely to reduce large oaks and oak snags, and in 40 years there is likely to be no or limited recruitment of large oaks. Therefore, the CWHR-based evaluation is probably represents an overly optimistic picture of the response of oak associates. It is possible to extract information on the density of mature oaks and the fate of existing large oaks from tree lists used in modeling. This information could be used in conjunction with CWHR to better inform evaluations of species dependent and associated with this important habitat element.

Few exotic vertebrates currently occur in this landscape. An evaluation of the group consisting of only 4 species was not terribly informative, other than to illustrate that in this landscape exotic vertebrates are only present in a small proportion of the landscape, and biomass harvest activities are not expected to increase the prevalence of exotic vertebrates. Exotic plant species are far more speciose is this landscape, potentially numbering over 40 species (based on exotic plant species encountered in the nearby Lake Tahoe basin). Exotic plants can have substantial ecological impacts on forested ecosystems. We did not have data on the composition of exotic plant species in the study area, and the vegetation modeling could not address their potential response to harvest treatments. We mention this here simply to acknowledge that we were not able to address this important ecological consequence.

Seed dispersers, bioturbers, and early seral species all tracked and had a positive response to the conversion of size class 6 to size class 4M. Species in these three groups are associated with ground and understory conditions. Understory plant cover (and their associated root masses) were not modeled in the vegetation growth models. It is likely that, although canopy closure is reduced as a result of biomass treatments, the understory will be disturbed in the course of treatment activities and cover of shrubs and herbs will be reduced. Bare ground is likely to increase in cover, which can enhance habitat conditions for some seed dispersers (e.g., chipmunk species), but only if seeds are still abundant at a site. Similarly, bioturbers may or may not benefit from harvest activities, depending on how they affect litter and soil properties and vegetative ground cover. Thus, the potential positive benefits associated with more open canopies may not result in benefits to these species groups.

Pollinators and decomposers showed essentially no response to treatments. As with exotic vertebrate species, an evaluation of the pollinator group consisting of only 3 species is limited. Vertebrates do not widely represent the suite of species that perform pollinator functions, since the majority of pollination is performed by invertebrates and wind. Thus, the response of this group was not terribly informative, either in terms of the effects on pollinators or the services that pollinators perform. The decomposer group was predominantly composed of cavity excavators and nesters. Again, vertebrates are probably not the strongest representatives of this ecosystem function, but they do represent players in the process of decomposition. If a plausible evaluation of snag and log dependent species could be conducted, it would eclipse the utility of this ecosystem services group unless one could first quantify the degree to which vertebrate cavity associates contribute to decomposition.

Insect regulators overall were slightly more speciose as a result of biomass harvest compared to the let-grow treatment. Vertebrates provide a strong representation of the species performing the service of regulating insects, particularly insect outbreaks. We have no information on the abundance of insects and its effect on their predators – only the habitat requirements of the species that prey on insects and thus perform this function. Changes in the character of insect fauna are likely to occur in managed forests with simplified vertical structure (i.e., shift from carnivorous to herbivorous insects) may affect the ability of insect regulators to perform this function.

Herbivore regulators were treated in two groups – primary and secondary – representing top and mid-level carnivores, respectively. Primary herbivore regulators generally followed the pattern of change in M canopy cover. This result is unlikely to be accurate for a number of reasons. First, upper trophic level species tend to have large home range requirements and are sensitive to habitat fragmentation and human disturbance – we were unable to account for the effects of habitat fragmentation or disturbance in our evaluation. Second, we suspect that the linkage between the richness of this SPU and moderate canopy cover may be a function of the landscape being initially classified as primarily size class 6, which lacks suitability ratings for many species. Secondary herbivore regulators showed no response among the management scenarios, which may be function of the diversity of habitat needs of species in this group, which would result in some species benefiting and others experiencing negative effects from changes resulting from harvest treatments. Thus, it is likely that herbivore regulation may not be directly affected as a result of changes to carnivores, but if top level carnivores are reduced in diversity and/or abundance, it is likely that changes in the composition and abundance of lower trophic level species will result. In addition, changes to common prey species, such as small mammals and smaller-bodied birds, may change with increased harvest treatments, in turn affecting upper trophic level species. We did not evaluate this potential feedback loop in this analysis.

American Marten

Of PSW's detections inside Lassen Volcanic National Park, two were in the highest suitability range, and the third was in the second highest category. The southernmost detection in the B2E project area was also in this moderate-to-high category. The remaining marten was found in the lowest suitability class; however, it was just beyond the larger region of moderate-to-high suitability in the nearby Caribou Wilderness. Additionally, several areas with marten detections on the far west side of the B2E project area, located on the Lassen National Forest, were in areas predicted to have moderate-to-high suitability. This represents a substantial improvement over the previous modeling efforts.

The current distribution of habitat within the B2E project area is highly fragmented with the largest amount of contiguous moderate-to-high suitability habitat in the vicinity of Lassen Volcanic National Park. This is consistent with the region having the greatest density of marten detections. However, several small and isolated patches of moderate-to-high suitability located along the western boundary are of particular significance; these are located in the Humboldt Peak area and in Bucks Lake Wilderness. Both of these locations represent important areas of reproductive habitat near known population centers. The large patch in the vicinity of Gold Lake, middle south on map, is another area of high value, as it represents the northernmost extent of the population center at the southern edge of the project area. These areas are of greater conservation value than other moderate-to-high suitability regions located on the far eastern side of the project area.

Several relatively large areas are identified as highly suitable habitat on the east side of the Plumas National Forest. However, this may be misleading as no historical or contemporary marten detections are known from this region. It is worth noting that a good portion of what has been classified as moderate-to-highly suitable habitat is located in this area. It may be best to take a conservative view of the suitable habitat patches in the eastern portion of the B2E project area and consider them only as 'potential' marten habitat until martens are detected there.

CONSIDERATIONS FOR FUTURE EFFORTS

In the course of conducting this analysis, we identified a number of steps that could improve the reliability of the modeling predictions. They are intended to serve as points of consideration in the interpretation of the results in this report and future endeavors in this landscape analysis or similar efforts in other landscapes.

Forest Growth Models

A combination of the simplified process used to assign tree lists to cells, the use of QMD75 as the basis for CWHR diameter classes, and the apparent assumption that most treated stands will be multilayered once they exceed average diameters of >24 in resulted in a questionable representation of the landscape with virtually all stands with average diameter >12 in dbh and all stands with average diameters of >24 in being typed as size class 6. Also, snag and log values were questionable. Each of these contributors are discussed below.

Issue: Average tree diameter based on QMD75 does not represent changes in tree density or tree diameter distribution, and remains high or increases in value with the removal of smaller diameter understory trees, and even the removal of larger trees concomitant with the removal of smaller diameter trees.

- Using QMD in lieu of or in addition to QMD75 would provide a more sensitive measure of change in forest structure. QMD was not used because it did not conform to the polygon labels derived from satellite imagery, so its use to create a map would result in changes to polygon labels.
- When evaluating individual species for which we have systematic survey data, a greater array of variables can be used to represent changes in forest structure (e.g., tree density by diameter class, basal area).

Issue: A single averaged tree list was assigned to each strata (e.g., 5M) within the study area, as opposed to the attribution of individual polygons or cells within polygons based on some more complex attribution process (e.g. random allocation of tree lists from individual FIA plots within the polygon) that maintained the diversity of conditions represented among the FIA plots. It is likely that the majority of the stands with >24 in dbh would not have been typed as size class 6 if a more sophisticated attribution process had been used.

- Attribute tree lists in a manner that results in a more realistic and representative suite of conditions across the landscape.
- The diversity of conditions is a critical element to wildlife habitat.

Issue: Canopy cover changes resulting from the m treatment may not have been represented accurately. Although the prescription is defined and represented in modeling as resulting in M canopy cover class, treatments in DFPZs commonly result in canopies below 40%.

- Create an additional treatment for public lands to account for treatments resulting in canopy cover <40%.

Issue: Salvage logging outside of treated areas was not represented in the snag and log densities that we were provided, and within many treated areas that had been salvaged logged snag densities were still high (hundreds per acre as opposed to the 5 per ac standard), so it seems likely that the snag and log values we had were higher than would be expected.

- Revamp snag retention expectations associated with treatments, particularly burned areas that are salvage logged.

Wildfire

Specific areas of improvement are discussed in the fire module. Here we only discuss one element that was lacking in the fire modeling that would improve the resulting vegetation data for evaluations of wildlife habitat.

Issue: Shrub and meadow habitats were not burned or grown. This is likely to result in an overestimate of suitable habitat for species associated with older seral stages in these types.

- A simple set of assumptions could be made to represent deterministic alterations in seral conditions of shrub and meadows.

CWHR Habitat Interpretations per Cell

We found that generally, CWHR produced credible interpretations of habitat conditions for groups of species representing various associations. We identify a few considerations for improving the plausibility of interpretations.

Issue: Silvicultural prescriptions (*m* treatment) on NFS lands are designed stands down to 40% canopy cover, the lower limit of the M canopy cover class. Most mature and old forest associates are assumed to find sites with > 40% canopy cover suitable, but marginally so.

- It is likely that these altered stands are not providing habitat for many mature and old forest associated species for some period following treatment because (1) stand conditions changed quickly (disturbance), and (2) canopy cover is at a minimum value. Thus, modeling is likely to over estimate the amount of suitable habitat for mature and old forest associates
- We recommend that treated sites where canopy cover has been reduced to 40% be treated as having the suitability associated with the 10-40% canopy cover (P) for the decade following treatment. The alteration could be greater or lesser than a decade, as informed by forest tree growth modeling and when we think the stand would recover to let's say 45% canopy cover.
- If we treated suitability as a continuous variable (varying from 0 to 1) as opposed to bivariate (0/1), suitability could be "fuzzed" on either side of the threshold. This would be a superior option that could be applied to any condition (canopy classes and diameter classes).

Issue: We considered habitat suitable if it was rated M or H for all three uses. By requiring all 3 uses to be suitable, this approach weights suitability toward species with smaller home ranges (i.e., they typically get all their needs met within one habitat condition) and species with larger home ranges that are either stenotypic (i.e., use a singular habitat type for all their life history needs) or are generalists (i.e., everything is suitable). It also has the potential to mask the highest quality habitat, since M habitats are lumped with H habitats.

- We conducted a sensitivity analysis on the indicator taxa (terrestrial and aquatic) to determine the relative degree of potential bias associated with 2 or 3 of the uses meeting a criterion, and the inclusion of M in assessments of suitability. We summed the number of habitat type conditions (type, canopy, density combos) meeting these various criteria.
- The difference between the threshold of 2 or 3 of the uses meeting the suitability criterion (H or M) did not have as much of an impact on the number of suitable types as the difference between H and M. If we restrict suitability to 2/3 or 3/3 of the uses must

be high, then over twice as many conditions are suitable compared to if moderate is included.

CRITERON	TOTAL
HIGH 2/3	12602
HIGH3/3	8804
HM 2/3	30385
HM 3/3	23096

COMPARISON	RATIO	
h2 comp h3	1.431395	40 % more types if only 2/3
hm2 comp hm3	1.315596	30% more types if only 2/3
hm3 comp h3	2.623353	160% more types if m included
hm2 comp h2	2.411125	140% more sites if m included
hm2 comp h3	3.451272	250% more types between most and least restrictive

- High quality habitat conditions could be analyzed separately, since their fate may have the greatest impact on the persistence of individual species. Suitability criteria would be changed to 2 of 3 types of uses being H to be considered suitable.

Issue: When using CWHR, we treated habitat as suitable or unsuitable, so we could determine species richness for various species groups. For individual species, we could create a more sensitive measure of change if we quantified L, M, and H.

- For example, if we gave L, M, H values (0.3, 0.6, 1.0, respectively), then a given habitat condition could be represented by a sum of the values for foraging, cover, and reproduction. Reproduction could be weighted, if desired, to count twice as much as the other two uses. This would result in a suitability value that ranges from 0 to 6 for each cell, or this value/6 so the index varied from 0 to 1.
- Individual species in each group were given equal weight in the evaluation of richness; however, species can be weighted based on their characteristics. For example, rarity is a commonly used attribute to weight species to reflect the relative magnitude of loss to biodiversity if they are extirpated from some or all of an area. Other characteristics that reflect contribution to biodiversity are endemism and keystone functions.

Issue: Aquatic-associated species were not analyzed in this evaluation; however, upland conditions affect habitat suitability and quality for aquatic species to varying degrees. For example, many amphibian species spend a significant portion of their life span in terrestrial environments. For those species largely or entirely restricted to aquatic environments, the condition of upland habitats can affect aquatic habitat conditions through sediment delivery, nutrient delivery, and shading.

- CWHR can be used to evaluate the status of upland habitat conditions for species that spend a significant stage or portion of their life in terrestrial environments.
- A combination of CWHR and spatial analysis can be used to evaluate the degree to which upland conditions can affect dispersal and in-water habitat conditions for fully aquatic species and aquatic life stages.

CWHR Habitat Interpretations across the Landscape

The spatial distribution of suitable habitat for individual species and species groups has important implications for sustaining populations and biological diversity. Connectivity measures are one option that we did not have the opportunity to evaluate, such as contagion of sites with various values (suitability or richness). The number of territories of larger home-range species (such as marten or goshawk) that a landscape can support is another measure that takes into consideration the spatial distribution of suitable habitat. The proximity of major and minor habitat core areas to one another (e.g., territory clusters/isolates or areas of high richness) can be used to weight the value of areas (closer and larger habitat is more valuable than farther and smaller habitat) pre and post treatment over time. There are some HSI models that weight CWHR habitat suitability by proximity criteria (e.g., distance to water, clustering) for individual species of common interest (e.g., pileated woodpecker, northern flying squirrel).

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TABLES

Table 1. Amount of each CWHR vegetation type occurring within the study area.

Vegetation Type		Area (ha) and % of the landscape covered			
		< 6" dbh	**6 – 24" dbh**	**>24" dbh**	**All size classes**
Forest:					
SMC	Sierran mixed conifer*	117 (< 1%)	292,799 (26%)	151,706 (14%)	444,622 (40%)
SCN	Subalpine conifer*		270 (<1%)	14 (< 1%)	284 (< 1%)
EPN	Eastside pine*	13,552 (1%)	146,048 (13%)		159,600 (14%)
JPN	Jeffrey pine*	2 (<1%)	5,730 (1%)	131 (<1%)	5,863 (1%)
LPP	Lodgepole pine		10,948 (1%)	177 (<1%)	11,125 (1%)
PPN	Ponderosa pine*	37 (<1%)	11,895 (1%)	11,010 (1%)	22,942 (2%)
DFR	Douglas fir*	743 (<1%)	13,381 (1%)	53,922 (5%)	68,046 (6%)
RFR	Red fir*	377 (< 1%)	31,268 (3%)	9,047 (1%)	40,692 (4%)
WFR	White fir*		44,028 (4%)	23,795 (2%)	67,823 (6%)
JUN	Juniper		4,941 (4%)		4,941 (4%)
BOP	Blue oak – digger pine		5,682 (1%)		5,682 (1%)
BOW	Blue oak woodland		1,919 (<1%)		1,919 (<1%)
COW	Coastal oak woodland		16 (<1%)		16 (<1%)
VOW	Valley oak woodland		2 (< 1%)		2 (< 1%)
ASP	Aspen		383 (<1%)		383 (<1%)
MHW	Montane hardwood		32,301 (3%)		32,301 (3%)
MRI	Montane riparian	1,900 (<1%)	1,226 (<1%)		3,126 (<1%)
Shrub:					
LSG	Low sagebrush	254 (<1%)			
SGB	sagebrush	71,143 (6%)			
BBR	Bitterbrush	1 (<1%)			
MCH	Mixed chaparral	43,534 (4%)			
Herbaceous:					
AGS	Annual grassland	25,217 (2%)			
PGS	Perennial grassland	38,005 (3%)			

WTM	Wet meadow	11,327 (1%)
Other		
LAC	Lacustrine	35,091 (3%)
BAR	Barren	9,954 (1%)
URB	Urban	2,362 (< 1%)

- Indicates vegetation types most likely to change as a result of fuel treatments.

Table 2. Vegetation variables generated for each 1 ha grid cell in the B2E landscape.

Variable	Description
CWHR_type	CWHR type
CWHR_size	CWHR size class
CWHR_density	CWHR density class
CC	canopy cover
CC_6up	canopy cover for trees ge 6" dbh
CC_11up	canopy cover for trees ge 11" dbh
CC_24up	canopy cover for trees ge 24" dbh
QMD	quadratic mean diameter
QMD_6up	quadratic mean diameter for trees ge 6" dbh
QMD_11up	quadratic mean diameter for trees ge 11" dbh
QMD_24up	quadratic mean diameter for trees ge 24" dbh
SNAGdens10to24	snag density for trees 10 to 24" dbh
SNAGdens24to36	snag density for trees 24 to 36" dbh
SNAGdens36up	snag density for trees ge 36" dbh
LOGdens10to24	log density 10 to 24" diameter
LOGdens24to36	log density 24 to 36" diameter
LOGdens36up	log density ge 36" diameter

Table 3. Predictor variables used in developing the 1 km-scale predictive model for probability of occupancy by marten application in the B2E landscape.

Variable Name	**Description**
RFR*	Percent Red fir forest in the landscape
WFR*	Percent White fir forest in the landscape
LPN*	Percent Lodgepole pine forest in the landscape
SCN*	Percent Sub alpine conifer forest in the landscape
MRI*	Percent Montane riparian forest in the landscape
SZ_4	Percent CWHR size class 4 forest in the landscape
SZ_5	Percent CWHR size class 5 forest in the landscape
CC_M	Percent CWHR moderate canopy forest in the landscape
CC_D	Percent CWHR dense canopy forest in the landscape
STREAM	Density (km/km^2) of streams
ROAD	Density (km/km^2)of roads
ELEV	Elevation (meters) at center of sample unit
PRECIP	Average precipitation occurring as rain (mm)

* CWHR forest types, size classes 4, 5, and 6, and canopy cover M and D.

Table 4. Analysis of variance comparing conditions throughout a 40 year period resulting from each of three management scenarios.

			Pair-wise comparisons (*P*)			
	Adj.R^2	*P*	12	23	13	Interpretation
Forest structure						
Average diameter						
5 to 12 in	0.048	0.669				All no change
12 to 24 in	0.044	0.224				Decline S1 (30%), less decline S3 (15%)
>24 in	0.123	**0.080**	0.259	1.000	0.103	Increase in S1 (30%), less increase S3 (15%)
Canopy cover						
10-25%	0.109	**0.096**	0.164	1.000	0.204	All slight increase, most in S3
25-40%	0.340	**0.003**	**0.010**	1.000	**0.005**	Slight decline S1, more variable in S2 & S3
40-60%	0.460	**<0.001**	**0.082**	**0.051**	**<0.001**	Decline S1, no change S3
> 60%	0.506	**0.001**	**0.011**	0.145	**<0.001**	Increase S1 (20%), no change S3
WHR habitat type						
4SP	0.223	**0.019**	**0.068**	1.000	**0.027**	Slight decline S1 (5%), variable S2 & S3
4MD	0.030	0.544				All decline, S1 most
5SP	0.068	0.847				All no change (< 5% of landscape)
5MD6	0.164	**0.045**	0.160	1.000	**0.058**	Increase S1, (30%), slight increase S3 (15%)
5M	0.464	**<0.001**	1.000	0.001	0.001	Slight increase S1, greater increase S3
5D6	0.314	**0.004**	0.090	0.540	0.003	Large increase S1, no change S3
Forest structure associates						
Old forest associates						
0 sp	0.018	0.473				All increase

			Pair-wise comparisons (*P*)			
	Adj.R^2	*P*	12	23	13	Interpretation
1 to 20	0.073	0.894				All no change
21 to 40	0.072	0.886				All decline
>40	0.498	**<0.001**	1.000	**0.001**	**<0.001**	Increase with more treatment
Old forest dependents						
0 sp	0.060	0.772				No change
1 to 5	0.285	**0.007**	**0.093**	0.767	**0.006**	Decline in S1, no change in S3
6 to 10	0.433	**<0.001**	**0.012**	0.541	**<0.001**	Decline in S1, no change in S3
>10	0.580	**<0.001**	**<0.001**	0.485	**<0.001**	Increase in S1, no change in S3
Early seral associates						
0 sp	0.012	0.440				All no change
1 to 20	0.638	**<0.001**	**0.001**	**0.045**	**<0.001**	Increase in S1, decline in S3
21 to 40	0.519	**<0.001**	**0.024**	**0.049**	**<0.001**	Decline in S1, no change in S3
>40	0.383	**0.001**	**0.005**	1.000	**0.003**	No directional change, more variable in S3
Oak associates						
0 sp	0.049	0.680				All slight increase
1 to 5	0.727	**<0.001**	**<0.001**	**0.008**	**<0.001**	Increase S1, decrease S3
6 to 10	0.694	**<0.001**	**0.004**	**0.001**	**<0.001**	Decline S1, no change S3
>10	0.411	**0.001**	**0.019**	0.525	**0.001**	Decline in S1, no change S3
Snag associates						
Log associates						

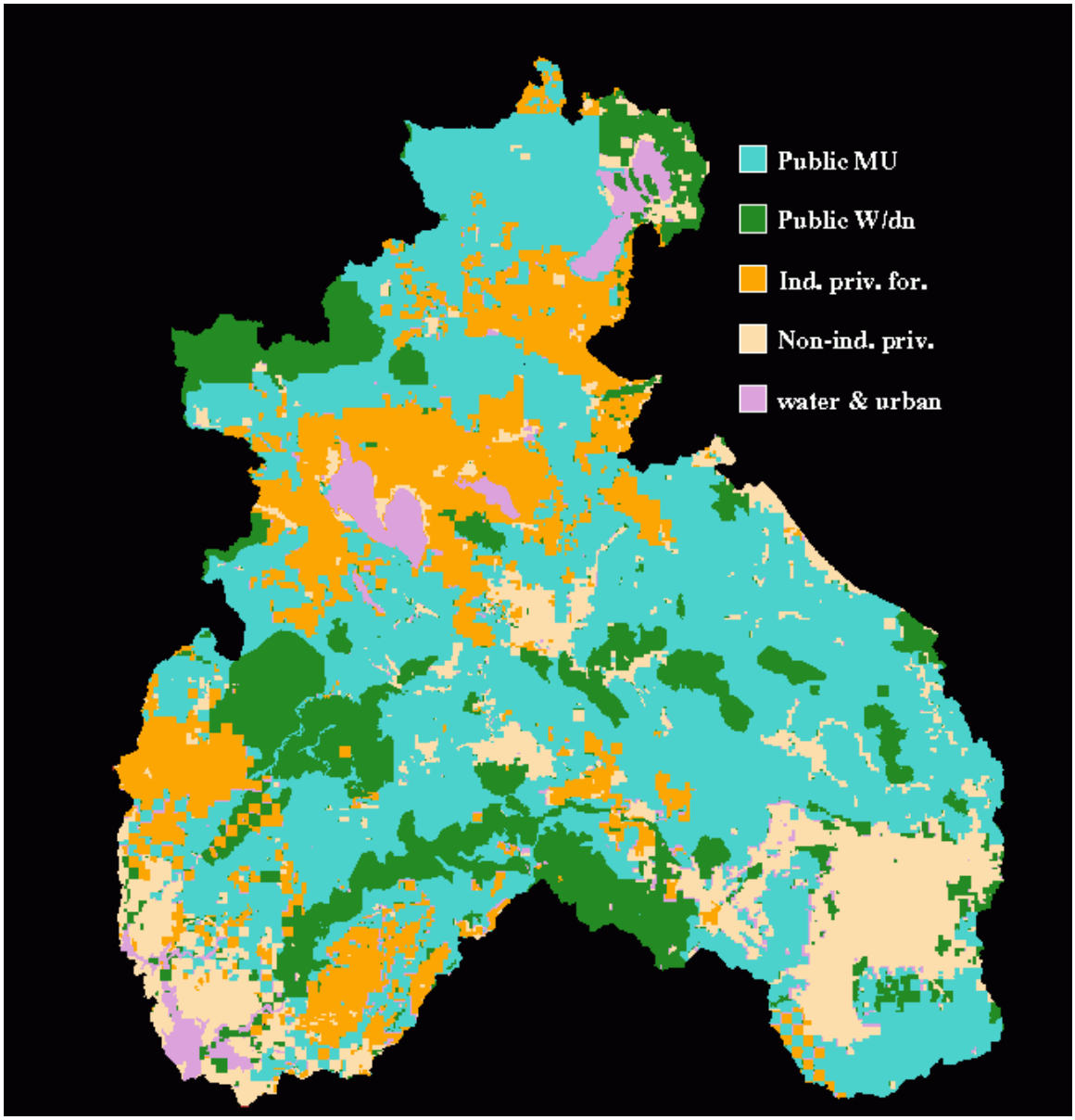
			Pair-wise comparisons (*P*)			
	Adj.R^2	*P*	12	23	13	Interpretation
Exotic species						
0 sp	0.156	**0.050**	**0.086**	1.000	0.116	No difference between scenarios???
>0	0.156	**0.050**	**0.086**	1.000	0.116	No difference between scenarios???
Ecosystem services						
Insect regulators						
0 sp	0.012	0.440				All slight increase
1 to 20 sp	0.026	0.277				All slight increase
21 to 40 sp	0.488	**<0.001**	**0.014**	0.160	**<0.001**	No change S1, decline in S3
>40 sp	0.601	**<0.001**	**0.007**	**0.018**	**<0.001**	Decline in S1, slight increase S3
Seed dispersers						
0 sp	0.011	0.437				All slight increase, more in S1
1 to 5 sp	0.569	**<0.001**	**0.004**	**0.076**	**<0.001**	Increase S1, decline S3
6 to 10 sp	0.273	**0.008**	0.112	0.757	**0.008**	Decline S1, no change S3
>10 sp	0.495	**<0.001**	**0.034**	**0.058**	**<0.001**	Increase in S3
Pollinators						
0 sp	0.395	**0.001**	**0.004**	1.000	**0.002**	Slight increase in S1
1 sp	0.432	**<0.001**	**0.002**	1.000	**0.001**	Decline in S1, slight increase S3
2 sp	0.310	**0.004**	**0.014**	1.000	**0.010**	Decline in S1, slight increase S3
Decomposers						
0 sp	0.061	0.783				All increase
1 to 5 sp	0.082	0.984				All no change
>5 sp	0.036	0.583				All slight decline

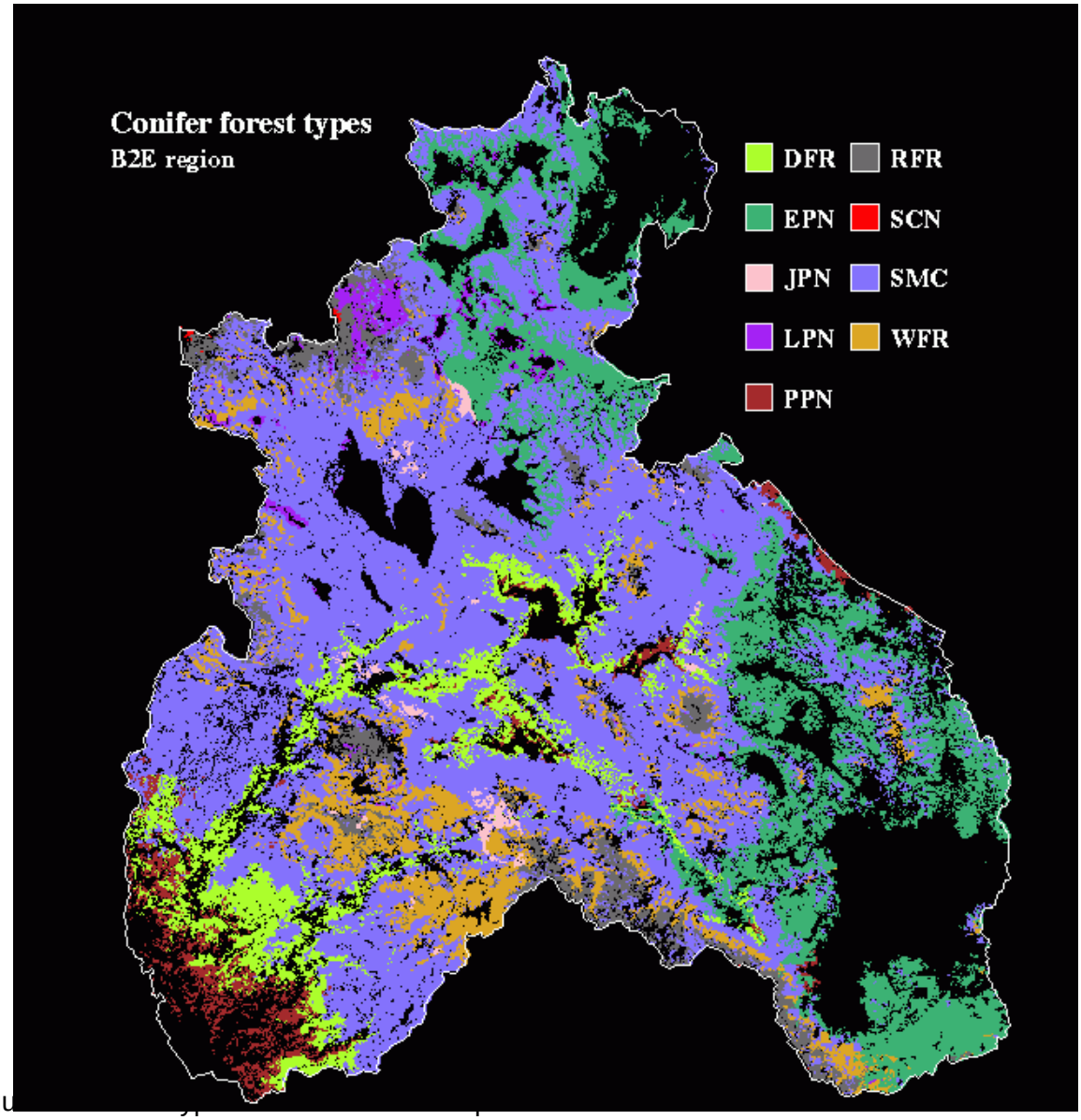
			Pair-wise comparisons (*P*)			
	Adj.R^2	*P*	12	23	13	Interpretation
Bioturbators						
0 sp	0.025	0.513				All slight decline
1 to 4 sp	0.584	**<0.001**	**0.004**	**0.051**	**<0.001**	Increase in S1, decline in S3
>4 sp	0.479	**<0.001**	**0.019**	0.151	**<0.001**	Decline in S1, no change in S3
Herbivore regulators primary						
0 sp	0.012	0.440				All increase
1 to 5 sp	0.038	0.595				All no change
6 to 10 sp	0.074	0.904				All decline
Herbivore regulators secondary						
0 sp	0.056	0.733				All increase
1 to 2 sp	0.407	**0.001**	**0.024**	0.447	**0.001**	Greater decline S1 to S3
3 to 4 sp	0.139	**0.064**	1.000	0.268	**0.074**	Increase in S1, no change S3
>4 sp	0.510	**<0.001**	**0.047**	**0.031**	**<0.001**	Decline S1, no change in S3

Table 5. Top five models of marten occurrence based on AICc values.

Model Number	**Variables**	**AIC_c**	**Δ AICc**
49	SZ_4 ROAD STREAM ELEV	72.685	0
47	SZ_4 STREAM ELEV	73.133	0.448
74	ELEV ROAD STREAM	73.665	0.979
65	CC_D ELEV	73.914	1.229
55	SZ_5 ROAD STREAM ELEV	74.462	1.776

FIGURES




Conifer forest types
B2E region
DFR
RFR
EPN
SCN
JPN
SMC
LPN
WFR
PPN

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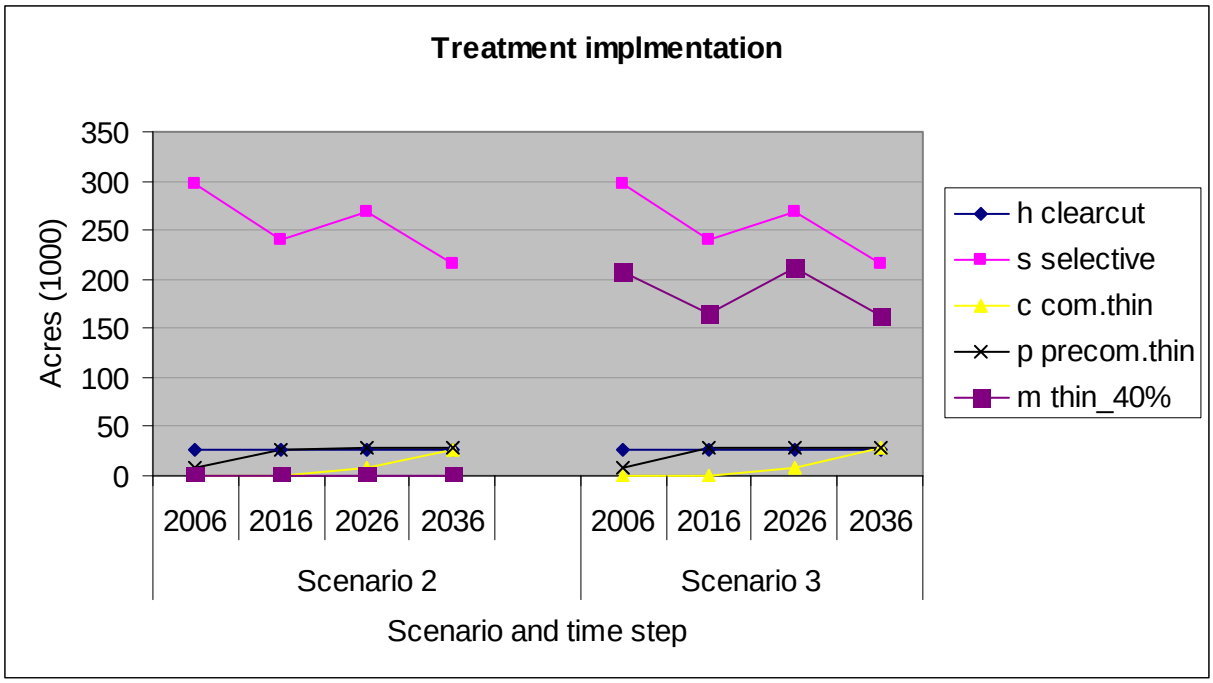


Figure 3. Acres of each silvicultural treatment applied to the B2E landscape in each decade for Scenario 2 (private land only) and Scenario 3 (public plus private lands).

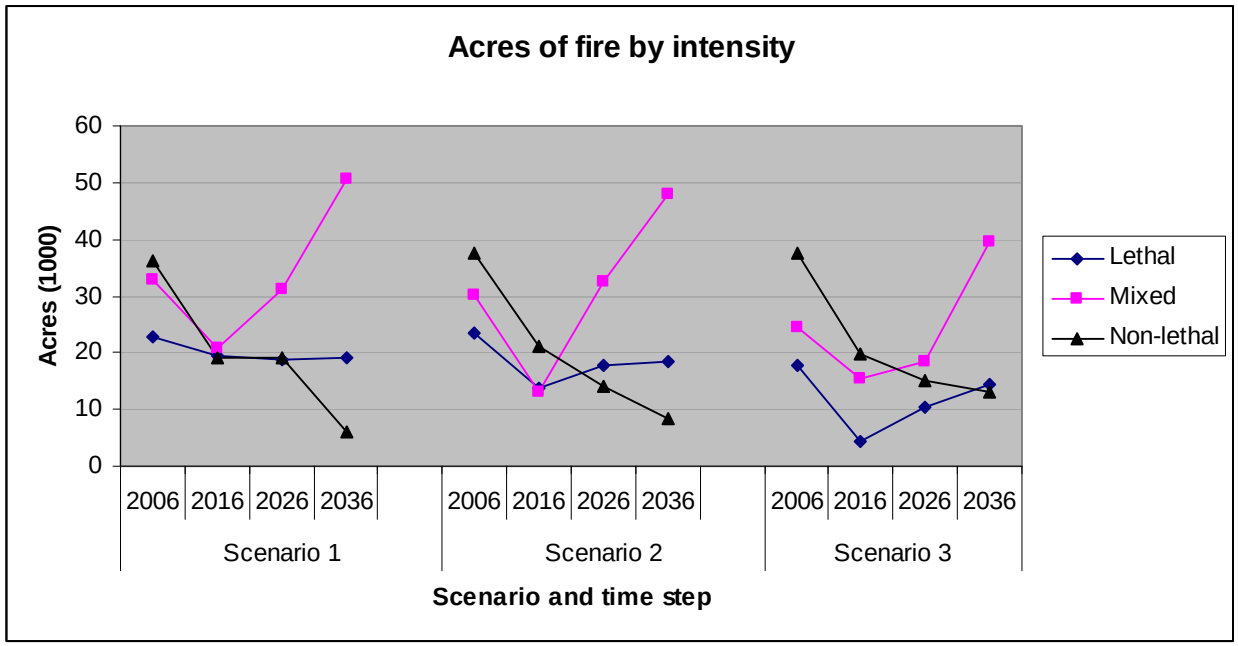


Figure 4. Acres of wildfire by three intensity classes for each management scenario and decadal time step.

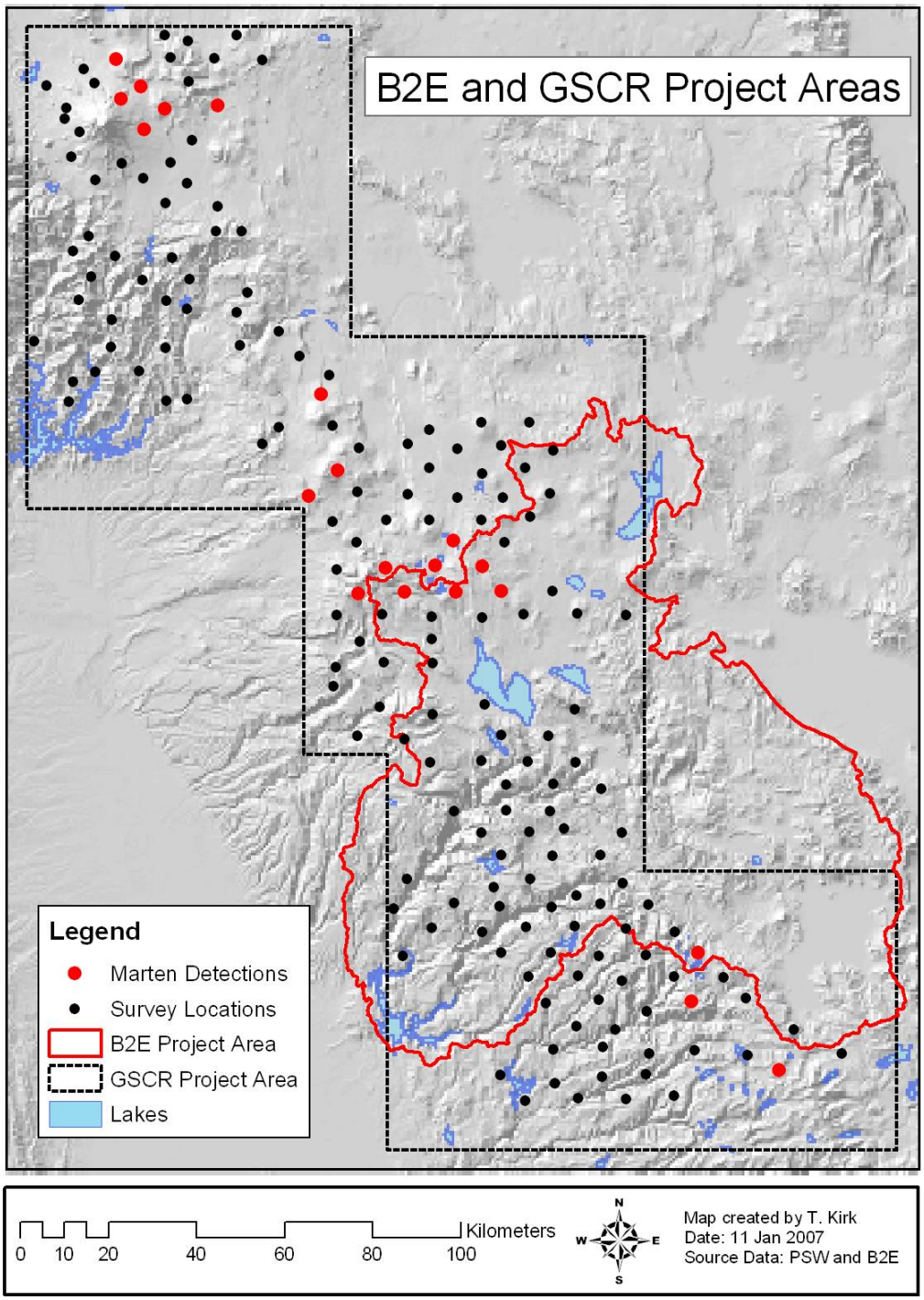


Figure 5. Location of the marten survey area (GSCR) and sample sites and the B2E beta test project area. Sample sites with detections are indicated.

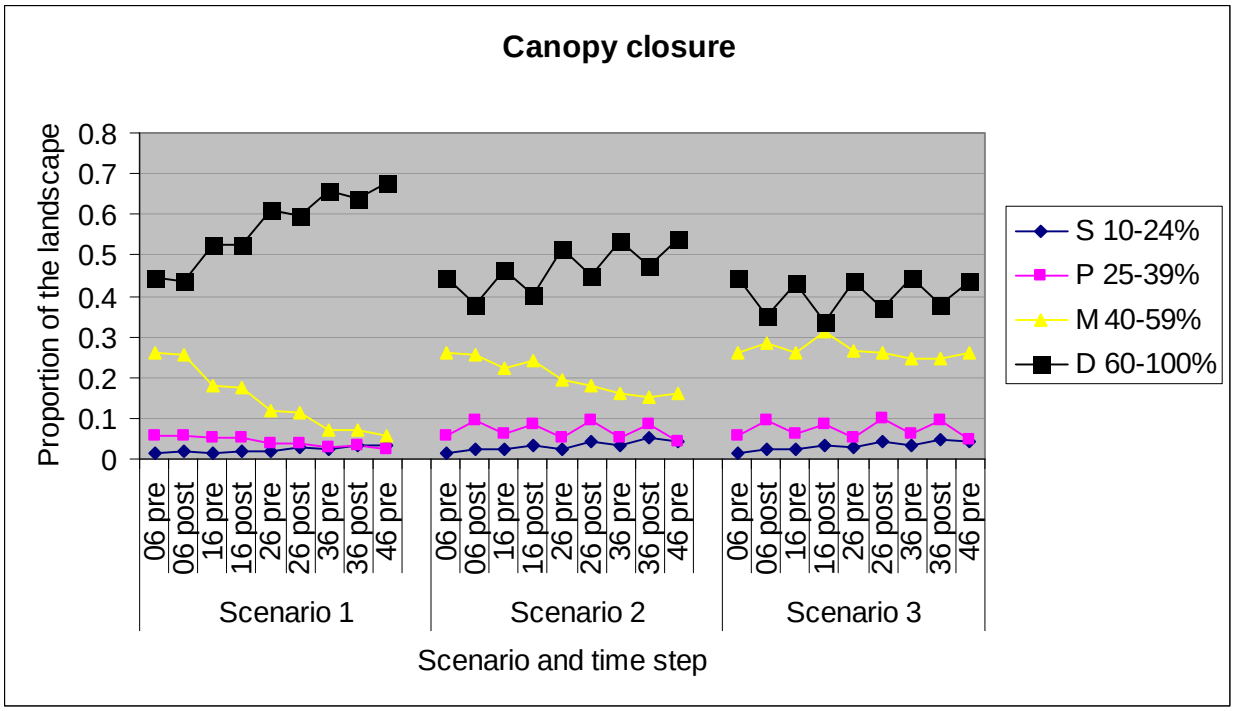


Figure 6. Proportion of the 3 million ac landscape occupied by each of four canopy cover classes over a 40-year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

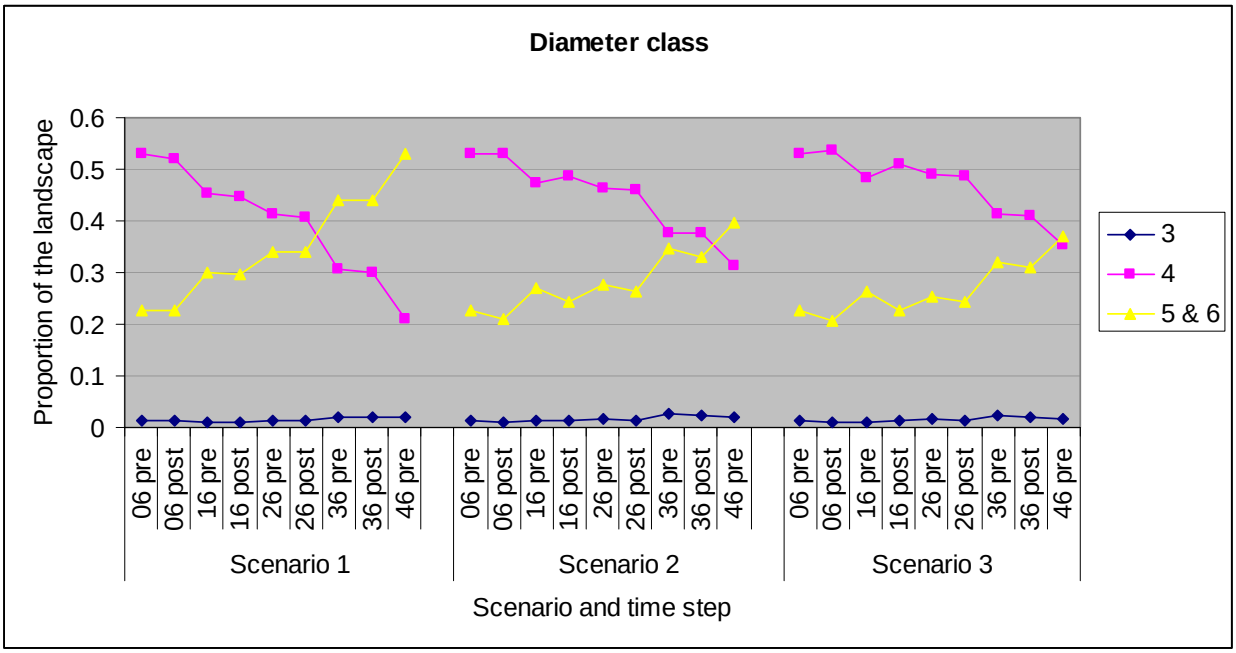


Figure 7. Proportion of the 3 million ac landscape occupied by each of three tree diameter classes over a 40 year period for each of three management scenarios (1 = no management,

wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

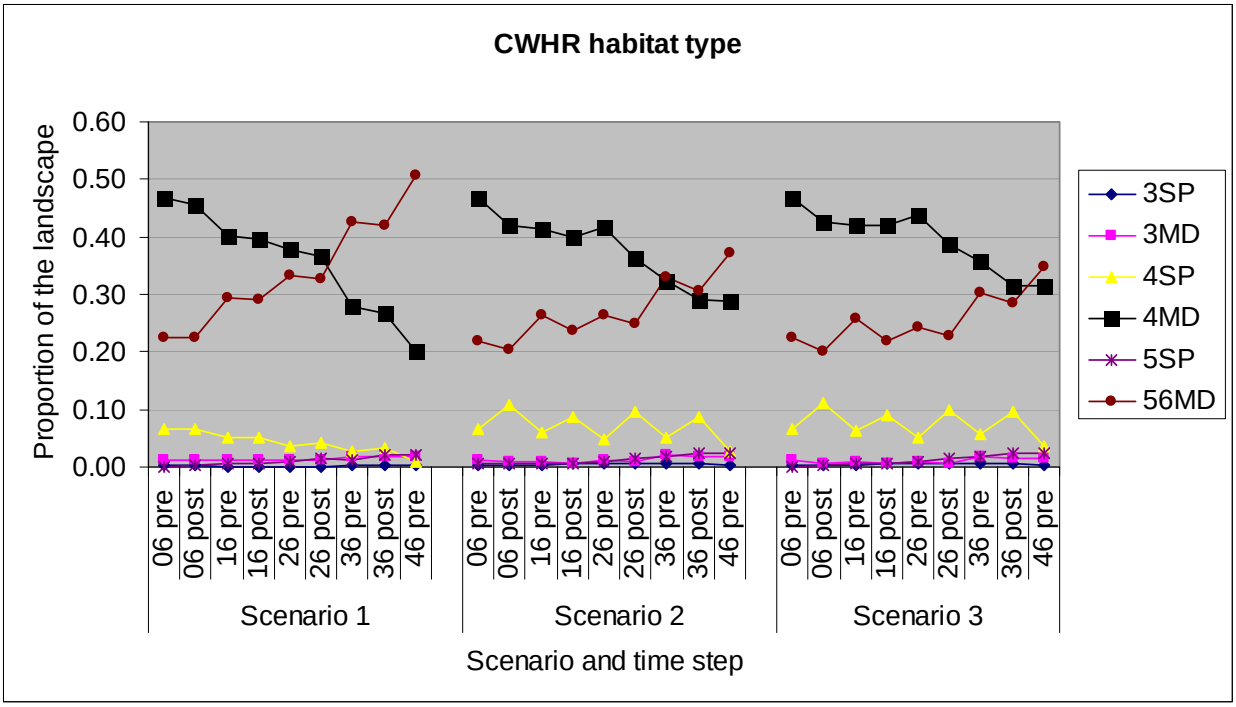
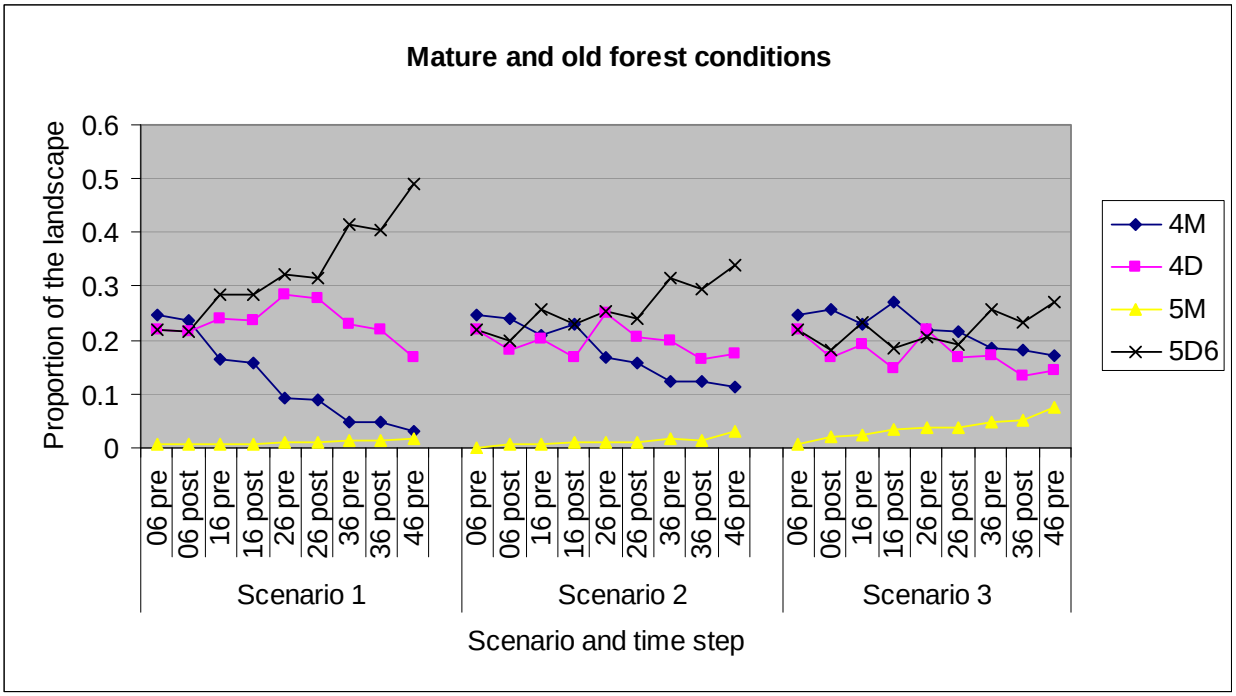


Figure 8. Proportion of the 3 million ac landscape occupied by each of six CWHR habitat types over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire). 4 = average diameter 12-24 in, 5 = average diameter >24 in, 6 = average diameter >24 in and multilayered canopy. SP = canopy cover 10-40%, MD = canopy cover >40%.

a)



b)

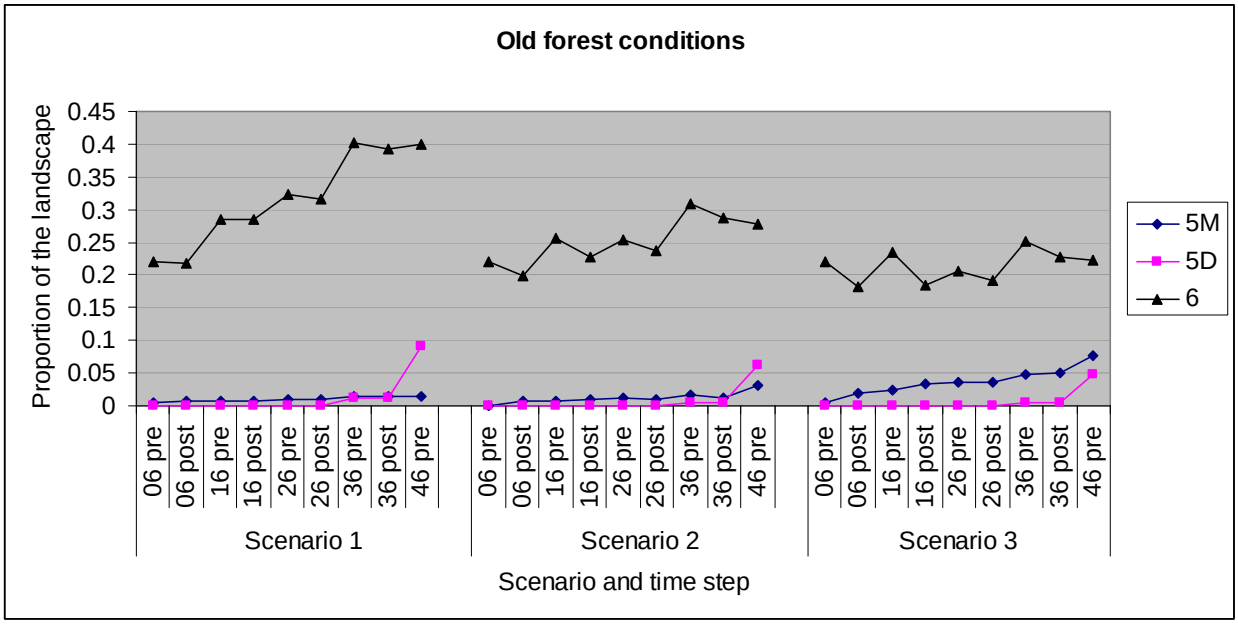


Figure 9. Proportion of the 3 million ac landscape occupied by a) the combination of mature and old forest conditions, and b) three different CWHR structural classes of old forests over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire). 5 = average diameter >24 in, 6 = average diameter >24 in and multilayered canopy and canopy closure >60%. M = canopy cover 40 to 60%; D = canopy cover >60%.

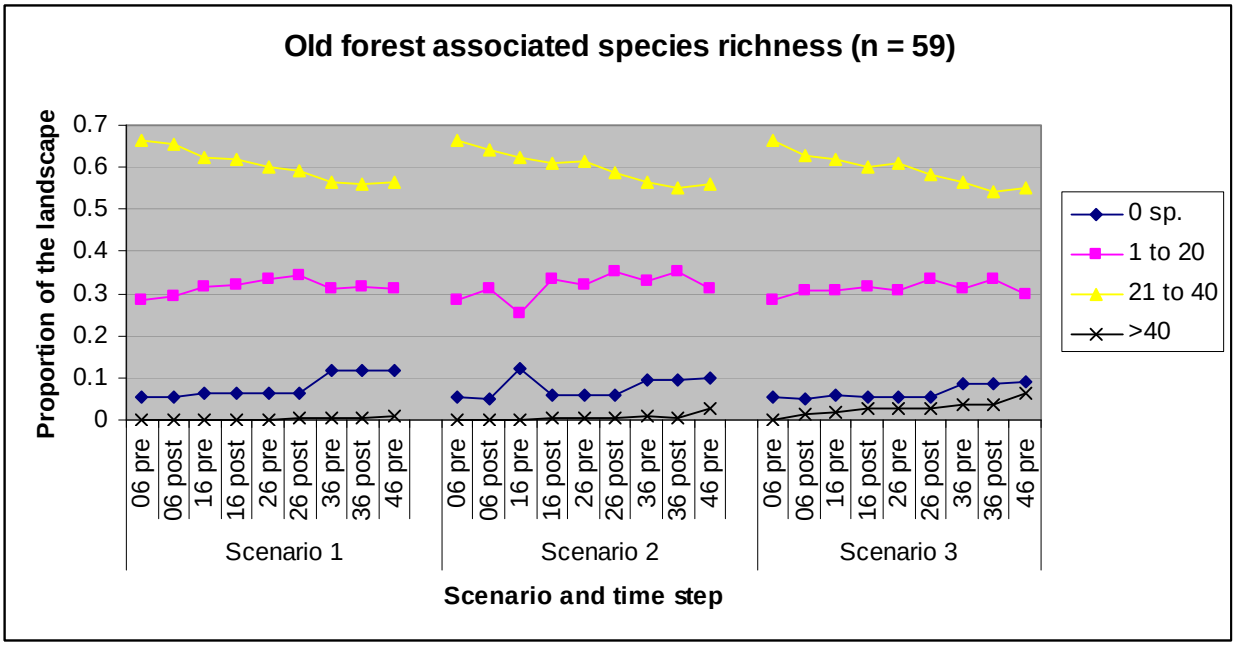


Figure 10. Proportion of the 3 million ac landscape occupied by each of four richness classes of old forest associated species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

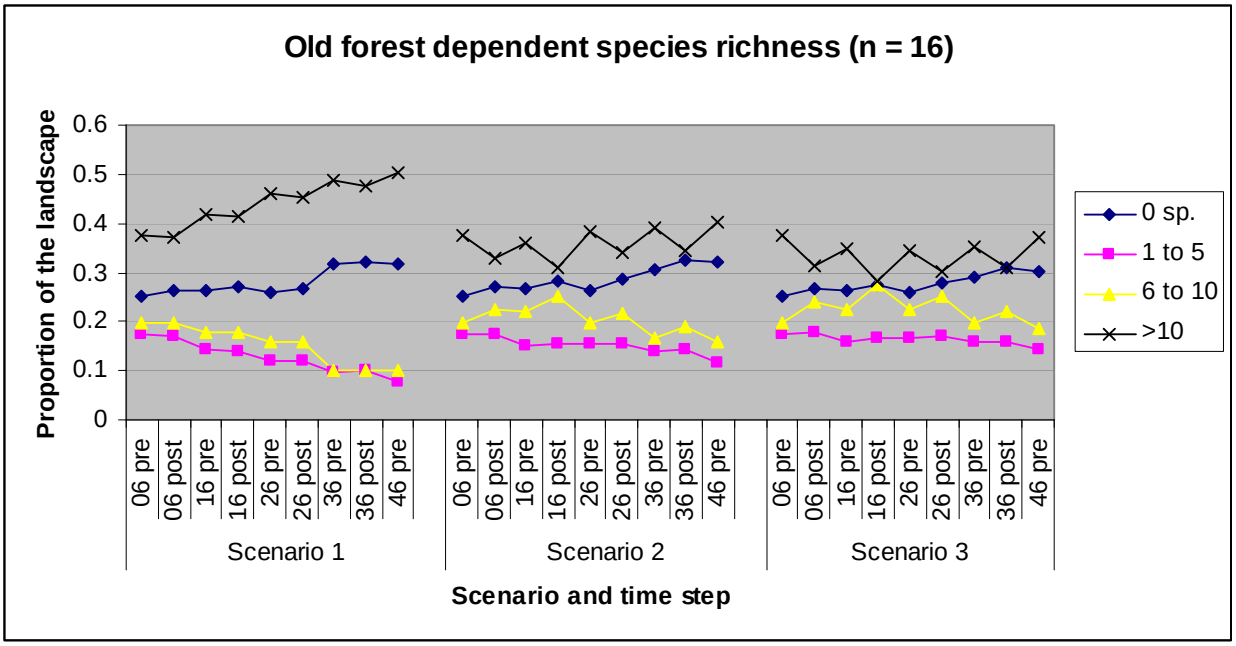


Figure 11. Proportion of the 3 million ac landscape occupied by each of four richness classes of old forest dependent species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

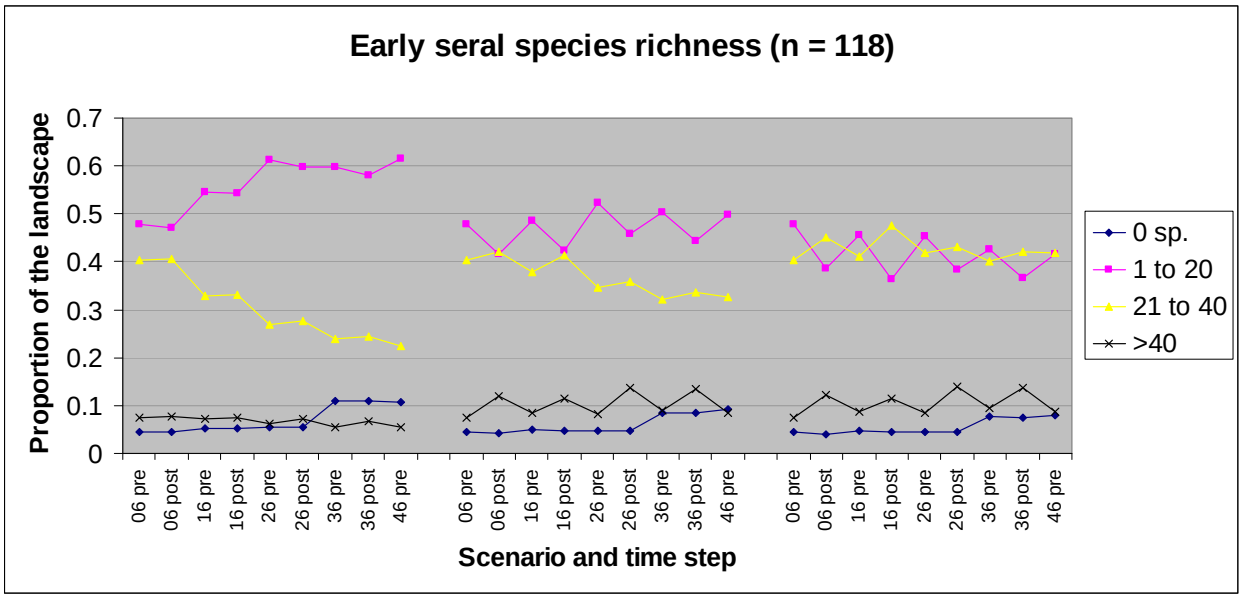


Figure 12. Proportion of the 3 million ac landscape occupied by each of four richness classes of early seral associated species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

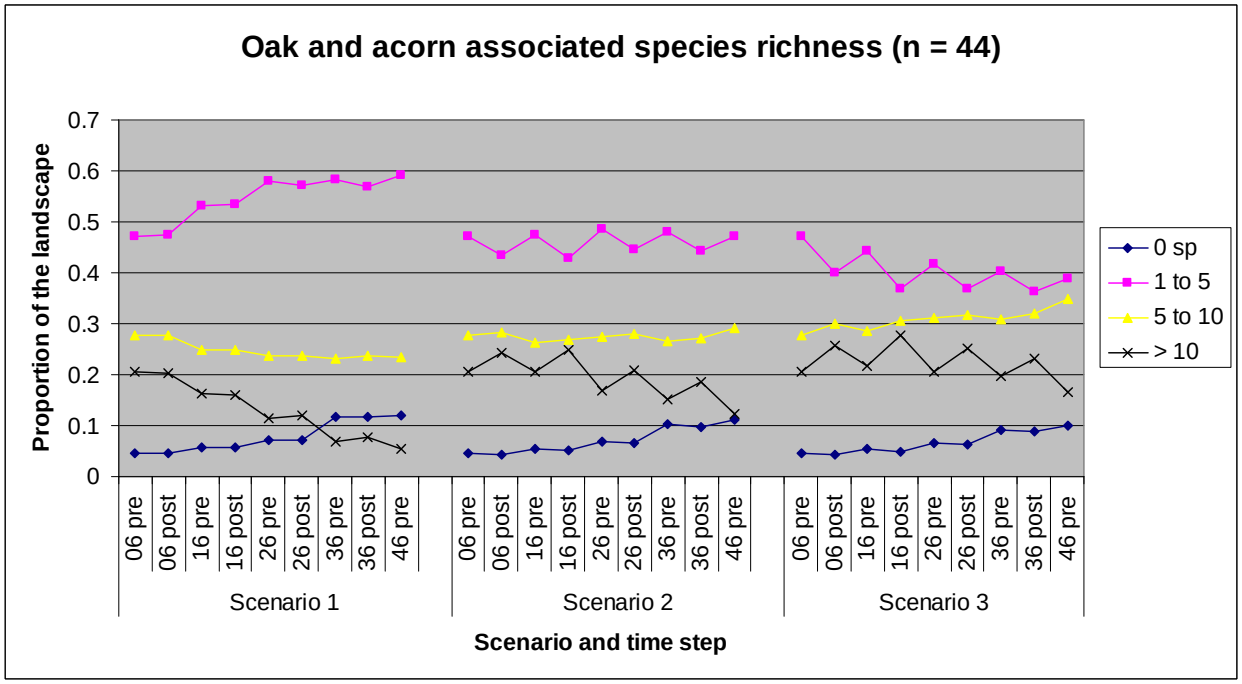


Figure 13. Proportion of the 3 million ac landscape occupied by each of four richness classes of oak associated species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

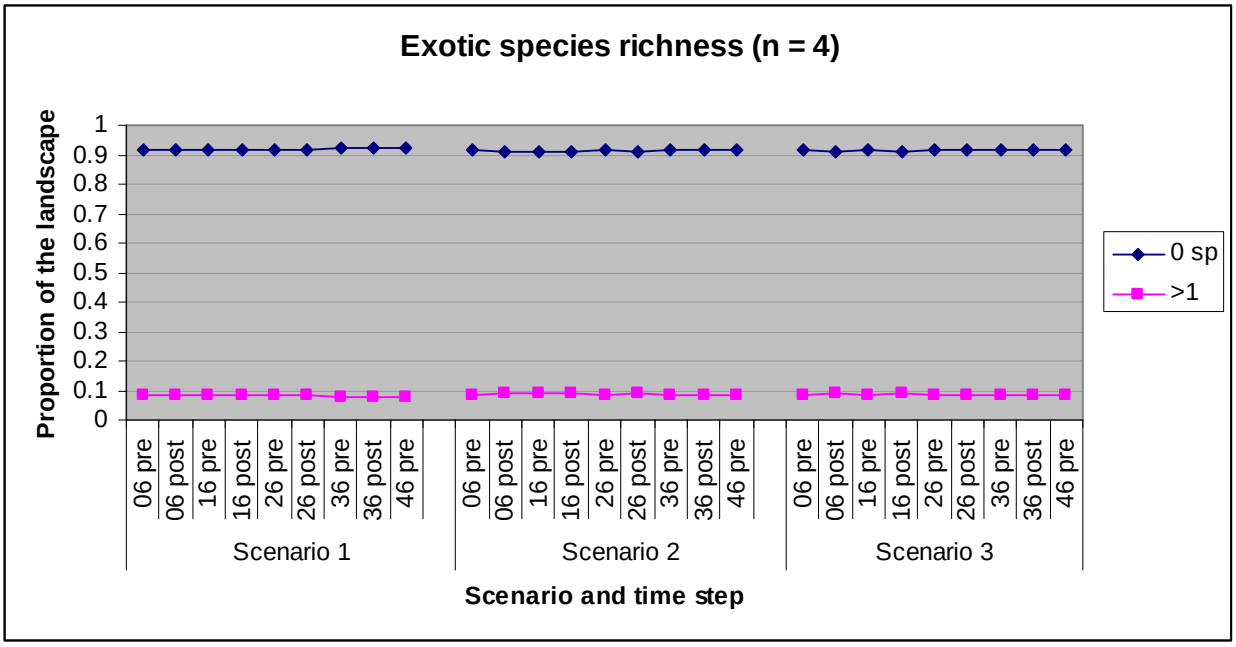


Figure 14. Proportion of the 3 million ac landscape occupied by each of two richness classes of exotic animal species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

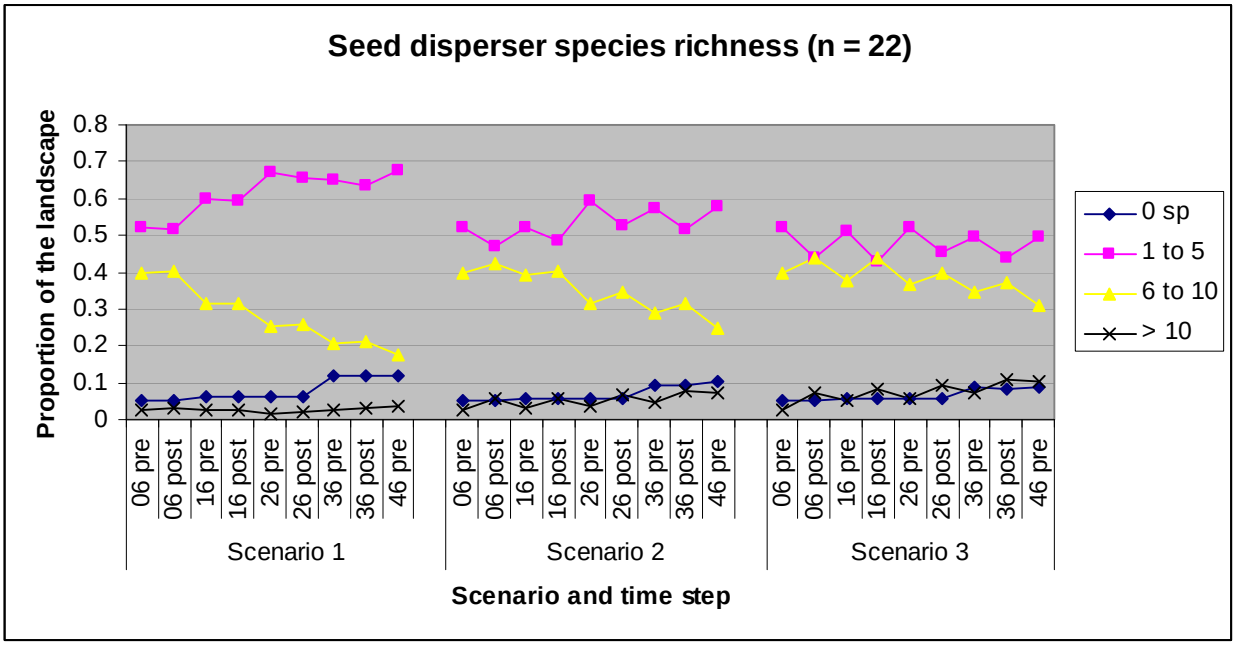


Figure 15. Proportion of the 3 million ac landscape occupied by each of four richness classes of seed dispersing species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

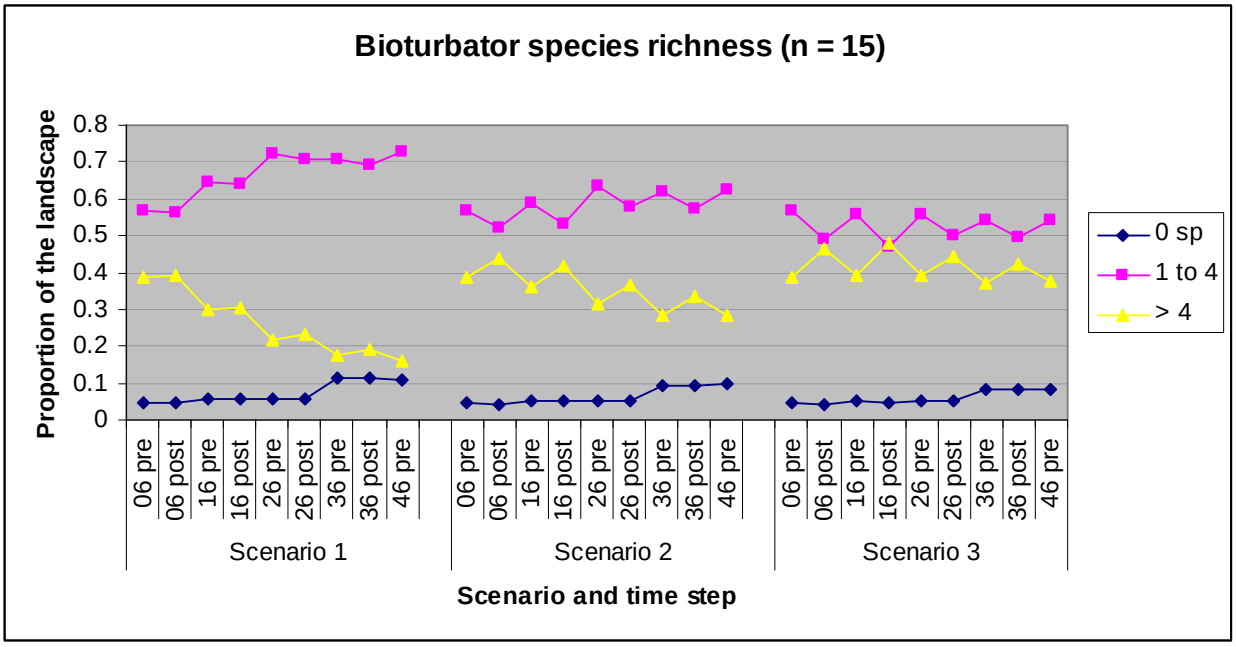


Figure 16. Proportion of the 3 million ac landscape occupied by each of three richness classes of bioturber species over 40 years for each of three management scenarios (1 = no mgt, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

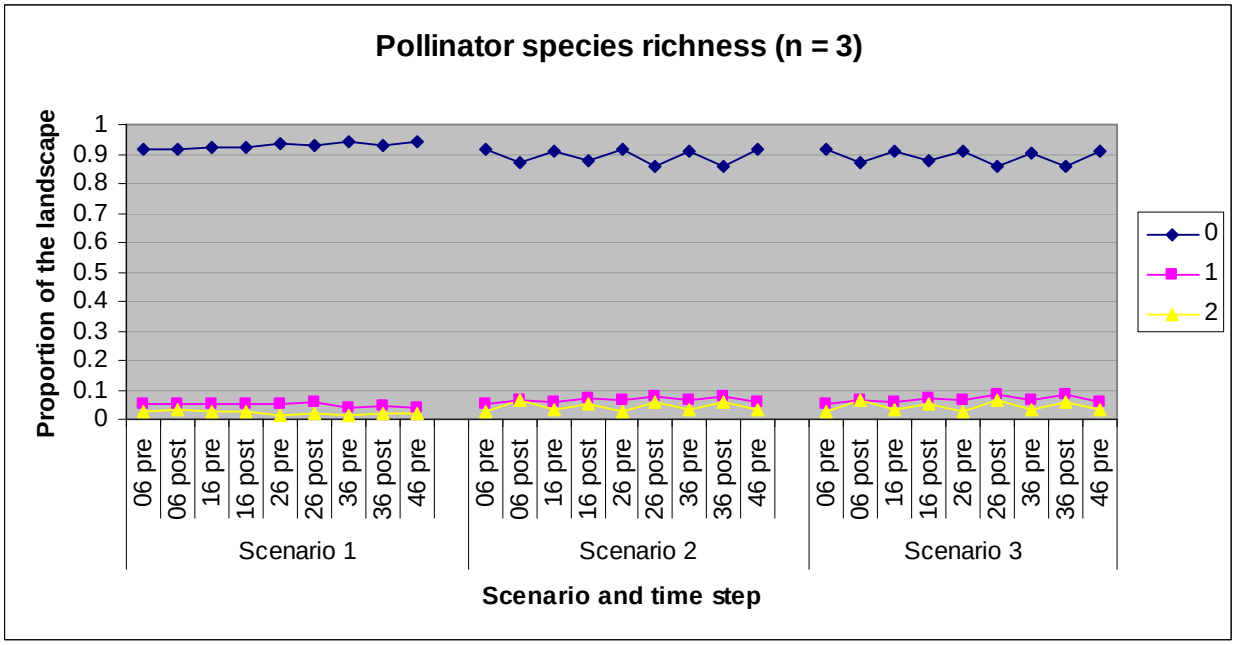


Figure 17. Proportion of the 3 million ac landscape occupied by each of two richness classes of pollinator species over 40 years for each of three management scenarios (1 = no mgt, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

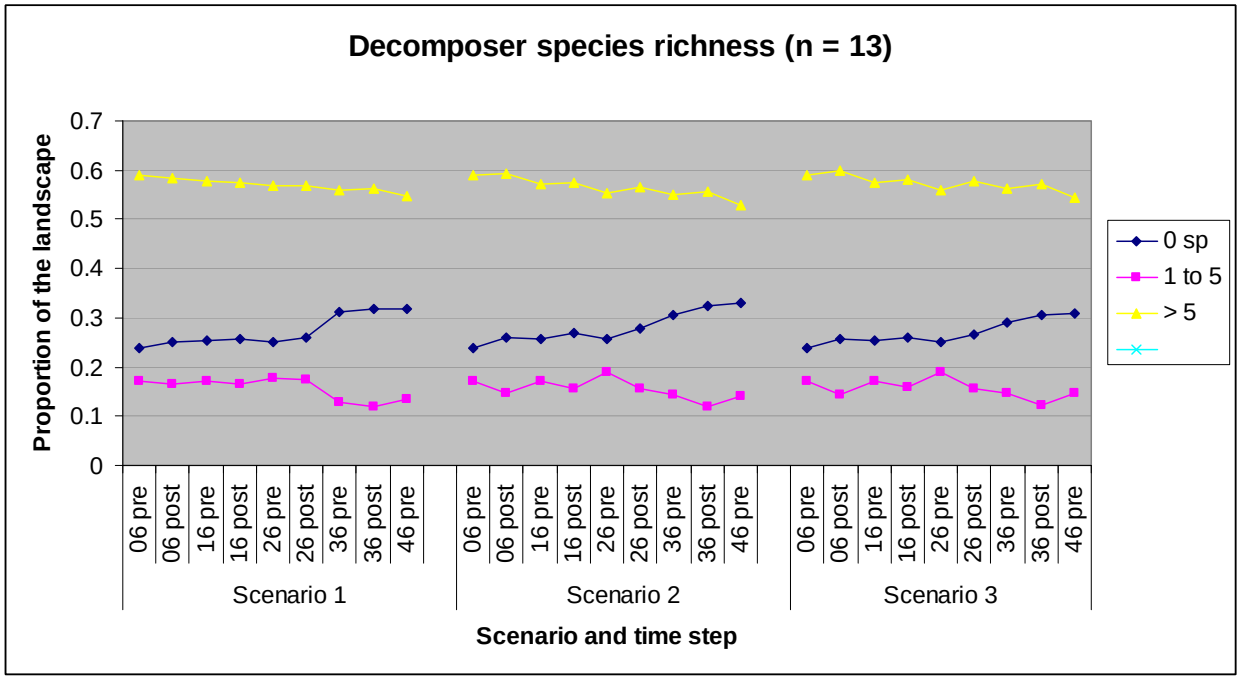


Figure 18. Proportion of the 3 million ac landscape occupied by each of three richness classes of decomposer species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

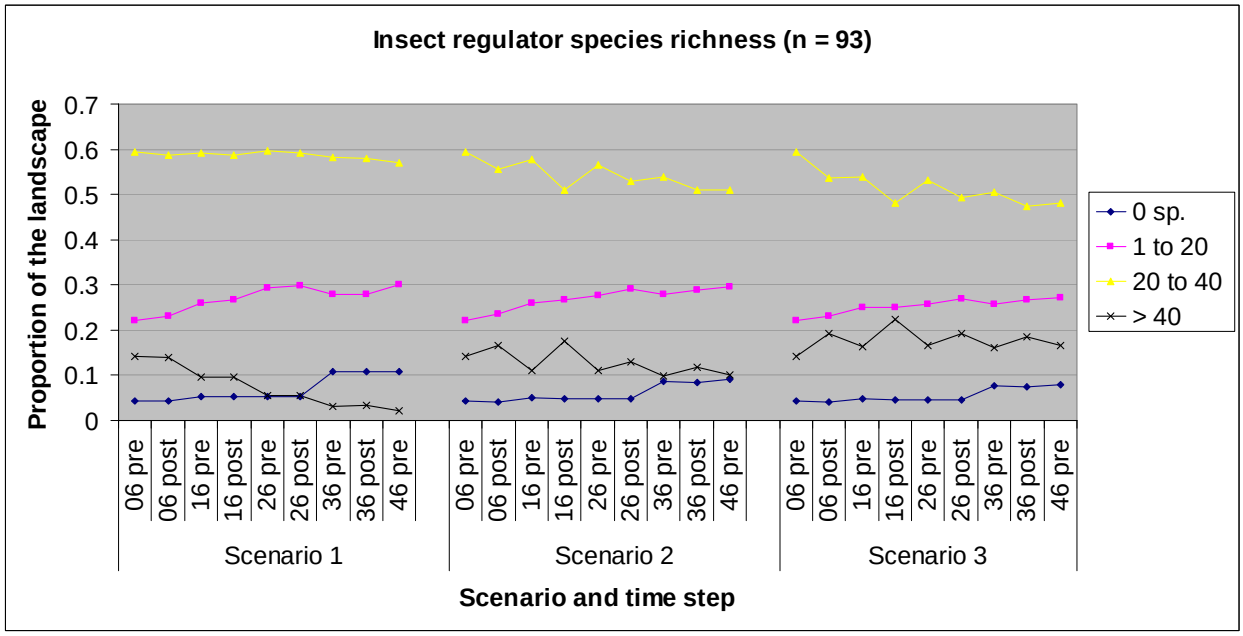
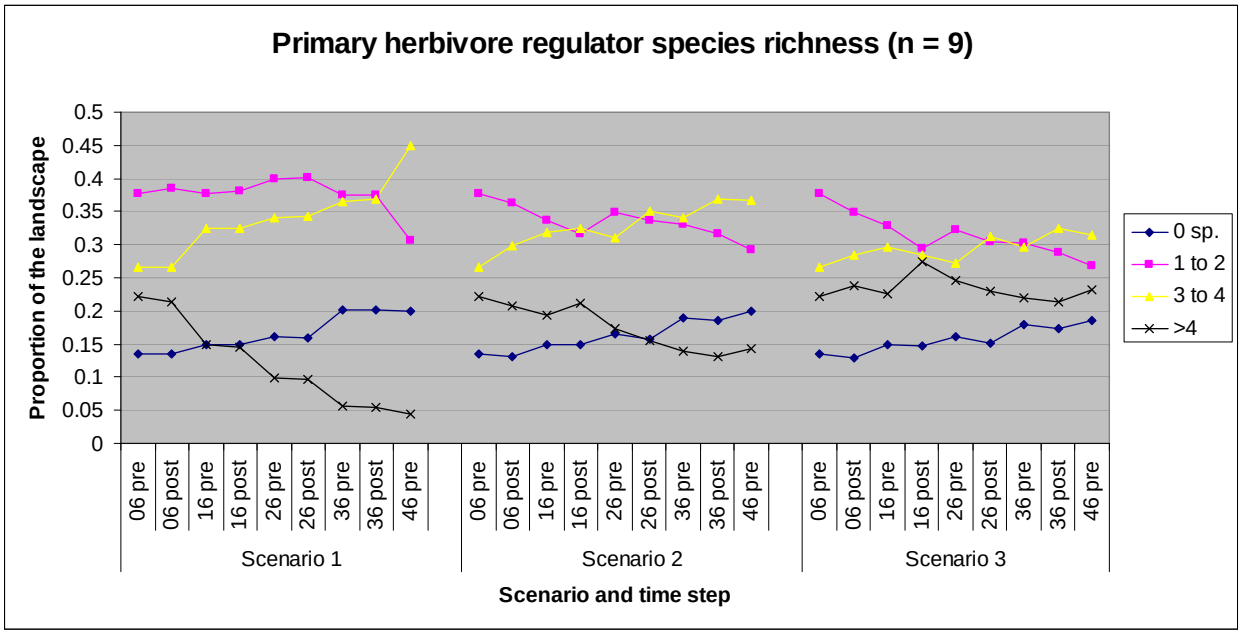


Figure 19. Proportion of the 3 million ac landscape occupied by each of four richness classes of insect regulating species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

a)



b)

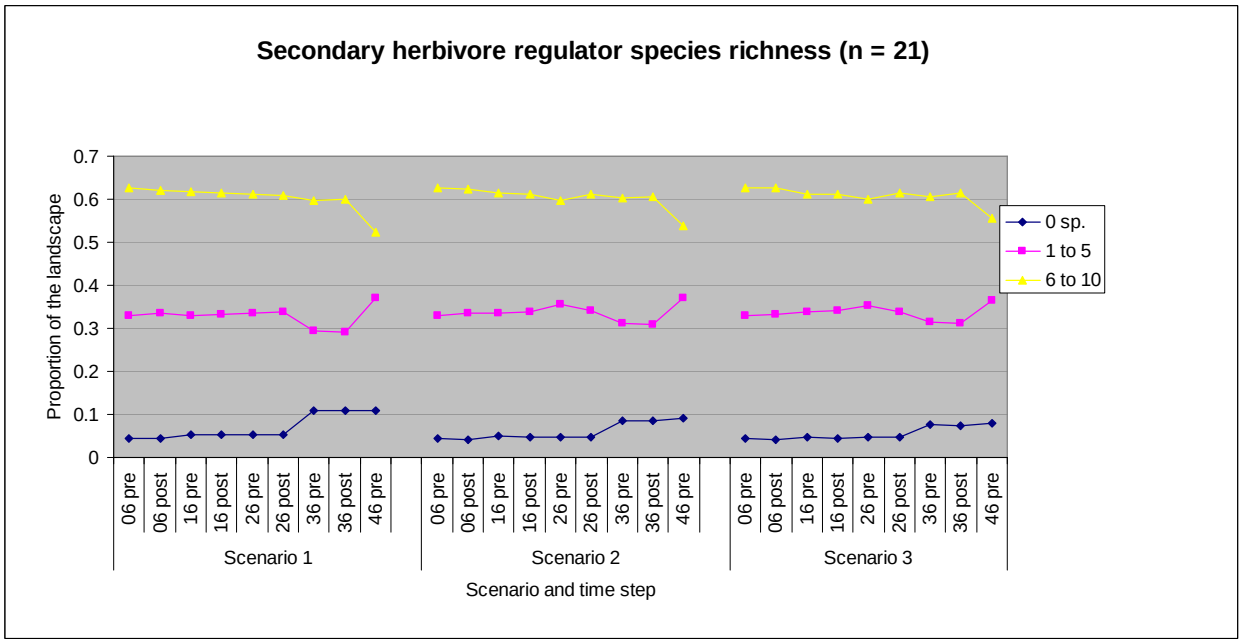
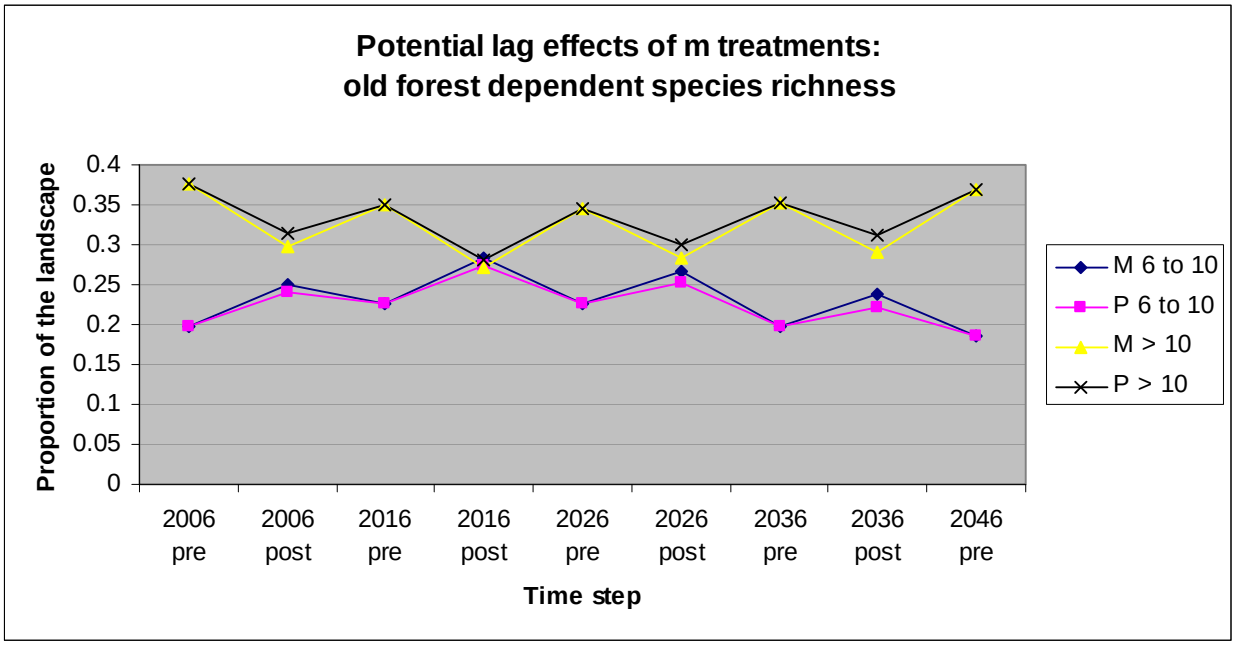


Figure 20. Proportion of the 3 million ac landscape occupied by a) each of three richness classes of primary herbivore regulating species, and b) each of four richness classes of secondary herbivore regulating species over a 40 year period for each of three management scenarios (1 = no management, wildfire only; 2 = timber harvest on private lands and wildfire; 3 = timber harvest on private and public lands and wildfire).

a)



b)

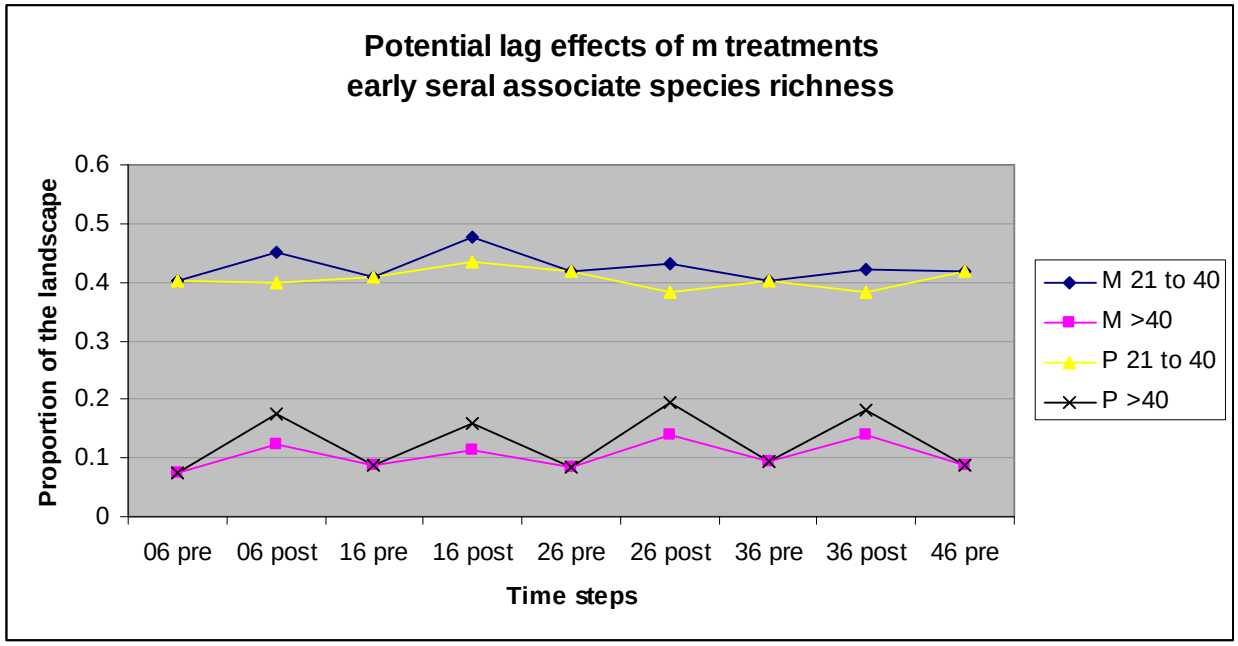


Figure 21. Differences in the proportion of the 3 million ac landscape occupied by the two highest richness classes for a) old forest dependent species (6 to 10, and >10 species) and b) early seral species (21 to 40, and >40 species) when stands treated with the *m* prescription (resulting in 40% canopy cover) are evaluated as having P canopy cover (10 to 40%) for the decade following treatment.

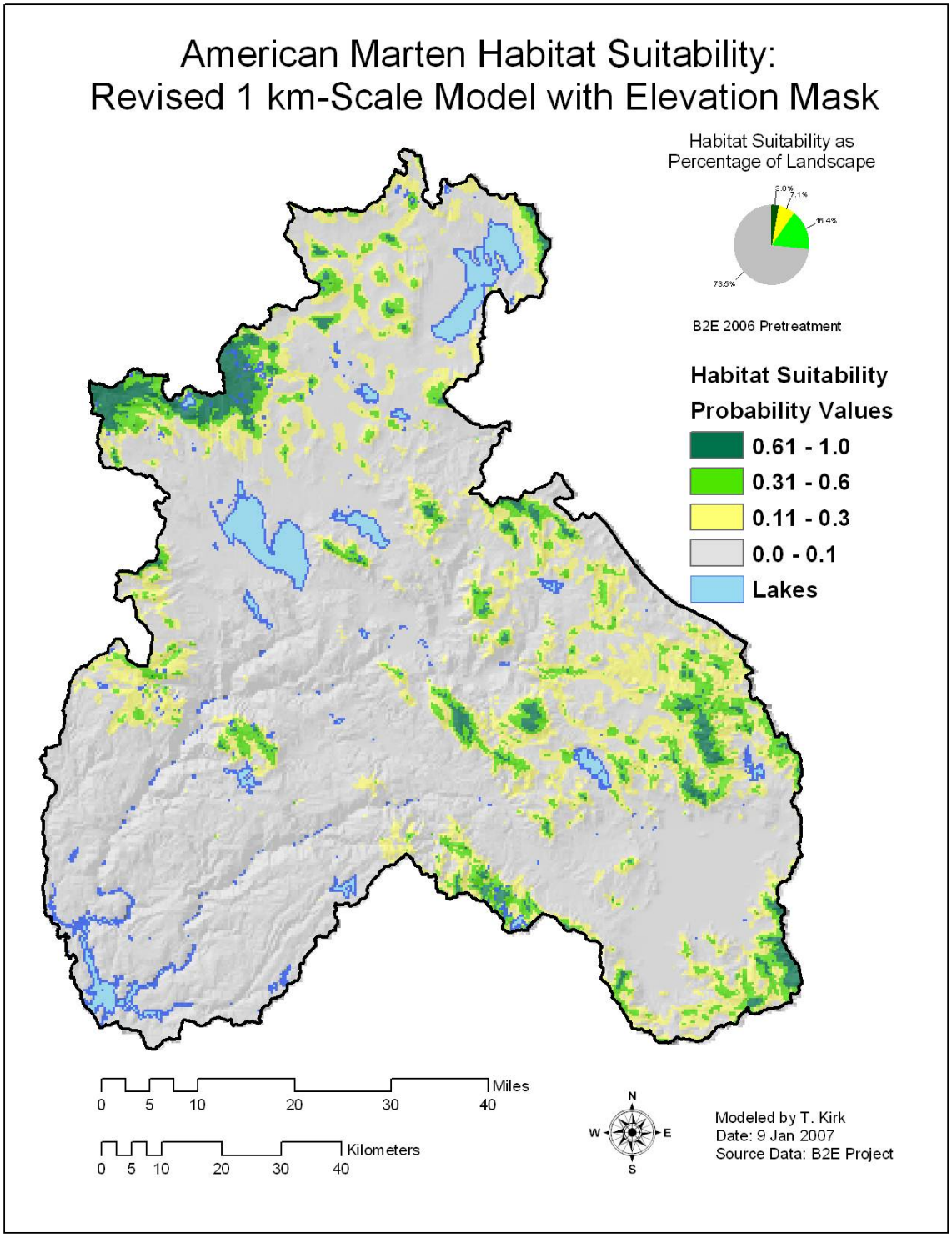


Figure 22. Map of predicted current reproductive habitat suitability for American marten (*Martes americana*) in the B2E project area.

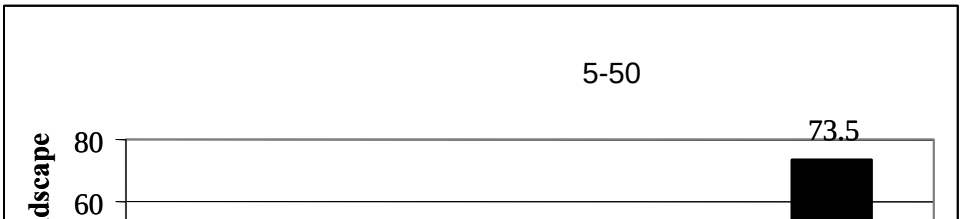


Figure 23. Percent of the B2E landscape occupied by suitable reproductive habitat for marten (*Martes Americana*) based on predictive models.

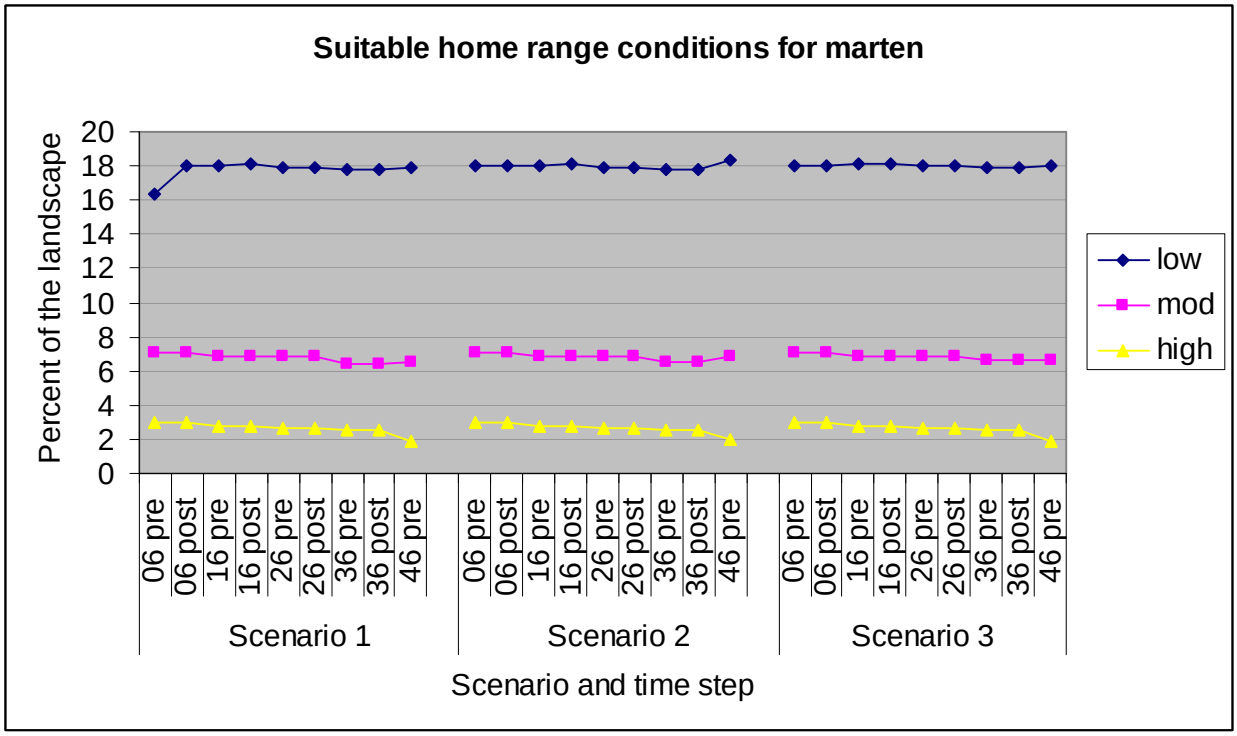


Figure 24. Probability of occupancy of home ranges by marten over a 40 year period based on scenario 1 management (no harvest, wildfire only). Probability of occupancy: no (≤0.10), low (0.11 to 0.3), moderate (0.31 to 0.6), high (>0.6).

Appendix A:
Species List for the B2E Landscape

A) TERRESTRIAL SPECIES

WHR code	Common name	Scientific name	AQUATIC	OLD FOREST	LOG	SNAG	OAK/ACORN	EARLY SERAL	EXOTIC	FSS/MIS	INSECT REG.	DECOMPOSITION	BIOTURBATORS	POLLINATORS	HERBIVORE REG. 1	HERBIVORE REG. 2	SEEED DISPERSAL
A012	ENSATINA	*Ensatina eschscholtzii*		X	X						X						
B116	COOPER'S HAWK	*Accipiter cooperii*		X												X	
B117	NORTHERN GOSHAWK	*Accipiter gentilis*		X						X					X		
B134	BLUE GROUSE	*Dendragapus obscurus*		X													
B251	BAND-TAILED PIGEON	*Columba fasciata*		X			X										
B263	FLAMMULATED OWL	*Otus flammeolus*		X		X					X						
B267	NORTHERN PYGMY-OWL	*Glaucidium gnoma*		X		X											
B270	CALIFORNIA SPOTTED OWL	*Strix occidentalis*		X						X					X		
B272	LONG-EARED OWL	*Asio otus*		X			X								X		
B274	NORTHERN SAW-WHET OWL	*Aegolius acadicus*		X		X											
B281	VAUX'S SWIFT	*Chaetura vauxi*		X		X					X						
B299	RED-BREASTED SAPSUCKER	*Sphyrapicus ruber*		X		X					X	X					
B300	WILLIAMSON'S SAPSUCKER	*Sphyrapicus thyroideus*		X		X					X						
B304	HAIRY WOODPECKER	*Picoides villosus*		X							X						
B305	WHITE-HEADED WOODPECKE	*Picoides albolarvatus*		X		X						X					
B306	BLACK-BACKED WOODPECKE	*Picoides arcticus*		X		X					X						
B308	PILEATED WOODPECKER	*Dryocopus pileatus*		X	X	X				X	X	X					
B309	OLIVE-SIDED FLYCATCHER	*Contopus cooperi*		X							X	X					
B315	WILLOW FLYCATCHER	*Empidonax traillii*		X							X						
B317	HAMMOND'S FLYCATCHER	*Empidonax hammondii*		X							X						
B339	TREE SWALLOW	*Tachycineta bicolor*		X		X					X						
B345	GRAY JAY	*Perisoreus canadensis*		X													
B346	STELLER'S JAY	*Cyanocitta stelleri*		X													
B357	CHESTNUT-BACKED CHICKAD	*Poecile rufescens*		X		X					X	X					
B361	RED-BREASTED NUTHATCH	*Sitta canadensis*		X		X					X	X					
B362	WHITE-BREASTED NUTHATCH	*Sitta carolinensis*		X		X	X				X	X					
B363	PYGMY NUTHATCH	*Sitta pygmaea*		X		X					X	X					
B364	BROWN CREEPER	*Certhia americana*		X							X						
B370	WINTER WREN	*Troglodytes troglodytes*		X	X						X						
B375	GOLDEN-CROWNED KINGLET	*Regulus satrapa*		X							X						
B386	HERMIT THRUSH	*Catharus guttatus*		X							X						
B415	CASSIN'S VIREO	*Vireo plumbeous*		X							X						
B438	HERMIT WARBLER	*Dendroica occidentalis*		X							X						
B536	PURPLE FINCH	*Carpodacus purpureus*		X			X										
B537	CASSIN'S FINCH	*Carpodacus cassinii*		X													
B546	EVENING GROSBEAK	*Coccothraustes vespertinus*		X													
B699	BARRED OWL	*Stirx varia*		X													
M003	VAGRANT SHREW	*Sorex vagrans*		X							X						
M012	TROWBRIDGE'S SHREW	*Sorex trowbridgii*		X							X						
M015	SHREW-MOLE	*Neurotrichus gibbsii*		X							X						
M021	LITTLE BROWN MYOTIS	*Myotis lucifugus*		X				X			X						
M023	YUMA MYOTIS	*Myotis yumanensis*		X							X						
M027	LONG-LEGGED MYOTIS	*Myotis volans*		X							X						
M030	SILVER-HAIRED BAT	*Lasionycteris noctivagans*		X							X						
M034	HOARY BAT	*Lasiurus cinereus*		X							X						
M077	WESTERN GRAY SQUIRREL	*Sciurus griseus*		X			X			X			X				X
M079	DOUGLAS SQUIRREL	*Tamiasciurus douglasii*		X		X							X				X
M080	NORTHERN FLYING SQUIRREL	*Glaucomys sabrinus*		X													
M127	DUSKY-FOOTED WOODRAT	*Neotoma fuscipes*		X													X
M129	WESTERN RED-BACKED VOLE	*Clethrionomys californicus*		X													
M143	WESTERN JUMPING MOUSE	*Zapus princeps*		X													
M145	PORCUPINE	*Erethizon dorsatum*		X													
M147	RED FOX	*Vulpes vulpes*		X	X	X				X					X		
M151	BLACK BEAR	*Ursus americanus*		X											X		
M154	MARTEN	*Martes americana*		X	X	X				X					X		
M155	FISHER	*Martes pennanti*		X	X	X				X					X		
M156	ERMINE	*Mustela erminea*		X		X										X	
M159	WOLVERINE	*Gulo gulo*		X	X					X					X		
R071	NIGHT SNAKE	*Hypsiglena torquata*		X													
B108	TURKEY VULTURE	*Cathartes aura*					X	X									
B114	NORTHERN HARRIER	*Circus cyaneus*						X							X		
B115	SHARP-SHINNED HAWK	*Accipiter striatus*														X	
B119	RED-SHOULDERED HAWK	*Buteo lineatus*					X	X							X		
B123	RED-TAILED HAWK	*Buteo jamaicensis*						X							X		
B126	GOLDEN EAGLE	*Aquila chrysaetos*						X							X		

WHR code	Common name	Scientific name	AQUATIC	OLD FOREST	LOG	SNAG	OAK/ACORN	EARLY SERAL	EXOTIC	FSS/MIS	INSECT REG.	DECOMPOSITION	BIOTURBATORS	POLLINATORS	HERBIVORE REG. 1	HERBIVORE REG. 2	SEEED DISPERSAL
B127	AMERICAN KESTREL	*Falco sparverius*					X	X								X	
B129	PEREGRINE FALCON	*Falco peregrinus*						X		X					X		
B138	WILD TURKEY	*Meleagris gallopavo*					X	X									
B140	CALIFORNIA QUAIL	*Callipepla californica*						X									
B141	MOUNTAIN QUAIL	*Oreortyx pictus*						X									
B250	ROCK DOVE	*Columba livia*						X	X								
B255	MOURNING DOVE	*Zenaida macroura*					X	X									
B262	BARN OWL	*Tyto alba*					X	X							X		
B264	WESTERN SCREECH-OWL	*Otus kennicottii*				X											
B265	GREAT-HORNED OWL	*Bubo virginianus*						X							X		
B269	BURROWING OWL	*Athene cunicularia*					X	X					X				
B273	SHORT-EARED OWL	*Asio flammeus*					X	X							X		
B276	COMMON NIGHTHAWK	*Chordeiles minor*						X			X						
B277	COMMON POORWILL	*Phalaenoptilus nuttallii*						X			X						
B279	BLACK SWIFT	*Cypseloides niger*						X			X						
B282	WHITE-THROATED SWIFT	*Aeronautes saxatalis*						X			X						
B287	ANNA'S HUMMINGBIRD	*Calypte anna*						X						X			
B289	CALLIOPE HUMMINGBIRD	*Stellula calliope*						X						X			
B291	RUFOUS HUMMINGBIRD	*Selasphorus rufus*												X			
B294	LEWIS'S WOODPECKER	*Melanerpes lewis*										X					
B296	ACORN WOODPECKER	*Melanerpes formicivorus*				X	X					X					
B302	NUTTALL'S WOODPECKER	*Picoides nuttallii*				X	X				X	X					
B303	DOWNY WOODPECKER	*Picoides pubescens*				X					X						
B307	NORTHERN FLICKER	*Colaptes auratus*				X					X	X					
B311	WESTERN WOOD-PEWEE	*Contopus sordidulus*									X						
B318	DUSKY FLYCATCHER	*Empidonax oberholseri*						X			X						
B320	PACIFIC-SLOPE FLYCATCHER	*Empidonax difficilis*						X			X						
B321	BLACK PHOEBE	*Sayornis nigricans*						X			X						
B326	ASH-THROATED FLYCATCHER	*Myiarchus cinerascens*						X			X						
B333	WESTERN KINGBIRD	*Tyrannus verticalis*						X			X						
B337	HORNED LARK	*Eremophila alpestris*						X									
B338	PURPLE MARTIN	*Progne subis*				X					X						
B340	VIOLET-GREEN SWALLOW	*Tachycineta thalassina*				X					X						
B343	CLIFF SWALLOW	*Petrochelidon pyrrhonota*						X			X						
B344	BARN SWALLOW	*Hirundo rustica*						X			X						
B348	WESTERN SCRUB JAY	*Aphelocoma californica*					X	X									
B349	PINYON JAY	*Gymnorhinus cyanocephalus*															X
B350	CLARK'S NUTCRACKER	*Nucifraga columbiana*															X
B351	BLACK-BILLED MAGPIE	*Pica pica*						x									
B353	AMERICAN CROW	*Corvus brachyrhynchos*						X									
B354	COMMON RAVEN	*Corvus corax*						X									
B356	MOUNTAIN CHICKADEE	*Poecile gambeli*				X					X						
B358	OAK TITMOUSE	*Baeolophus inornatus*				X	X										
B360	BUSHTIT	*Psaltriparus minimus*					X	X			X						
B366	ROCK WREN	*Salpinctes obsoletus*					X	X			X						
B367	CANYON WREN	*Catherpes mexicanus*						X			X						
B368	BEWICK'S WREN	*Thryomanes bewickii*					X	X			X						
B369	HOUSE WREN	*Troglodytes aedon*				X		X			X						
B376	RUBY-CROWNED KINGLET	*Regulus calendula*									X						
B377	BLUE-GRAY GNATCATCHER	*Polioptila caerulea*					X				X						
B380	WESTERN BLUEBIRD	*Sialia mexicana*				X		X			X						
B381	MOUNTAIN BLUEBIRD	*Sialia currucoides*						X			X						
B382	TOWNSEND'S SOLITAIRE	*Myadestes towsendi*									X						
B385	SWAINSON'S THRUSH	*Catharus ustulatus*									X						
B389	AMERICAN ROBIN	*Turdus migratorius*						X			X						
B391	WRENTIT	*Chamaea fasciata*					X										
B393	NORTHERN MOCKINGBIRD	*Mimus polyglottos*					X	X									
B410	LOGGERHEAD SHRIKE	*Lanius ludovicianus*					X	X			X						
B411	EUROPEAN STARLING	*Sturnus vulgaris*					X	X	X								
B417	HUTTON'S VIREO	*Vireo huttoni*					X				X						
B418	WARBLING VIREO	*Vireo gilvus*									X						
B425	ORANGE-CROWNED WARBLE	*Vermivora celata*									X						
B426	NASHVILLE WARBLER	*Vermivora ruficapilla*						X			X						
B435	YELLOW-RUMPED WARBLER	*Dendroica coronata*									X						
B436	BLACK-THROATED GRAY WAR	*Dendroica nigrescens*									X						
B460	MACGILLIVRAY'S WARBLER	*Oporornis tolmiei*									X						

WHR code	Common name	Scientific name	AQUATIC	OLD FOREST	LOG	SNAG	OAK/ACORN	EARLY SERAL	EXOTIC	FSS/MIS	INSECT REG.	DECOMPOSITION	BIOTURBATORS	POLLINATORS	HERBIVORE REG. 1	HERBIVORE REG. 2	SEEED DISPERSAL
B471	WESTERN TANAGER	*Piranga ludoviciana*									X						
B475	BLACK-HEADED GROSBEAK	*Pheucticus melanocephalus*						X			X						
B477	LAZULI BUNTING	*Passerina amoena*						X			X						
B482	GREEN-TAILED TOWHEE	*Pipilo chlorurus*						X									
B483	SPOTTED TOWHEE	*Pipilo maculatus*						X									
B484	CALIFORNIA TOWHEE	*Pipilo crissalis*					X	X									
B489	CHIPPING SPARROW	*Spizella passerina*						X									
B491	BREWER'S SPARROW	*Spizella breweri*						X									
B494	VESPER SPARROW	*Pooecetes gramineus*					X	X									
B499	SAVANNAH SPARROW	*Passerculus sandwichensis*					X	x									
B504	FOX SPARROW	*Passerella iliaca*						X									
B505	SONG SPARROW	*Melospiza melodia*						X									
B506	LINCOLN'S SPARROW	*Melospiza lincolnii*						X									
B510	WHITE-CROWNED SPARROW	*Zonotrichia leucophrys*						X									
B512	DARK-EYED JUNCO	*Junco hyemalis*						X									
B521	WESTERN MEADOWLARK	*Sturnella neglecta*					X	X									
B524	BREWER'S BLACKBIRD	*Euphagus cyanocephalus*						X									
B528	BROWN-HEADED COWBIRD	*Molothrus ater*						X									
B532	BULLOCK'S ORIOLE	*Icterus bullockii*					X				X						
B534	GRAY-CROWNED ROSY-FINCH	*Leucosticte tephrocotis*						X									
B535	PINE GROSBEAK	*Pinicola enucleator*															X
B538	HOUSE FINCH	*Carpodacus mexicanus*					X	X									
B539	RED CROSSBILL	*Loxia curvirostra*															X
B542	PINE SISKIN	*Carduelis pinus*															X
B543	LESSER GOLDFINCH	*Carduelis psaltria*						X									
B547	HOUSE SPARROW	*Passer domesticus*						X	X								
B550	CORDILLERAN FLYCATCHER	*Empidonax occidentalis*						X			X						
B554	CASSIN'S VIREO	*Vireo cassinii*									X						
M001	VIRGINIA OPOSSUM	*Didelphis virginiana*					X	X									
M018	BROAD-FOOTED MOLE	*Scapanus latimanus*						X			X						
M025	LONG-EARED MYOTIS	Myotis evotis						X			X						
M026	FRINGED MYOTIS	*Myotis thysanodes*									X						
M028	CALIFORNIA MYOTIS	*Myotis californicus*						X			X						
M029	SMALL-FOOTED MYOTIS	*Myotis ciliolabrum*									X						
M031	WESTERN PIPISTRELLE	*Pipistrellus hesperus*					X				X						
M032	BIG BROWN BAT	*Eptesicus fuscus*						X			X						
M033	WESTERN RED BAT	*Lasiurus blossevillii*					X			X	X						
M036	SPOTTED BAT	*Euderma maculatum*									X						
M037	TOWNSEND'S BIG-EARED BAT	*Corynorhinus townsendii*								X	X						
M038	PALLID BAT	*Antrozous pallidus*					X			X	X						
M039	BRAZILIAN FREE-TAILED BAT	*Tadarida brasiliensis*					X				X						
M043	PIKA	*Ochotona princeps*						X									
M045	BRUSH RABBIT	*Sylvilagus bachmani*					X	X									
M046	MONTANE COTTONTAIL	*Sylvilagus nuttallii*						X									
M049	SNOWSHOE HARE	*Lepus americanus*						X									
M050	WHITE-TAILED HARE	*Lepus townsendii*						X									
M051	BLACK-TAILED HARE	*Lepus californicus*						X									
M055	YELLOW-PINE CHIPMUNK	*Tamias amoenus*											X				X
M057	SHADOW CHIPMUNK	*Tamias senex*											X				X
M062	LONG-EARED CHIPMUNK	*Tamias quadrimaculatus*											X				X
M063	LODGEPOLE CHIPMUNK	*Tamias speciosus*											X				X
M066	YELLOW-BELLIED MARMOT	*Marmota flaviventris*						X					X				X
M070	BELDING'S GROUND SQUIRREL	*Spermophilus beldingi*						X					X				X
M072	CALIFORNIA GROUND SQUIRREL	*Spermophilus beecheyi*						X					X				X
M075	GOLDEN-MANTLED GROUND SQUIRREL	Spermophilus lateralis						X					X				X
M081	BOTTA'S POCKET GOPHER	*Thomomys bottae*						X					X				
M085	MOUNTAIN POCKET GOPHER	*Thomomys monticola*						X					X				
M113	WESTERN HARVEST MOUSE	*Reithrodontomys megalotis*						X									X
M117	DEER MOUSE	*Peromyscus maniculatus*						X									X
M119	BRUSH MOUSE	*Peromyscus boylii*					X	X									X
M120	PINYON MOUSE	*Peromyscus truei*					X	X									X
M128	BUSHY-TAILED WOODRAT	*Neotoma cinerea*						X									X
M133	MONTANE VOLE	*Microtus montanus*						X					X				
M136	LONG-TAILED VOLE	*Microtus longicaudus*											X				
M142	HOUSE MOUSE	*Mus musculus*						X	X								X

WHR code	Common name	Scientific name	AQUATIC	OLD FOREST	LOG	SNAG	OAK/ACORN	EARLY SERAL	EXOTIC	FSS/MIS	INSECT REG.	DECOMPOSITION	BIOTURBATORS	POLLINATORS	HERBIVORE REG. 1	HERBIVORE REG. 2	SEEED DISPERSAL
M146	COYOTE	*Canis latrans*						X							X		
M149	GRAY FOX	*Urocyon cinereoargenteus*						X				X			X		
M152	RINGTAIL	*Bassariscus astutus*			X	X		X								X	
M153	RACCOON	*Procyon lotor*			X	X										X	
M157	LONG-TAILED WEASEL	*Mustela frenata*			X	X		X								X	
M160	BADGER	*Taxidea taxus*						X							X		
M161	WESTERN SPOTTED SKUNK	*Spilogale gracilis*			X	X		X								X	
M162	STRIPED SKUNK	*Mephitis mephitis*			X			X								X	
M165	MOUNTAIN LION	*Felis concolor*						X							X		
M166	BOBCAT	*Felis rufus*			X			X							X		
M181	MULE DEER	*Odocoileus hemionus*					X	x		X							
M182	PRONGHORN	*Antilocapra americana*						X		X							
R022	WESTERN FENCE LIZARD	*Sceloporus occidentalis*						X			X						
R023	SAGEBRUSH LIZARD	*Sceloporus graciosus*						X			X						
R024	SIDE-BLOTCHED LIZARD	*Uta stansburiana*						X			X						
R036	WESTERN SKINK	*Eumeces skiltonianus*			X			X			X						
R040	SOUTHERN ALLIGATOR LIZARD	*Elgaria multicarinata*						X			X						
R042	NORTHERN ALLIGATOR LIZARD	*Elgaria coerulea*						X			X						
R046	RUBBER BOA	*Charina bottae*			X												
R048	RINGNECK SNAKE	*Diadophis punctatus*					X										
R049	SHARP-TAILED SNAKE	*Contia tenuis*			X			X									
R051	RACER	*Coluber constrictor*						X									
R057	WESTERN GOPHER SNAKE	*Pituophis catenifer*						X									
R058	COMMON KINGSNAKE	*Lampropeltis getula*					X	X									
R059	CALIFORNIA MOUNTAIN KINGSNAKE	*Lampropeltis zonata*						X									
R061	COMMON GARTER SNAKE	*Thamnophis sirtalis*					X	X									
R076	WESTERN RATTLESNAKE	*Crotalus viridis*						X									
				59	16	34	44	118	4	14	0 93	13	15	3	21	9	22

REMAINING TERRESTRIAL SPECIES IN LANDSCAPE

B351	BLACK-BILLED MAGPIE	*Pica pica*
M046	NUTTALL'S COTTONTAIL	*Sylvilagus nuttallii*

B) RIPARIAN OR AQUATIC OBLIGATES (NON-FISH)

WHR code	Common name	Scientific name	AQUATIC	EXOTIC	FSS/MIS	INSECT REG.	PRIMARY PROD. REG.	HERBIVORE REG. 1	HERBIVORE REG. 2
A003	LONG-TOED SALAMANDER	*Ambystoma macrodactylum*	X			X			
A006	ROUGH-SKINNED NEWT	*Taricha granulosa*	X			X			
A007	SIERRA NEWT	*Taricha torosa*	X			X			
A023	MOUNT LYELL SALAMANDER	*Hydromantes platycephalus*	X						
A029	GREAT BASIN SPADEFOOT TOAD	*Scaphiopus intermontanus*	X						
A032	WESTERN TOAD	*Bufo boreas*	X						
A033	YOSEMITE TOAD	*Bufo canorus*	X						
A039	PACIFIC TREEFROG	*Hyla regilla*	X						
A040	RED-LEGGED FROG	*Rana aurora*	X						
A042	CASCADE FROG	*Rana cascadae*	X		X				
A043	FOOTHILL YELLOW-LEGGED FROG	*Rana boylii*	X		X				
A044	MOUNTAIN YELLOW-LEGGED FROG	*Rana muscosa*	X		X				
A045	NORTHERN LEOPARD FROG	*Rana pipiens*	X		X				
A046	BULLFROG	*Rana catesbeiana*	X	X					
B006	PIED-BILLED GREBE	*Podilymbus podiceps*	X						X
B009	EARED GREBE	*Podiceps nigricollis*	X						X
B010	WESTERN/CLARK'S GREBE	*Aechmophorus occidentalis*	X						X
B042	AMERICAN WHITE PELICAN	*Pelecanus erythrorhynchos*	X					X	
B044	DOUBLE-CRESTED CORMORANT	*Phalacrocorax auritus*	X						X
B051	GREAT BLUE HERON	*Ardea herodias*	X						X
B053	SNOWY EGRET	*Egretta thula*	X						X
B058	GREEN HERON	*Butorides virescens*	X						X
B059	BLACK-CROWNED NIGHT-HERON	*Nycticorax nycticorax*	X						X
B075	CANADA GOOSE	*Branta canadensis*	X		X				
B076	WOOD DUCK	*Aix sponsa*	X			X	X		
B077	GREEN-WINGED TEAL	*Anas crecca*	X						
B079	MALLARD	*Anas platyrhynchos*	X		X		X		
B080	NORTHERN PINTAIL	*Anas acuta*	X				X		
B082	BLUE-WINGED TEAL	*Anas discors*	X				X		
B083	CINNAMON TEAL	*Anas cyanoptera*	X				X		
B084	NORTHERN SHOVELER	*Anas clypeata*	X				X		
B085	GADWALL	*Anas strepera*	X				X		
B087	AMERICAN WIGEON	*Anas americana*	X				X		
B089	CANVASBACK	*Aythya valisineria*	X				X		
B090	REDHEAD	*Aythya americana*	X				X		
B091	RING-NECKED DUCK	*Aythya collaris*	X				X		
B094	LESSER SCAUP	*Aythya affinis*	X			X			
B101	COMMON GOLDEN EYE	*Bucephala clangula*	X						
B102	BARROW'S GOLDENEYE	*Budephala islandiica*	X						
B103	BUFFLEHEAD	*Bucephala albeola*	X			X			
B104	HOODED MERGANSER	*Lophodytes cucullatus*	X						X
B105	COMMON MERGANSER	*Mergus merganser*	X						X
B107	RUDDY DUCK	*Oxyura jamaicensis*	X			X			
B110	OSPREY	*Pandion haliaetus*	X		X			X	
B113	BALD EAGLE	*Haliaeetus leucocephalus*	X		X			X	
B145	VIRGINIA RAIL	*Rallus limicola*	X			X			
B146	SORA	*Porzana carolina*	X				X		
B149	AMERICAN COOT	*Fulica americana*	X				X		
B150	SANDHILL CRANE	*Grus canadensis*	X						
B158	KILLDEER	*Charadrius vociferus*	X			X			
B163	BLACK-NECKED STILT	*Himantopus mexicanus*	X			X			
B164	AMERICAN AVOCET	*Recurvirostra americana*	X			X			
B168	WILLET	*Catoptrophorus semipalmatus*	X			X			
B170	SPOTTED SANDPIPER	*Actitis macularia*	X			X			
B173	LONG-BILLED CURLEW	*Numenius americanus*	X			X			
B199	COMMON SNIPE	*Gallinago gallinago*	X			X			
B200	WILSON'S PHALAROPE	*Phalaropus tricolor*	X			X			
B214	RING-BILLED GULL	*Larus delawarensis*	X						
B215	CALIFORNIA GULL	*Larus californicus*	X						
B227	CASPIAN TERN	*Sterna caspia*	X						X
B233	FORSTER'S TERN	*Sterna forsteri*	X						X
B235	BLACK TERN	*Chlidonias niger*	X						X
B293	BELTED KINGFISHER	*Ceryle alcyon*	X						X
B341	NORTHERN ROUGH-WINGED SWALLOW	*Stelgidopteryx serripennis*	X			X			
B342	BANK SWALLOW	*Riparia riparia*	X			X			

WHR code	Common name	Scientific name	AQUATIC	EXOTIC	FSS/MIS	INSECT REG.	PRIMARY PROD. REG.	HERBIVORE REG. 1	HERBIVORE REG. 2
B372	MARSH WREN	*Cistothorus palustris*	X			X			
B373	AMERICAN DIPPER	*Cinclus mexicanus*	X			X			
B404	AMERICAN PIPIT	*Anthus rubescens*	X			X			
B430	YELLOW WARBLER	*Dendroica petechia*	X			X			
B461	COMMON YELLOWTHROAT	*Geothlypis trichas*	X			X			
B467	YELLOW-BREASTED CHAT	*Icteria virens*	X			X			
B519	RED-WINGED BLACKBIRD	*Agelaius phoeniceus*	X						
B522	YELLOW-HEADED BLACKBIRD	*Xanthocephalus xanthocephalus*	X						
M010	WATER SHREW	*Sorex palustris*	X			X			
M052	MOUNTAIN BEAVER	*Aplodontia rufa*	X						
M112	BEAVER	*Castor canadensis*	X						
M139	MUSKRAT	*Ondatra zibethicus*	X						
M158	MINK	*Mustela vison*	X						
M163	RIVER OTTER	*Lutra canadensis*	X					X	
R004	WESTERN POND TURTLE	*Clemmys marmorata*	X		X				
R062	WESTERN TERRESTRIAL GARTER SNAK	*Thamnophis elegans*	X						
R063	WESTERN AQUATIC GARTER SNAKE	*Thamnophis couchii*	X						
			82	0	1	9	25	13	4	14

C) FISH SPECIES

Common name	Scientific name	AQUATIC	EXOTIC	FSS/MIS
Tui Chub	*Siphateles bicolor*	X		
Lahontan Redside	*Richardsonius egregious*	X		
California Roach	*Lavinia symmetricus*	X		
Hardhead	*Mylophardon conocephalus*	X		X
Sacramento Pikeminnow	*Ptychocheilus grandis*	X		
Speckled Dace	*Rhinichthys osculus*	X		
Golden Shiner	*Notemigonus crysoleucas*	X	X	
Common Carp	*Cyprinus carpio*	X	X	
Sacramento Sucker	*Catostomus occidentalis*	X		
Tahoe Sucker	*Catostomus tahoensis*	X		
Black Bullhead	*Ameiurus melas*	X	X	
Brown Bullhead	*Ameiurus nebulsus*	X	X	
Channel Catfish	*Ictalurus punctatus*	X	X	
Wakasagi	*Hypomesus nipponensis*	X	X	
Kokanee (Sockeye Salmon)	*Onchorhynchus nerka*	X	X	
Rainbow Trout	*Oncorhynchus mykiss*	X		
Redband Trout	*Oncorhynchus mykiss (stonei?)*	X		X
Brown Trout	*Salmo trutta*	X	X	
Brook Trout	*Salvelinus fontinalis*	X	X	
Riffle Sculpin	*Cottus gulosus*	X		
Bluegill	*Lepomis macrochirus*	X	X	
Redear Sunfish	*Lepomis microlophus*	X	X	
Pumpkinseed	*Lepomis gibbosus*	X	X	
Green Sunfish	*Lepomis cyanellus*	X	X	
White Crappie	*Pomoxis annularis*	X	X	
Black Crappie	*Pomoxis nigromaculatus*	X	X	
Largemouth Bass	*Micropterus salmoides*	X	X	
Smallmouth Bass	*Micropterus dolomieu*	X	X	
Chinook salmon, Central Valley spring-run	*Oncorhynchus tshawytscha*	X		
Steelhead, Central Valley winter-run (anadro	*Oncorhynchus mykiss*	X		
Eagle Lake Rainbow Rrout (subspecies of ra	*Oncorhynchus mykiss*	X		
Rough Sculpin	*Cottus asperrimus*	X		X
Sacramento Perch	*Archoplites interruptus*	X		X
Tule Perch	*Hysterocarpus traski*	X		
		34	0 17	4

Appendix B:
Habitat Modeling Assumptions

1) We gave all LAC WHR types a zone of 1 (open waters; 'LAC1').
2) The B2E model shows that areas such Sierra Valley and Indian Valley as the 'CRP' WHR type, which refers to cropland. Our expert opinion is that these areas should be labeled pasture (PGS1M) and will be labeled as such in the CWHR modeling of the B2E landscape. In all reality, the CWHR label "PAS" may be more appropriate. However, S. Parks discovered that most species did not contain a suitability class for "PAS" vegetation types. S. Parks spoke with Monica Parisi from the CWHR program of DFG and found that this is most likely an error and that PGS would be more "fitting" considering the error with the PAS type.

3) Any tree WHR type with a size and/or density of 'X' was given a size class of 1. For example, a WHR combination of 'EPNXX' was changed to 'EPN1' so that the CWHR habitat models would work.

4) The B2E model results show 70 pixels with a CalVeg type of WJ (translated to WHR type of JUN. These pixels, however, have no WHR size or density class and have a Strata regional forest type of 'Z' (shrub type), indicating that these pixels are considered shrub by the B2E modeling. This is presumably an error of some kind. I am labeling them 'JUN1' for the sake of simplicity.

5) There are 23 pixels in the B2E model results with a WHR type of 'URB' and a size and density different from null. This seems to stem from the fact that these pixels were labeled with the 'IC' (ornamental conifer) VegType, which translates to an 'URB' CWHR type. These pixels must have been placed in a stratum with trees that were modeled. I am labeling them 'URB' for the sake of simplicity (and because there are only 23 pixels with this issue).

6) The "fixes" in steps 4 through 8 are incorporated into the grids described in step 3.

Appendix C:
Marten Habitat Model

Introduction

In 1999 to 2002, USDA Forest Service, Pacific Southwest Research Station (PSW) conducted a survey for mammalian carnivores in the Greater Southern Cascades Region (GSCR) of northeastern California using baited trackplate and camera stations (Barrett 1983, Kirk 2007). These data were used to investigate American marten (*Martes americana*) habitat suitability and develop a predictive model for marten occurrence for the GSCR using Geographic Information Systems (GIS). Habitat suitable for reproduction was determined based on a modified version of the California Wildlife-Habitat Relationships (CWHR) system. The CWHR marten model was modified to account for differences in marten use of some forest types in this portion of the state, as evidenced by survey results (Kirk 2007). The survey data, suitable habitat definitions, and environmental characteristics of each survey site (n = 184) were used to develop a predictive model of marten occurrence for the GSCR landscape.

The GSCR landscape overlaps the B2E landscape, extending far to the north but not as far east as the B2E project area (Fig. C1). Nonetheless, the GSCR landscape is comprised of vegetation and other environmental conditions typical of the B2E landscape, so it was determined that predictive models developed for the GSCR landscape could be reliably applied to the B2E project area. The development of the predictive model for marten within the GSCR landscape and its application within the B2E landscape were conducted by Thomas A. Kirk, Pacific Southwest Research Station. Multiple approaches were tested in the course of developing the final models presented here, including models of habitat at larger scales and the inclusion of other variables. Early modeling efforts are described in Appendix A.

Methods

Home Range Regression Model Development

A two-stage modeling approach was used to first identify areas with any probability of detection, and then to estimate the probability where it can occur. Specifically, the first stage of the modeling process involved determining an elevational cut-off for the inclusion of data points used in the development of the revised 1 km-scale model. Elevations of survey locations ranged from 1280 – 7580 ft. The marten's preference for higher elevation coniferous forests in the mountains of northeastern California is well documented in natural history accounts (Grinnell et al. 1937) and more recent studies (Simon 1980, Spencer et al. 1983, and Ellis 1998). They have developed specialized subnivean hunting techniques and morphological adaptations which allow them to maintain their home ranges during winter, despite large annual snowfall levels. Recent province-wide systematic sampling of forest carnivores indicates martens are rarely detected at lower elevations in the vicinity of the B2E project area (Zielinski et al. 2005). Logistic regression models accounting for imperfect detection probability included elevation as the sole predictor variable, with sample sites classified into 500 ft. elevation increments. We then used only those sites above the elevation threshold in the second stage of modeling to predict the probability of occurrence based on habitat characteristics.

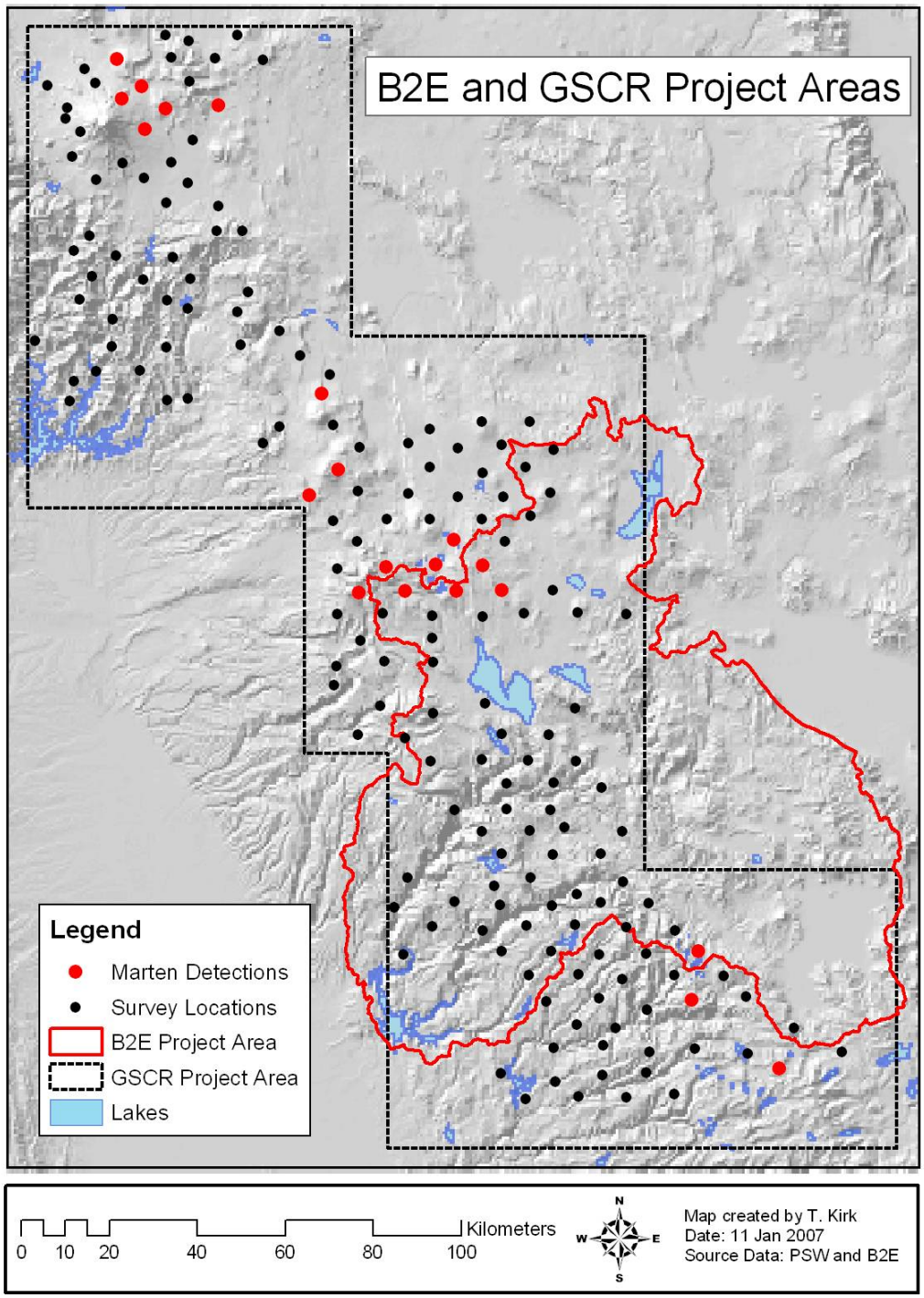


Figure C1. Location of the marten survey area (GSCR) and sample sites and the B2E beta test project area. Sample sites with detections are indicated.

For the second analysis stage, we included an array of vegetation and environmental variables in a multivariate logistic regression accounting for imperfect detection probability (Table C1). Habitat suitable for reproduction was limited to conifer and riparian types, and the

inclusion of size classes to 4 (11-24 in dbh) and 5 (> 24 in dbh) and canopy cover classes M (40-60%) and D (>60%). Red fir, White fir, and Lodgepole pine habitats were the only exceptions, where size class 6 was also included as suitable reproductive habitat based on CWHR. Structured Query Language (SQL) was used to select specific habitat attributes including: specific forest types (RFR, WFR, LPN, SCN, and MRI), canopy covers classes (M and D), and size classes (4, 5 and 6). These variables were represented as the % of the area within a 1 km radius scale using Arc Macro Language (AML) programs and FRAGSTATS spatial analysis software.

Four non-vegetative variables were included in the second stage regression model: elevation, precipitation, road density, and stream density. The revised model also included the variable ROAD, kilometers of road per square kilometer. We combined two comprehensive road layers, provided by the Plumas National Forest and Lassen National Forest in 2002, and removed all duplicate roads by clipping coverages to their respective boundaries using ArcInfo and ArcEdit. Roads in this coverage included: main highways, paved, gravel, and logging roads. The variable ROAD was assessed at the 1 km radius scale using an AML program which computed kilometers of road per square kilometer.

Table C1. Predictor variables used in developing the 1 km-scale model for application in the B2E landscape.

Variable Name	**Description**
RFR*	Percent Red fir forest in the landscape
WFR*	Percent White fir forest in the landscape
LPN*	Percent Lodgepole pine forest in the landscape
SCN*	Percent Sub alpine conifer forest in the landscape
MRI*	Percent Montane riparian forest in the landscape
SZ_4	Percent CWHR size class 4 forest in the landscape
SZ_5	Percent CWHR size class 5 forest in the landscape
CC_M	Percent CWHR moderate canopy forest in the landscape
CC_D	Percent CWHR dense canopy forest in the landscape
STREAM	Density (km/km^2) of streams
ROAD	Density (km/km^2)of roads
ELEV	Elevation (meters) at center of sample unit
PRECIP	Average precipitation occurring as rain (mm)

* CWHR forest types, size classes 4, 5, and 6, and canopy cover M and D.

A digital elevation model (DEM) with 100 meter cell resolution was created for the original study area and the B2E landscape by mosaicing one hundred ninety-four United States Geological Survey (USGS) DEMs together and clipping them to the study area boundaries. Elevations were determined for the central station of each sample unit using the LATTICESPOT command in ArcGrid v. 8.3 (ESRI 2002).

The variable STREAM was defined as the length of stream channels in kilometers per square kilometer. Stream channel lengths were considered measures of riparian habitat which have been identified as important for martens in the Sierra Nevada (Simon 1980**,** Spencer et al. 1983). The FLOWDIRECTION, FLOWACCUMULATION, STREAMLINK, and STREAMLINE commands were used in ArcGrid to delineate stream channels (ESRI 2002). The FLOWACCUMULATION command used a weight grid to determine realistic precipitation values (ESRI 2002). The weight grid used represents

the average annual rainfall of the study region over a sixty year period (1960-1990) (Daly et al. 1994).

The conventional approach to determining stream channel networks with raster data (DEM) uses an eight flow direction matrix (D8). A large body of research has identified limitations of the rather coarse drainage structure obtained with this method. In areas of equal elevation it is not possible to determine if a river continues to flow or a lake forms (Turcotte et al. 2001). The hydrologic network, hereafter referred to as the streams coverage, was clipped using a comprehensive coverage of lakes to remove areas containing flat surfaces that resulted from the D8 modeling process. The resulting coverage accurately depicts only streams and rivers, with no differentiation of stream orders. In ArcInfo, a moving window calculated the total amount of streams. This stream grid was then divided by the area within the analysis circle (314 ha) to yield kilometers of stream per square kilometer.

The PRECIPITATION grid was created using PRISM precipitation data (Daly et al. 1994). PRISM is an expert system that uses point data and a DEM to generate gridded estimates of climate parameters at a 2 km resolution. The LATTICESPOT command was used to determine average yearly precipitation at each sample unit. The amount of annual precipitation defines ecological gradients in mountainous regions and affects the presence of vegetation types preferred by martens. Inclusion of climatic variables, such as precipitation, in large-landscape modeling can identify regions with large annual snowfall which marten's may have a competitive advantage over other forest carnivores. It was assumed precipitation above 6000 ft. largely occurred as snow (Bailey et al. 1994).

Landscape Predictions

The landscape predictions in the B2E landscape were based on habitat data provided by B2E modelers, with all other variables generated using the same approaches used to generate variables on the GSCR sample study area. The forests of size class 5 variable (SZ_5) was created with SQL statements using B2E modeled vegetation data. The lack of habitat data *outside* the B2E project area posed a challenge because landscape-scale habitat assessments were originally computed using the spatial analysis program FRAGSTATS, which requires that data exist for the entire landscape within the moving window. Habitat outside the boundary could not be included in the moving window assessment, resulting in missing values. The missing values were not extrapolated using ArcInfo, instead they were replaced with zeros prior to computing moving window percentages for the entire landscape; this resulted in a slight, but acceptable, reduction in habitat suitability values in some locations along the boundary of the B2E project area. Moving window grids were computed for ROAD, STREAM, and SZ_5 variables using FRAGSTATS for the B2E project area. The DEM used in the spatial implementation of the regression models was modified. All lakes were reclassified as NoData, effectively removing them from consideration as habitat.

Results

Home Range Occupancy Regression Model

The logistic regression of marten occurrence and elevation indicted that survey sites above 5000 ft had a greater correct classification of marten detections than those below 5000 ft. Probability of occurrence was calculated for sites above and below 5000 ft using maximum likelihood methods in a SAS program (J. Baldwin, USDA Forest Service, unpublished data; SAS

1999) which resembles the method advocated by MacKenzie et al. (2002). The probability of occurrence > 4500 ft = 0.24 > 5500 = -0.21- > 5000 = 0.3, > 6000 = -0.08 for marten at a sample unit under 5000 ft was 65.6 %, compared to 99.3 % for sample units above 5000 ft (P = 0.0015, t = 3.68, df = 20). Of the 184 sample sites in the GCSR study area, 100 were > 5000 ft in elevation; only two of the 20 marten detections in the original dataset were below 5000 ft, leaving 18 sites with detections in the second stage of analysis. This essentially resulted in the removal of small amounts of what would have otherwise been classified as low-to-moderate suitability reproductive habitat primarily near Sierraville.

Based on the 100 sample sites > 5000 ft elevation, the second stage regression model had relatively high model selection uncertainty (Burnham and Anderson 1998); five models had an AIC_c difference of < 2 (Table C2). The first and fifth models were very similar in composition and overall model performance; both models contained elevation, stream density, and road density, with the only difference being tree size class (size class 4 or 5 and 6). These two models also had very similar kappa statistics (the proportion of predictions that were accurate based on the sample data): the model based on size class 4 (> 28 cm dbh; > 11 in dbh) had a kappa statistic of 0.43, and the model based on size class 5 (> 61 cm dbh; 24 in) was = 0.43. The model including size class 5 and 6 (SZ_5) was chosen as the final model to represent marten *reproductive habitat* based on the importance of older forests in providing essential maternal dens and rest sites. Forest size class, elevation, and stream were all positively associated with marten occurrence; road was negatively associated.

Table C2. Top five models of marten occurrence based on AICc values.

Model Number	**Variables**	**AIC_c**	**Δ AICc**
49	SZ_4 ROAD STREAM ELEV	72.685	0
47	SZ_4 STREAM ELEV	73.133	0.448
74	ELEV ROAD STREAM	73.665	0.979
65	CC_D ELEV	73.914	1.229
55	SZ_5 ROAD STREAM ELEV	74.462	1.776