The Importance of the Individual Legacy Old Growth Tree in the Maintenance of Biodiversity in Commercial Redwood Forests: A Report to Save-the-Redwoods League

M.J. Mazurek and William J. Zielinski

Recommended Citation:
Mazurek, M.J. and William J. Zielinski. 2003. Distribution and the importance of the individual legacy old growth tree in the maintenance of biodiversity in commercial redwood forests: A report to Save-the-Redwoods League. USDA Forest Service, Pacific Southwest Research Station. Arcata, CA.

The Importance of the Individual Legacy Old-growth Tree in the Maintenance of Biodiversity in Commercial Redwood Forests

FINAL REPORT

April 29, 2003

M.J. Mazurek
Pacific Southwest Research Station
US Forest Service
1700 Bayview Dr.
Arcata, CA 95521
707-825-2995
(mmazurek@fs.fed.us)

William J. Zielinski
Pacific Southwest Research Station
US Forest Service
1700 Bayview Dr.
Arcata, CA 95521
707-825-2959
(bzielinski@fs.fed.us)

SUMMARY

We investigated the use of individual legacy old-growth redwood trees by wildlife and compared this use to randomly selected commercially-mature trees within stands managed for timber production. Legacy trees have, for one reason or another, been spared during harvest or have survived stand-replacing natural disturbances. We hypothesized that wildlife activity would be greater at legacy trees compared to other non-legacy trees. Our goal was to provide scientific information about the use of legacy trees that can be applied to conservation planning and forest management on public and private lands in the redwood region. During the spring of 2001 and 2002 we selected and paired 30 individual legacy trees with 30 control, non-legacy trees for sampling and analysis. At each legacy/control tree pair we sampled for bats using electronic bat detectors, for small mammals using live traps, for large mammals using remote sensor cameras, and for birds using time-constrained observation surveys. We chose these groups of animals for study, because they possess sufficient mobility to move within the environment and to select from a variety of habitat elements. Legacy old-growth trees containing basal hollows were equipped with 'guano traps'; monthly guano weight was used as an index of roosting by bats. In addition, 100 guano pellets were selected for species identification using new genetic techniques. We collected vegetation data to characterize the stand characteristics in the immediate vicinity of each legacy and control tree. The diversity and richness of wildlife species recorded at legacy trees was significantly greater than at control trees (Shannon index = 2.85 vs. 2.16; species = 41 vs. 24, respectively). The index of bat activity was significantly greater at legacy trees compared to control trees. Every basal hollow and every fire-scarred cavity sampled contained some guano and genetic methods confirmed their use by 4 species of bats. We observed 24 species of birds and mammals at legacy trees compared to 10 species at control trees, as a result of the time-constrained observation surveys. There were a greater number of individuals (primarily birds of the bark gleaning foraging guild) observed at legacy trees compared to control trees and they spent a greater amount of time at legacy trees compared to the controls. Vaux's swifts, pygmy nuthatches, and violet-green swallows were observed nesting in legacy trees. We found no statistical differences between legacy and control trees in the numbers of small mammals captured or in the number of species photographed using remote cameras, though insectivores were captured more often at the base of legacy trees. As measured by species richness, species diversity, and use by a number of different taxa, legacy trees appear to add important habitat value to redwood forests managed for timber. The use of legacy trees by wildlife was demonstrated by evidence of their nesting, roosting and resting, which were not observed at control trees. This difference is probably related to the structural complexity offered by legacy trees. The presence of a basal hollow, which only occur in legacy trees, was the feature that appeared to add the greatest habitat value to legacy trees, and to commercial forest stands. Basal hollows were used by every taxa sampled, but appear to be particularly important to bats and birds. Because of their rarity in commercial forests, the first step in the management of legacy trees is to determine their locations and protect them from logging or from physical degradation of the site. Because legacy redwoods with *basal hollows* are even more rare, locating and protecting these should be the highest priority. The re-introduction of fire will be necessary to ensure the future recruitment of basal hollows. The results of our study call for an appreciation for particular individual trees as habitat for wildlife in managed stands. This is a spatial resolution of analysis that, heretofore, has not been expected of managers. Our results suggest that the cumulative effects of the retention, and recruitment, of legacy and residual trees in

commercial forest lands will yield important benefits to vertebrate wildlife and other species of plants and animals that are associated with biological legacies.

INTRODUCTION

The conservation of old-growth forests has received much attention in recent decades with the heart of the debate focusing on the value of old-growth as habitat for wildlife. Structural components of old-growth forests, such as snags, living trees with decay, hollows, cavities and deeply furrowed bark, provide habitat for many species (Bull et al. 1997, Laudenslayer 2002). However, remnant old-growth trees and snags are rare in landscapes that are intensively managed for wood products. Homogenous young stands without structural complexity reduce the habitat value for species associated with old-growth forests (McComb et al. 1993). The value of residual and individual old-growth structures to wildlife in managed landscapes has received little attention by land managers or researchers (Hunter and Bond 2001).

In some forest ecosystems, lands managed for timber production occupy all but a small portion of the landscape. In coast redwood (*Sequoia sempervirens*) forests, only 3% - 5% of the original old-growth redwood forest remains, largely as fragments scattered throughout a matrix of second and third-growth forests (Fox 1996, Thornburgh et al. 2000). The remnants vary in size from large, contiguous forest patches protected in state and federal parks to patches of only a few hectares in size, to individual legacy trees in managed stands. Individual old-growth trees that have, for one reason or another, been spared during harvest, or have survived stand-replacing natural disturbances, are referred to as “legacy” trees (Franklin 1990). We envision legacy trees as having achieved near-maximum size and age, which is significantly larger and older than the average trees on the landscape. This distinguishes them from ‘residual’ trees, which may also have been spared from harvest but which may not always be significantly larger and older than the average trees in the landscape.

The rarity of old-growth forests in managed landscapes combined with the rising economic value of old-growth redwood increases the likelihood that legacy stands and individual legacy trees will be harvested. At this time, there is no specific requirement for the retention of legacy trees during timber harvests on private or public lands in California. Potentially valuable habitat may be lost with every proposed harvest. Exceptions occur on lands owned by companies that are certified as sustainable forest managers (e.g., Mendocino Redwood Company) and as such, are required to maintain and manage legacy old-growth trees (SmartWood Program 2000). Other exceptions may occur if companies have a ‘no-cut’ policy for trees that they consider are ‘old-growth’. However, the definition of old-growth varies widely and probably does not protect all individual legacy trees.

The majority of lands in the redwood region are in commercial timber production. Wildlife most closely associated with older forests may rely on legacy structures as important habitat elements within intensively managed landscapes (Lindenmayer and Franklin 1997, Thornburgh et al. 2000). A number of new studies have demonstrated the importance of legacy and residual trees to wildlife. In Douglas-fir (*Pseudotsuga menziesii*) forests, flying squirrel abundance and nest locations were most often found in second-growth forests containing residual trees (Carey et al. 1997, Wilson and Carey 2000). In addition, horizontal structural complexity increased in stands containing residuals (Zenner 2000). In eastern hardwood forests, residual trees provided important habitat elements to forest birds in regenerating clear-cut stands (Rodewald and Yahner 2000). In young and homogenous stands of regenerating redwood forests, residual old-growth legacy trees appear to be important roosting, foraging, resting, and breeding sites for spotted owls (*Strix occidentalis*), fishers (*Martes pennanti*), bats, vaux swift's (*Chaetura vauxi*), and marbled murrelets (*Brachyramphus marmoratus*) (Folliard 1993, Klug unpubl. data, Thome et al. 1999, Zielinski and Gellman 1999, Hunter and Mazurek submitted). In the preceding studies, the value of legacy structures was identified only as a consequence of studies on the autecology of individual wildlife species. Our goal was instead to focus our research effort on the rare habitat element itself (the legacy tree) and determine how a variety of wildlife taxa may use it differently than other trees in a stand.

Planned harvest rotations on most commercial forestlands will not permit trees to mature to their age of maximum value to wildlife. The retention of legacy trees in commercial stands may add considerable habitat value with little effort. Without a clear understanding of the value of legacy trees to wildlife, however, we risk losing these slowly renewing elements in the short term, and will lack the scientific basis to propose their management in the future. Our goal is to characterize the use of individual legacy redwood trees in commercial redwood forests and to compare this use to the use of nearby non-legacy trees selected from the managed stand. Contrasts of these results will help us understand the habitat values added to managed timberlands when biological legacy structures are retained.

METHODS

Study Area

The research was conducted in Mendocino County, California in the central portion of the redwood range (Sawyer et al. 2000), within the Northern California Coast ecoregion (Bailey 1994). The study area was approximately 1,750 km^2 in size and included lands owned and managed by the Mendocino Redwood Company (MRC), the California Department of Forestry and Fire Protection - Jackson State Demonstration Forest (JSDF), and Hawthorne Timber Company, LLC (HTC)/Campbell Timberland Management (Campbell). These landowners manage approximately 65% of all coast redwood timberlands in Mendocino County.

Elevations ranged from 44 m to 576 m. Seasonal temperatures vary little and range from 18.2^{o}C to 9.4^{o}C in summer and from 13.3 ^{o}C to 5.5 ^{o}C in winter. Forests in this region are dominated by coast redwood. Other common trees species include Douglas fir, grand fir (*Abies grandis*), tan oak (*Lithocarpus densiflora*), bigleaf maple (*Acer macrophyllum*), and Pacific madrone (*Arbutus menziesii*).

MRC lands comprise 94,089 ha of timberlands in Mendocino and Sonoma Counties and are certified as sustainable under the Forest Stewardship Council and the Smart Wood Programs (Certificate Number: SW-FM/COC-128). Sustainable forest methods include the protection of individual old-growth legacy trees. HTC/Campbell land includes 74,264 ha of commercial redwood forest from which the remaining old-growth stands were harvested in the 1970s and 1980s. Residual old-growth is in the form of legacy trees and snags. HTC/Campbell foresters generally leave remnant old-growth trees, damaged trees, and large or rare hardwoods. JDSF is 20,639 ha of primarily second and third-growth redwood and Douglas-fir forests. Under a new management plan, old-growth reserves and individual old-growth trees (trees present before the first historic logging, circa 1860) are preserved from harvest unless they pose a potential health risk during timber operations. Silvicultural prescriptions for each of the ownerships include about equal measures of even and uneven-aged harvest.

Site and Tree Selection

For the purposes of our research, we defined a legacy tree as any old-growth redwood tree that was > 100 cm diameter at breast height (dbh) and possessed the following set of characteristics: deeply furrowed bark, reiterated crown, basal fire scars, platforms, cavities, and one or more 'dead-tops'. Many legacy trees also had basal hollows ('goose pens') but absence of this trait did not exclude a tree from consideration.

In 2001, 20 legacy trees and 20 control trees were selected in May and June using information provided by the landowners/managers and by our own reconnaissance. In the summer of 2002, we added 10 legacy trees and 10 control trees, bringing the total number of trees to 60 (Figure 1). For a legacy tree to be selected for study, the stand surrounding it must not have undergone timber operations at least one year prior to sampling nor could the stand have been proposed for alteration during the course of the study. The most recent harvest method varied from stand to stand but the majority of stands (n = 27) had been harvested under some type of selection method.

Legacy trees included those with and without basal hollows. Basal hollows occur in large, old, redwoods and are important roost sites for bats (Gellman and Zielinski 1996, Zielinski and Gellman 1999). These structures develop over centuries as periodic fires produce repeated scarring and healing (Finney 1996). To qualify as a hollow, the internal height must have been greater than the external height of the opening. Otherwise, the structure was considered a fire scar when the cambium of the tree showed clear signs of affects from fire. We assumed that legacy trees did not need to have basal hollows to be of value to wildlife, therefore, 15 legacy trees were selected that contained hollows and 15 did not. Trees were further classified as having a single-stem structure (originating from a single structure), a multi-stem structure (originating from multiple sprout growth), or a snag-like tree structure (typically a broken top tree containing some dead wood with few, if any, large lateral branches).

Control trees were selected by locating several (range = 3 – 10) of the largest commercially-mature trees in the immediate vicinity (from 50 – 100 m) of the legacy tree. The set of candidates was reduced by eliminating from consideration all trees that did not share the same general environmental features with the legacy tree (i.e., similar distance to water and roads, similar slope and aspect). One control tree was then randomly selected from the candidates that remained.

Wildlife Sampling

General

An initial inspection was conducted of all trees that contained basal hollows (n = 15) and fire scars (n = 14) by examining the interior of the hollow or fire scar using a flashlight. These surveys were conducted during the initial portion of the study so as not to interfere with protocols designed to sample focal taxa (i.e., bats, small mammals). The hollow ceiling was searched for bats and nests of birds, woodrats (*Neotoma fuscipes*) and other mammals. The interior substrate of the hollow or fire scar was inspected for evidence of use (e.g., feces, feathers, hair, prey remains). Legacy and control trees were also visited regularly during the application of other taxa-specific survey methods. Each time a tree was visited, field personnel would conduct an initial inspection for signs of use by wildlife.

Bats

Acoustic Sampling

We used Anabat II bat detectors to record bat vocalizations at the trees, following the methods of Hayes and Hounihan (1994). The total number of vocalizations ('bat passes': Krusic et al. 1996, Hayes 1997, Zielinski and Gellman 1999) was used to compare activity in the immediate vicinity of the legacy and control trees. To account for temporal variations in bat detections, we used a paired design and sampled simultaneously at the legacy and control trees at each site (Hayes 1997). Bat detectors were placed 1.4 m above the ground and at a 45° angle directed at the tree, a configuration that maximizes detection rates (Weller and Zabel 2002). Each pair was sampled 4 times for 2 nights each, between either June (2001) or July (2002) and September.

Guano Sampling

Guano sampling occurred only at trees containing basal hollows. All legacy trees that contained basal hollows (except tree 390) were sampled for guano following the methods outlined by Gellman and Zielinski (1996). The oven-dried weight of guano served as an index of bat use. In 2001, we installed guano traps in 11 legacy trees in July and August and 4 additional traps were installed in May 2002. To determine if bats would use fire-scarred legacy trees, 3 were also equipped with guano traps in July 2002.

A sample of 100 guano pellets were selected and sent to Dr. Jan Zinck at Portland State University for species identification. We selected pellets for analysis by first choosing one pellet from each tree sampled each year, then selecting one pellet per tree sampled each season (i.e., spring and summer), until we reached 100 pellets. All trees sampled contributed at least one pellet for analysis. Dr. Zinck has developed species-specific genetic markers from a 1.56 kilobase region of mitochondrial DNA spanning the majority of the 12S and 16S ribosomal RNA genes (Zinck and Ormsbee 2001). She has validated this technique by matching the DNA sequences from a wing biopsy with the sequences from DNA extracted from guano produced by the same individual. Eight species that occur in our study area can be identified using this method and 1 group of 3 species can be distinguished from others but not from each other.

Small Mammals

We sampled non-volant mammals using live traps. Each tree selected for study was sampled using 6 Sherman live traps (8 x 9 x 23 cm) and 2 Tomahawk live traps (13 x 13 x 41 cm) placed at the base. Also, 2 Sherman traps and 1 Tomahawk trap were elevated 1.5 m and attached to the sides of the tree in an attempt to capture arboreal mammals. Traps contained seed bait and a small amount of polyester batting for insulation and bedding. We recorded the species, age, sex, reproductive status, and weight (g) of each mammal captured. A small amount of fur was clipped from the rear hindquarter (on the left if captured at the legacy tree; on the right if captured at the control) to distinguish individuals. A trapping session consisted of 5 consecutive days and we conducted two trapping sessions at each tree. Each tree selected for study in 2001 was sampled once in July and once in August; trees selected for study in 2002 were sampled from June through August.

Observation Surveys

Time-constrained Visual Observation

We observed each legacy and control tree for evidence of use or occupancy by wildlife. In 2001 we conducted one 30 – min. observation session in each of 3 time intervals: (1) two hours centered at dawn, (2) mid-day centered between 1100 – 1400 h, and (3) two hours centered at dusk. In 2002, we conducted one 30 – min. observation session within two hours of sunrise and sunset. All wildlife observed on the tree or within 5 m of the tree was recorded. Each time an animal was observed, the observer would note 1 occurrence (incident) per animal, the species, the amount of time spent at the tree and the activity. Observations were categorized as perching, fly/perch, foraging, roosting, fledging, or ‘present’ (for non-avian species).

Remote Photographic Sampling

In 2001, we tested the use of remote camera sampling to detect medium and large mammals at a subsample of trees. We used the Trailmaster TM550 (Trailmaster Infrared Trail Monitors, Lenexa, KS) passive infrared trail monitor with attachments to a 35-mm camera. When the trail monitor sensor detected a change in heat and motion the sensor triggered the camera; any warm animal that moved in front of the sensor triggered the camera. We set sensors and cameras a few meters from the tree and directed the sensor at the base. We restricted the field of view of the sensor such that only animals directly in front of the tree base would be detected.

In 2001, 4 pairs of legacy and control trees were surveyed from 21 – 34 days resulting in 102 camera survey days. In 2002, the 20 additional trees that were selected for study and 36 of the 40 trees selected for study in 2001 were sampled for three consecutive weeks between April and September resulting in 1,176 camera days. Cameras were visited one day after installation, to check that they were operating, and then every 5 days. Cameras operated simultaneously at each legacy and control tree in a pair. In 2002, we compared photographs with sensor data to obtain the time and date each photo was taken. Each photo of an animal was considered ‘1 detection’, but was restricted to include only one photo per species per tree per 24-hour period. This eliminated instances where animals, typically rodents, would be present at the tree for several hours, thus triggering the camera repeatedly.

Vegetation Sampling

We collected physical measurements of each tree and of all basal hollows using variables described in Gellman and Zielinski (1999). We also measured vegetation attributes in the immediate vicinity of a subsample of trees to determine whether the structure of the vegetation surrounding legacy and control trees were different. If such differences exist, it is possible that they would affect the use of the trees, independent of the characteristics of legacy and control trees themselves. Fifteen pairs of trees were sampled (5 randomly selected from each ownership). We used variable-radius plot methods to estimate basal area (20-factor prism), and each tree that was included in the prism sample was also identified to species and its diameter, height, and condition was recorded. Within an 11.3 m fixed radius plot, and centered on the legacy or control tree, all logs > 25.4 cm diameter were recorded by species and their length and diameter measured. Canopy, shrub, herbaceous, and ground cover (duff and downed wood) were estimated visually within a 5 m-fixed radius plot.

Species Diversity

We used the Shannon index (Magurran 1988:34) to characterize the diversity of species detected at legacy and control trees. Diversity indices were calculated separately for the results from the time-constrained observation surveys, remote camera surveys, small mammal sampling and for these 3 survey methods combined. We used the number of captures (small mammal surveys) and the number of detections (observation and camera surveys) to calculate the proportion of individuals observed for all species. We also calculated species evenness, a measure of the ratio of observed diversity to maximum diversity (Pielou 1969), for each survey type described above.

Statistical Analyses

Species diversity indices were statistically compared using the methods of Hutcheson (1970), which calculates a variance for each diversity statistic then provides a method of calculating ‘t’ values to test for significant differences between samples (Magurran 1988:35). Small mammal trapping, time-constrained observation and remote photograph (large mammals only) data were analyzed using matched-pair t-tests. The response variables were transformed (ln), when necessary, to meet the assumptions of normality. We were unable to normalize the results of the photo (all animals) data and thus used a non-parametric signed-rank test (S) to compare the number of photographs (detections) at legacy and control trees. We used a mixed-effects model to compare bat detections between legacy and control trees. Data were transformed (ln bat passes + 1) to meet the assumptions of normality. Descriptive statistics were used to compare the amounts of guano collected at hollow-bearing and fire-scarred trees. Correlation analyses were used to determine associations between mean guano weights and basal hollow dimensions.

Tree characteristics, log characteristics, canopy cover, percent shrub and herb cover data were analyzed using matched-pair t-tests. The response variables were transformed, when necessary, to meet the assumptions of normality. Chi-squared goodness of fit tests were used to evaluate differences in the amount of ground cover (downed wood and duff), tree species, log species, and condition characteristics. All statistical analyses were conducted using SAS 8.1 (SAS Institute, Cary, N.C.). Statistical significance was implied if alpha was < 0.05.

RESULTS

As expected, legacy trees were larger in diameter and height than the control trees (Table 1). However, the mean diameter of control trees was 72.5 cm dbh, which is considered a commercially-mature size (R. Shively pers. comm., 2001, Mendocino Redwood Company). Physical characteristics of individual legacy and control trees, and the basal hollows, fire scars and other structures in legacy trees are described in Appendix I.

General Wildlife Observations

Initial examinations of the trees indicated that most of the hollows and fire-scars in legacy trees (n = 19; 63%) had evidence of small mammal use on the basis of the discovery of feces, food remains, or nest evidence (usually dusky-footed woodrat middens, n = 5). Six hollows (40%) contained guano, evidence of bat use. In addition, 4 'short-eared' bats of the genus *Myotis* (species of the genus *Myotis* are difficult to distinguish if not in the hand, however it is possible to designate as short or long-eared) were observed day-roosting in tree 336 on 23 May 2002. Four hollows or fire-scarred legacy trees (13%) had evidence of use (i.e., claw marks) by large mammals. In addition, the debris within the hollow of tree 390 contained a depression that was likely a rest site used by a large mammal. The detection of feces or nests indicated that 10 legacy trees (33%) were used by birds.

The general inspection of trees resulted in several noteworthy observations of reproductive activity:
(1) On 16 June 2002, 2 adult pygmy nuthatches (*Sitta pygmaea*) were observed repeatedly entering and exiting a cavity in legacy tree 400. The birds were observed entering the cavity with food, which was followed by vocalizations of young.
(2) Legacy tree 382 contained a large cavity that was occupied by barn owls (*Tyto alba*) during both years of the study. Fresh whitewash and food pellets were observed during each visit to the tree. Coincidently, this same tree contained a different cavity that was used by violet-green swallows (*Tachycineta thalassina*) for nesting.
(3) On 16 July 2002, violet-green swallows were observed repeatedly entering and exiting a cavity in tree 350. These behaviors, and the time of year, suggest the birds were nesting within the cavity (B.Williams, pers. comm., Williams Wildland Consulting Inc.).
(4) Vaux's swifts nested for two consecutive years in the hollow of tree 354.

Bats

Acoustic Sampling

We recorded a total of 10,799 bat passes over the two sample years. The mean index of bat activity was significantly greater at the legacy trees compared to the control trees ($F_{1, 45.7} = 17.66$, $P < 0.0001$) (Table 2, Figure 2). The mean index of bat activity at legacy trees with and without hollows was 34.8 (SD = 33.4) and 22.6 (SD = 15.9), respectively, a difference that was not statistically significant ($t = 1.27$, $P = 0.21$).

Guano Sampling

We collected guano monthly from July – October 2001 and April – October 2002, unless traps were rendered ineffective (i.e., torn down by animals, rain). All hollows showed evidence of bat use during some portion of the survey period (Table 3). Surprisingly, all fire scars sampled also showed evidence of bat use during some portion of the survey period (Table 4).

Average guano weight declined from August to October during both years (Figure 3). Mean guano weight for August and September 2001 positively correlated with internal hollow volume ($r^2 = 0.71$, $P = 0.02$) when the tree containing the maternity colony (see below) was excluded. There were no correlations between mean guano weights and hollow volume in 2002 when weights were averaged across months ($r^2 = 0.14$, $P = 0.62$), nor when years were combined ($r^2 = 0.54$, $P = 0.18$). Mean guano weight for the months of July, August and September was not significantly correlated with the difference between the internal height of the hollow and the external height of the hollow opening ($r^2 = 0.78$, $P = 0.085$).

Guano weight indicated that tree 384 had the greatest amount of use by bats (Table 3). The large quantity of guano, an observation on 23 July 2002 of a large number of bats in the hollow, and the discovery of a dead juvenile long-legged myotis (*Myotis volans*) on 31 July 2001 all indicate that this tree was used as a maternity colony roost.

Sixty-eight of the 100 guano samples submitted for analysis amplified adequate amounts of DNA for species analysis. Four species were verified to use legacy trees, with the long-legged myotis (*Myotis volans*) the most common (46%) (Table 5). The California bat (*Myotis californicus*) was the species detected at the greatest number of hollow-bearing trees (73%) and the total number of trees (hollow-bearing and fire-scarred [66%]). The big brown bat (*Eptesicus fuscus*) and the California bat were the only species identified from the 4 guano samples that originated from fire scars (Table 5).

Guano traps were also effective at capturing the feces of other species of wildlife. Birds used 5 hollows more frequently than others (Table 3). We may have underestimated use by bats in these hollows, as the bird feces were abundant and may have obscured guano. Small mammal feces (probably from woodrats and mice) were also often found on the traps. At tree hollow 354 a dehydrated bird egg was discovered that most closely matched that of a hummingbird.

Small Mammal Sampling

There were a slightly greater number of total small mammal captures at legacy trees compared to control trees (Table 6). There was also a greater number of individuals captured at the legacy trees compared to control trees, though this relationship was not statistically different ($t = 0.5$, $P = 0.62$). Two of the insectivores (shrew mole [*Neurotrichus gibbsi*] and Trowbridge's shrew [*Sorex trowbridgii*]) were the only species that appeared to be trapped more commonly at the base of legacy trees.

Observation Surveys

Time constrained observations were conducted from 8 July – 9 September 2001. Due to logistical limitations and the constraints of other sampling requirements, not all trees were sampled equally during the first season. In 2001, we conducted 97 surveys for a total of 48.5 observation hours. In 2002, surveys were conducted from 22 May – 22 August. Each legacy and control tree was sampled at least twice, resulting in a total of 132 surveys. Over the two-year sampling period we conducted 114.5 hours of surveys (Table 7).

We tallied the number of incidents (number of times a species was present on the sample tree) and the total amount of time spent by the subject animal at the focal tree (Table 7). There was a significantly greater amount of incidents ($t = 16.6$, $P < 0.0001$) and time spent ($t = 4.05$, $P = 0.0004$) at legacy trees compared to control trees. Wildlife (primarily birds) were observed about 9 times as frequently at legacy trees compared to control trees (Table 7). Of the activities observed, 82% was attributed to perching or flying. There was twice as much foraging activity at legacy trees (22 incidents) compared to control trees (10 incidents). There were 5 incidents of birds night-roosting at legacy trees and none at control trees. There were also more species observed at legacy trees compared to control trees (Table 8). Species often associated with large woody structures (i.e. woodpeckers, nuthatches, and swallows) were observed only at legacy trees; Acorn woodpeckers used tree 358 as a food storage location (i.e., granary). The majority of species observed were pygmy nuthatches, violet-green swallows, or unknown passerines. The behavior of the nuthatches and the swallows suggested that they were nesting (nuthatches in tree 366 and swallows in trees 382 and 390).

Remote camera observations were conducted primarily during the 2002 field season. In 2001, we developed 11 photos containing animals at 4 legacy trees and 5 photos containing animals at 4 control trees. We recorded the presence of one species, the western gray squirrel (*Sciurus griseus*), not previously captured or observed at legacy trees. All other photos were of mammals that were captured during small mammal surveys. Camera data for 2001 was not compared to sensor results, so we do not have documentation on the total number of photos of each species nor the time photos were taken. For this reason, and because so few trees were sampled in 2001, we present the results for 2002 only (Table 9).

We photographed 18 species at legacy and control trees (Table 9). Brush rabbit (*Sylvilagus bachmani*), Sonoma tree vole (*Arborimus pomo*), a bat (unknown species) and winter wren (*Troglodytes troglodytes*) were detected only at legacy trees. Raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), and western red-backed vole (*Clethrionomys californicus*) were detected only at control trees. All other species of mammals were photographed at both legacy and control trees.

The total numbers of detections (photos) was 84 at legacy trees (mean = 5.25/species) and 103 at control trees (mean = 7.36/species); the means were not statistically different ($S = 6$, $P = 0.86$). When we restricted detections to include only medium and large mammals (the species that could only be detected using cameras) the total numbers of detections were 14 (mean = 2.8/species) and 10 (mean = 1.4/species) at legacy and control trees respectively, but were not statistically different ($t = 1.15$, $P = 0.26$).

Vegetation Sampling

There were no differences in the vegetation characteristics in the area immediately surrounding the legacy and control trees. Basal areas, tree diameters, tree heights, log volumes, canopy cover, shrub cover, and herbaceous cover were statistically indistinguishable (Table 10). In addition, there were no significant differences in tree species, tree condition, log species, log condition, the amount of duff, or the amount of downed wood (Table 11). Thus, we concluded that the vegetation structure of the forest in the immediate vicinity of each tree of a pair was probably not responsible for differences in the use of the legacy and control trees.

Diversity Indices

The number and diversity of species using legacy trees was greater than those using control trees. This was true whether we considered only the time-constrained observation surveys, the remote camera surveys, or when we combined the results from the time-constrained observation surveys, camera surveys, and small mammal trapping (Table 12). Species richness was nearly twice as great at legacy trees (n = 41) than at control trees (n = 24) for all surveys. Using data from the timed observation surveys only, the species richness was more than twice as great at legacy trees (n = 24) than at control trees (n = 10). The Shannon diversity indices were statistically higher at legacy trees (2.85) than control trees (2.16) for the combined surveys and for the observational surveys (camera and human observer) (Table 12), but we did not find differences in the richness or diversity of small mammals when this dataset was analyzed separately (Table 12). Evenness was greater at legacy trees compared to control trees for the camera surveys, small mammal surveys and for the combined surveys (Table 12).

DISCUSSION

As measured by species richness, species diversity, and use by a number of different taxa, legacy trees appear to add important foraging and breeding habitat value to redwood forests managed for timber. The use of legacy trees by wildlife was demonstrated by evidence of their nesting, roosting and resting, which were not observed at control trees. This difference is probably related to the structural complexity offered by legacy trees (Bull et al. 1997, Laudenslayer 2002). Control trees were smooth-boled with very few large horizontal limbs, few cavities, and no basal hollows. Legacy trees possess these structural features, which probably account for their greater attractiveness to a variety of wildlife species.

The presence of a basal hollow, which only occur in legacy trees, was the feature that appeared to add the greatest habitat value to legacy trees and, as a result, to commercial forest stands. Basal hollows were used by every taxa sampled, but appear to be particularly important to bats and birds. In addition to the fact that guano was collected at every hollow we sampled, individual bats were observed in hollows, and reproduction was documented. Use of basal hollows by bats has been observed in other redwood regions (Gellman and Zielinski 1996, Zielinski and Gellman 1999, Purdy 2002, Mazurek (a) in prep.) and there are several previous reports of basal hollows used by bats for reproduction (Rainey et al. 1992, Mazurek (b) in prep.). Hollows also appear to be important nest sites for some bird species, in particular Vaux's swifts (Hunter and Bond 2001, Hunter and Mazurek submitted). Because roost and nest availability can limit the populations of birds and bats (Humphrey 1975, Kunz 1982, Brawn and Balda 1988, Christy and West 1993, Raphael and White 1984), basal hollows may play a critical role in the redwood region if they provide roost and nest sites in forests that are otherwise deficient. The increased use of legacy trees by insectivorous birds and bats may also be because the rugosity of the bark may harbor a greater diversity and abundance of insects (Ozanne et al. 2000, Willet 2001, Summerville and Crist 2002). Bark gleaners, such as brown creepers (*Certhia americana*), have been correlated with the abundance of spiders and other soft-bodied arthropods that are significantly associated with bark furrow depth (Mariani and Manuwal 1990); this may also explain the disproportionate use of legacy trees by nuthatches and woodpeckers. Finally, basal hollows not only benefit the wildlife that use them but the trees in which they are found. The feces of animals that are attracted to hollows can be an important source of nutrients for trees that may be on nutrient-poor sites (Kunz 1982, Rainey et al. 1992).

The mammal data (bats excluded) did not suggest a disproportionate association with either legacy or control trees. Possible exceptions include two insectivores, which were captured more at legacy trees, and the dusky-footed woodrat, whose nests were found in 5 of 15 basal hollows. Shrew moles are associated with older forests (Raphael 1988, Carey and Johnson 1995) and are infrequently found in logged areas (Tevis 1956). Several studies also found that Trowbridge's shrews have a similar association with mature forest conditions (Gashwiler 1970, Hooven and Black 1976, Carey and Johnson 1995).

The camera data did not reveal disproportionate use of legacy trees by mammals, primarily because so many of the detections were of small rodents, which our trapping data had already indicated were found at legacy and control trees in similar numbers. When the small mammals are excluded, the number of detections of medium and large mammals was greater at legacy trees, but not statistically different. Relatively few mammalian carnivores were detected at either type of tree, perhaps because some species (i.e., the marten [*Martes americana*] and the fisher [*M. pennanti*]) are sensitive to forest habitat loss and fragmentation (Buskirk and Powell 1994) and have been either extirpated from the region (Zielinski et al. 2001) or are very rare (Zielinski et al. 1995). With the exception of the two insectivores and woodrats, none of the non-volant mammals we sampled appeared to be strongly associated with the legacy trees. Unlike the passerine birds -- which use the structurally complex bark of legacy trees for foraging and cavities for nesting -- and the bats, which roost in hollows and bark crevices, our data do not indicate that legacy trees have exceptional value for rodents or for the carnivorous mammals that still occur in the region.

Our conclusions about the value of legacy trees to wildlife in the redwood region are supported by the results of studies on individual species of wildlife elsewhere. Legacy trees (also described as old-growth residuals) are used by northern (*Strix occidentalis caurina*) and California (*S. o. occidentalis*) spotted owls for nesting and roosting (Moen and Gutiérrez 1997, Irwin et al. 2000). Fishers use legacy conifers, and residual hardwoods, as daily rest sites in public Douglas-fir forests (Seglund 1995) and private redwood forests (R. Klug, pers. comm.). Flying squirrels were twice as abundant when legacy trees were retained in managed areas (Carey 2000) and their diet was found to be more diverse in legacy stands (Carey et al. 2002).

Our work was directed at assessing the value of individual *legacy* trees in stands, but there is a considerable body of research on the related question of what value *residual* trees and patches have in maintaining wildlife diversity in forests. Residual structures can add important structural diversity to which many species of wildlife respond. Songbirds in a variety of coniferous, mixed, and hardwood forest types have benefited from the retention of residual trees (Hobson and Schieck 1999, Rodewald and Yahner 2000, Schieck et al. 2000, Tittler et al. 2001, Whittman et al. 2002, Zimmerman 2002). Southern red-backed voles (*Clethrionomys gapperi*), a late-successional associated forest species, are also more common in harvested areas as the basal area in residual trees increases (Sullivan and Sullivan 2001). The retention of residual structure during logging appears to have benefits to wildlife, but additional research will be necessary to distinguish the effects of retaining commercially mature – but relatively young – trees for wildlife from retaining and managing legacy trees, which are much older.

The goal of this study was to document the pattern and frequency of use of legacy and control trees so that we might better understand how young and old elements are used within the matrix of commercial redwood forests. To do so we compared the occurrence of species and individuals, but did not evaluate how individual trees contribute to *survival* or *reproduction* (i.e., fitness) of individual species. Measures of abundance, or indices of abundance, are not sufficient to completely evaluate the effects of variation in habitat on wildlife populations; in some cases they can even mislead because not all places where animals occur are suitable for reproduction (Van Horne 1983). Our observations of reproductive behavior by a number of birds and at least one species of bat, however, suggest that legacy trees may influence the fitness of some species as well. The potential survival value of access to legacies was probably underestimated in our study because we evaluated use only during the climatically benign summer months. We expect that benefits of access to legacy trees would be the greatest during the winter when they would be used as refuges from inclement weather (e.g., Carey 1989).

If legacy trees provide one of the few choices for nesting and reproductive sites, and they are rare, then it is possible that they may be easily located and searched by predators making them population 'sinks' (Pulliam 1988). Tittler and Hannon (2000) did not find increased predation in this respect, but their study evaluated residual trees, which were more numerous and not as distinctive and obvious foraging locations as are the more structurally distinctive redwood legacy trees. It is clear, however, that the risks that wildlife may be subjected to when using, and perhaps congregating at, legacy structures will need to be evaluated with respect to the benefits.

Conservation and Management Implications

Our traditional view of conservation reserves is of large protected areas. However, few landscapes provide us with the opportunity to preserve large tracts of land and we must consider conserving biodiversity within the matrix of multiple use lands (Lindenmayer and Franklin 1997). Given the fragmented nature of mature forests in the redwood region, remnant patches of old-growth and individual legacy trees may function as 'mini-reserves' that promote species conservation and ecosystem function. Legacy structures increase structural complexity in harvested stands and, as a result, can provide the 'lifeboats' for species to re-establish in regenerating stands (Franklin et al. 2000). Although the lifeboat function may not be entirely fulfilled for vertebrates with large area needs, these habitat elements may make it possible for some species to: (1) breed in forest types where they may otherwise be unable and, (2) secure a greater number of important refuges from climatic extremes and predators. In addition, these functions may allow legacy trees to provide some measure of habitat connectivity ('stepping stones') to larger more contiguous tracts of old-growth forests (Tittler and Hannon 2000, Noss et al. 2000).

Because of their rarity in commercial forests, the first step in the management of legacy trees is to determine their locations and protect them from logging or from physical degradation of the site. Because legacy redwoods with basal hollows are even more rare, locating and protecting these should be the highest priority. In addition, the circumstances that lead to their genesis will be difficult to recreate, especially on commercial timberland. Hollows form by repeated exposure of the base of trees to fire (Finney 1996), and because most fires on private land are suppressed, prescribed fire would need to be repeatedly applied to trees that would be designated as 'future legacies' and which would to be excluded from harvest in perpetuity. We hasten to add, however, that legacy trees without basal hollows appear to have significant benefits to wildlife. Even without management to encourage basal hollows it will be necessary for managers to plan for the recruitment of trees that are destined to become legacies. This will require their protection over multiple cutting cycles. We expect that new silvicultural methods will be required to prescribe the process of identifying, culturing, and protecting residual legacy trees. Although we do not believe that any one tree will protect a species, we do believe that the cumulative effects of the retention, and recruitment, of legacy and residual trees in commercial forest lands will yield important benefits to vertebrate wildlife and other species of plants and animals that are associated with biological legacies.

The results of our study beg us to consider habitat at a spatial scale that is smaller than that of habitat patches or remnant stands; we conclude that *individual trees* can have very important values to wildlife. More research would be helpful, however, to specify the level of individual tree retention required to maintain biodiversity in managed lands (Lindenmayer and Franklin 1997). It would help to know, for example, whether the fitness of individual species, and the diversity of wildlife communities, is greater in legacy-rich landscapes compared to legacy-poor landscapes. It is possible that because legacy trees are rare -- despite their apparent values to wildlife -- that they do not affect wildlife diversity or productivity over large areas. It would also advance our knowledge to determine whether legacy trees in legacy-rich landscapes can function to maintain connectivity between protected stands of mature and old-growth forests. If so, the landscape context will be an important component of managing residual legacy trees and planning their recruitment across landscapes. For now, however, this study makes clear that protecting legacy trees will protect important habitat features that receive disproportionate use by many wildlife species. The protection and management of these trees can enhance wildlife conservation on lands where the opportunities to do so can be limited.

PRESENTATIONS

Mazurek, M.J. and W.J. Zielinski. 2001. The importance of legacy old-growth trees in the maintenance of biodiversity in redwood forests managed for multiple uses. Presentation to USFS Redwood Sciences Laboratory Wildlife Meeting.

Mazurek, M.J. 2002. Cavity use by bats in western forests and northern California. Presentation at the Wildlife Society – California North Coast Chapter "Wildlife and Tree Cavities: Ecology and Management in Northern California", Arcata, California

Mazurek, M.J., W.J. Zielinski, J.E. Hunter, and M. Goldstein. 2002. The importance of legacy old-growth trees in the maintenance of biodiversity in redwood forests managed for multiple uses. Presentation at the Wildlife Society-Western Section annual meeting, Visalia, California.

Mazurek, M.J. and W.J. Zielinski. 2002. The importance of legacy old-growth trees in the maintenance of biodiversity in commercial redwood forests. Presentation to USFWS, Arcata California; Forest Stewards Guild, Ukiah, California.

EXPECTED MANUSCRIPTS:

"The importance of the individual legacy old-growth tree in the maintenance of biodiversity in commercial redwood forests." (Forest Ecology and Management)

"Use by bats of individual legacy old-growth trees in commercial redwood forests." (Journal of Mammalogy)

A New Collaboration: The Soil Arthropod Community

In the spring of 2002 our project attracted entomologists Dr. Mike Camann and Dr. Karen LaMoncha from Humboldt State University. Dr.s Camann and LaMoncha are working cooperatively with us to investigate differences in soil arthropod abundance and diversity at legacy and control trees. In addition, the primary field assistant to the project during the 2002 field season has undertaken her graduate research project on a portion of the work overseen by Dr. Camann. During the 2002 field season, we participated in the collection of soil invertebrate samples at 20 of the legacy/control tree pairs.

ACKNOWLEDGEMENTS

We would like to thank the following contributors to this research: Ruskin Hartley and Save-the-Redwoods League, Mendocino Redwood Company, Jim Kennedy and Bat Conservation International, California Department of Forestry and Fire Protection, Jackson State Demonstration Forest, Campbell Timberland Management, USDI Fish and Wildlife Service, Arcata, California and the Pacific Southwest Research Station, USDA Forest Service, Redwood Sciences Laboratory. We are also indebted to our field staff, Michael Escobar, Tyler Zarubin, and Laura Hagenauer, for their hours upon hours of hard work and efforts that made this project possible. We also thank Jacob Bailey, logistics coordinator, for his various volunteer contributions. We are grateful to all landowners and managers for the opportunity to conduct this study on properties that they own or manage and for their assistance in locating field sites. In particular we thank: Robert Douglas, Sara Billig, Russ Shively, Jon Nickerson, Mike Jani, Jon Woessner, John Ramaley, Dave Frykman, Mike Spangenberg, Natalie Cull, Nancy Budge, Theron Brown, Melinda Clark, Dan Butterfield, Mike Holley, Dale Meese, Sal Silvestri, Matt Wilson, Mickey, Marc Jameson, Bill Baxter, Brian Barrett, Robert Horvat, Sebastian Roberts, Lynn Webb, Doug Meekins, Scott Fullerton, and Knox Marshall. We thank Mike Goldstein, formerly of MRC, for helping establish the foundation for the project and Chet Ogan and Ric Schlexer for logistical support and camera training. Jan Werren and Ron Knickerbocker provided GIS support and Becky Howard provided database management support. Jim Baldwin and Lisa Olivier provided statistical support and Michelle McKenzie helped edit this report. Thanks to Sherri O'Connor for transcribing our acoustic tapes. Special thanks to John Hunter and Monica Bond for providing the inspiration to embark on this research.

LITERATURE CITED

Bailey, R.G. 1994. Descriptions of the ecoregions of the United States. 2nd edition Washington D.C., Forest Service, U.S. Department of Agriculture. Misc. Publ. 1391 (rev).

Brawn, J.D., and R.P. Balda. 1988. Population biology of cavity-nesters in northern Arizona: do nest sites limit breeding densities? Condor 90:61-71.

Bull, E.L., C.G. Parks, and T.R. Torgersen. 1997. Trees and logs important to wildlife in the interior Columbia River basin. General Technical Report PNW-GTR-391. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 55 pp.

Buskirk, S.W. and R.A. Powell 1994. Habitat ecology of fishers and American martens. Pages 283-296 *In* Martens, sables and fishers: Biology and conservation. S.W. Buskirk, A.S. Harestad, M.G. Raphael and R.A. Powell (ed.) Comstock Publishing Associates, Cornell University Press, Ithaca, New York. 501 pp.

Carey, A.B. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. Natural Areas Journal 9:151-162.

Carey, A.B. 2000. Effects of new forest management strategies on squirrel populations. Ecological Applications 10:248-257.

Carey, A.B. and M.L. Johnson. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications 5:336-352.

Carey, A.B., T.M. Wilson, C.C. Maguire, and B.L. Biswell. 1997. Dens of northern flying squirrels in the Pacific Northwest. Journal of Wildlife Management 61:684-699.

Carey, A.B., W. Colgan, J.M. Trappe and R. Molina. 2002. Effects of forest management on truffle abundance and squirrel diets. Northwest Science 76:148-157.

Christy, R.E., and S.D. West. 1993. Biology of bats in Douglas-fir forests. PNW-GTR-308. USDA, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Finney, M.A. 1996. Development of fire scar cavities on old-growth coast redwood. Pages 96-98 *In* Coast Redwood Forest Ecology and Management, J. Leblanc, Editor, University of California, Berkeley, California.

Folliard, L. 1993. Nest site characteristics of northern spotted owls in managed forests of northwest California. M.S. Thesis, University of Idaho, Moscow, Idaho.

Fox, L. 1996. Current status and distribution of coast redwood. Pages 18-19 *In* Coast Redwood Forest Ecology and Management, J. Leblanc, Editor, University of California, Berkeley, California.

Franklin, J. F. 1990. Biological legacies: A critical management concept from Mount St. Helens. Trans. North American Wildlands Natural Resource Conference 55: 216-219.

Franklin J.F., D. Lindenmayer, J.A. MacMahon, A. McKee, J. Magnuson, D.A. Perry, R. Waide and D. Foster. 2000. Threads of continuity. Conservation Biology *in* Practice 1:9-16.

Gashwiler, J.S. 1970. Plant and mammal changes on a clearcut in west central Oregon. Ecology 51:1018-1026

Gellman, S.T. and W.J. Zielinski. 1996. Use by bats of old-growth redwood hollows on the north coast of California. Journal of Mammalogy 77:255-265.

Hayes, J.P. 1997. Temporal variation in activity of bats and the design of echolocation-monitoring studies. Journal of Mammalogy 78:514-524.

Hayes, J.P. and P. Hounihan. 1994. Field use of the Anabat II bat detector system to monitor bat activity. Bat Research News 35:1-3.

Hobson, K.A. and J.Schieck. 1999. Changes in bird communities in boreal mixedwood forest: harvest and wildfire effects over 30 years. Ecological Applications 9:849-863.

Hooven, E.F., and H.C. Black. 1976. Effects of some clearcutting practices on small-mammal populations in western Oregon. Northwest Science 50:189-208.

Humphrey, S.R. 1975. Nursery roosts and community diversity of nearctic bats. Journal of Mammalogy 56:321-346.

Hunter, J.E. and M.L. Bond. 2001. Residual trees: Wildlife associations and recommendations. Wildlife Society Bulletin 29:995-999.

Hunter, J.E. and M.J. Mazurek. Submitted. Some Vaux's swift nest and roost trees in northwestern California. Western Birds.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. Journal of Theoretical Biology 29:151-154.

Irwin, L.L., D.F. Rock, and G.P. Miller. 2000. Stand structures used by northern spotted owls in managed forests. Journal of Raptor Research 34:175-186.

Krusic, R.A., M. Yamasaki, C.D. Neefus, and P.J. Pekins. 1996. Bat habitat use in White Mountain National Forest. Journal of Wildlife Management 60:625-631.

Kunz, T.H. 1982. Roosting ecology of bats. Pages 1-55 i*n* T.H. Kunz, editor, Ecology of bats. 1982. Plenum Press, New York, New York, USA.

Laudenslayer, W. F. 2002. Cavity-nesting bird use of snags in eastside pine forests of northeastern California. Pages 223-236 *In* Proceedings of the symposium on the ecology and management of dead wood in western forests. Laudenslayer, W.F., P.J. Shea, V.E. Valentine, C.P. Weatherspoon, and T.E. Lisle (tech. coord.). 1999 November 2-4; Reno, Nevada, General Technical Report PSW-GTR-181. USDA Forest Service, Pacific Southwest Research Station, Albany, California.

Lindenmayer, D.B. and J.F. Franklin. 1997. Managing stand structure as part of ecologically sustainable forest management in Australian mountain ash forests. Conservation Biology 11:1053-1068.

Magurran, A. 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, New Jersey. 177 pp.

Mariani, J.M. and D.A. Manuwal. 1990. Factors influencing brown creeper (*Certhia americana*) abundance patterns in the southern Washington Cascade range. Studies in Avian Biology 13:53-57.

Mazurek, M.J. (a) In preparation. Wildlife use of old-growth redwood basal hollows in northwestern California.

Mazurek, M.J. (b) In preparation. Townsend's big-eared bat maternity colony uses old-growth redwood basal hollows in Grizzly Creek State Park, California.

McComb, W.C., K.M. McGarigal, and R.G. Anthony. 1993. Small mammals and amphibian abundance in streamside and upslope habitats of mature Douglas-fir stands, in western Oregon. Northwest Science 67:7-15.

Moen, C.A, and R.J. Gutiérrez. 1997. California spotted owl habitat selection in the central Sierra Nevada. Journal of Wildlife Management 61:1281-1287.

Noss, R.F., J.R. Strittholt, G.E. Heilman, P.A. Frost and M. Sorensen. 2000. Conservation planning in the redwood region. Pages 201-228 *In* The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. R.F. Noss (ed.) Island Press, Covelo, California. 339 pp.

Ozanne, C.M.P., M.R. Speight, C. Hambler, and H.F. Evans. 2000. Isolated trees and forest patches: patterns in canopy arthropod abundance and diversity in *Pinus sylvestris* (Scots pine). Forest Ecology and Management 137:53-63.

Pielou, E.C. 1969. An Introduction to Mathematical Ecology. Wiley, New York.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652-661.

Purdy, D. 2002. Bat use of old-growth redwood basal hollows: a study of capture methods and species use of redwoods. M.S. Thesis Department of Natural Resources, Humboldt State University, Arcata California.

Rainey, W.E., E.D. Pierson, M. Colberg and J.H. Barclay. 1992. Bats in hollow redwoods: seasonal use and role in nutrient transfer into old-growth communities. Bat Research News 33:71.

Raphael, M.G. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California. Pages 23-31 *In* Proceedings of the Symposium on the Management of Amphibians, Reptiles, and Small Mammals in North America. 1988 July 19-21; Flagstaff, Arizona. Szaro, R.C. Severson, K.E., and D.R. Patton (tech. coord.). General Technical Report RM-166. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Raphael, M.G. and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra-Nevada. Wildlife Monographs 86:1-66.

Rodewald, A.D. and R.H. Yahner. 2000. Bird communities associated with harvested hardwood stands containing residual trees. Journal of Wildlife Management 64:924-932.

SAS Institute Inc. 1999-2000. Version 8.1. SAS Institute, Cary, North Carolina.

Sawyer, J.O., S.C. Sillett, J.H. Popenoe, A. LaBanca, T. Sholars, D.L. Largent, F. Euphrat, R.F. Noss, and R. VanPelt. 2000. Characteristics of Redwood Forests. Pages 39-80 *In* The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. R.F. Noss (ed.) Island Press, Covelo, California. 339 pp.

Schieck, J., K. Stuart-Smith and M. Norton. 2000. Bird communities are affected by amount and dispersion of vegetation retained in mixedwood boreal forest harvest areas. Forest Ecology and Management 126:239-254.

Seglund, A.E. 1995. The use of resting sites by the pacific fisher. M.S. Thesis Department of Natural Resources, Humboldt State University, Arcata California.

SmartWood Program. 2000. Forest management public summary for Mendocino Redwood Company. SmartWood Program, New York, New York. 38pp.

Sullivan, T.P. and D.S. Sullivan. 2001. Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. Journal of Applied Ecology 38:1234-1252.

Summerville, K.S. and T.O. Crist. 2002. Effects of timber harvest on forest lepidoptera: community, guild and species responses. Ecological Applications 12:820-835.

Tevis, L. 1956. Responses of small mammal populations to logging of Douglas-fir. Journal of Mammalogy 37:189-196.

Thome, D.M., C.J. Zabel, L.V. Diller. 1999. Forest stand characteristics and reproduction of northern spotted owls in managed north-coastal California forests. Journal of Wildlife Management 63:44-59.

Thornburgh, D.A., R.F. Noss, D.P. Angelides, C.M. Olson, F.Euphrat, and H.J. Welsh. 2000. Managing Redwoods. Pages 229-262 *In* The Redwood Forest: History, Ecology, and Conservation of the Coast Redwoods. R.F. Noss (ed.) Island Press, Covelo, California. 339 pp.

Tittler, R. and S.J. Hannon. 2000. Nest predation in and adjacent to cutblocks with variable tree retention. Forest Ecology and Management 136:147-157.

Tittler, R., S.J. Hannon, and M.R. Norton. 2001. Residual tree retention ameliorates short-term effects of clear-cutting on some boreal songbirds. Ecological Applications 11:1656-1666.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Weller, T.J. and C.J. Zabel. 2002. Variation in bat detections due to detector orientation in a forest. Wildlife Society Bulletin 30:922-930.

Whittman, R.M., J.D. McCracken, C.M. Francis, and M.E. Gartshore. 2002. The effects of selective logging on nest-site selection and productivity of hooded warblers. Canadian Journal of Zoology 80:644-654.

Willett, T.R. 2001. Spiders and other arthropods as indicators in old-growth versus logged redwood stands. Restoration Ecology 9:410-420.

Wilson, S.M. and A.B. Carey. 2000. Legacy retention versus thinning: Influences on small mammals. Northwest Science 74:131-145.

Zenner, E. K. 2000. Do residual trees increase structural complexity in Pacific Northwest coniferous forests? Ecological Applications 10: 800-810.

Zielinski, W.J., T.E. Kucera, and R.H. Barrett. 1995. The current distribution of fishers in California. California Fish and Game 81:104-112.

Zielinski, W.J. and S.T. Gellman. 1999. Bat use of remnant old-growth redwood stands. Conservation Biology 13:160-167.

Zielinski, W. J., K. M. Slauson, C. R. Carroll, C. J. Kent and D. G. Kudrna. 2001. Status of American martens in coastal forests of the Pacific states. J. Mammalogy 82:478-490.

Zimmerman, K.L. 2002. Sustaining biological diversity in managed sub-boreal spruce landscapes: Residual habitat strategies for cavity nesting species. M.S. Thesis University of Northern British Columbia, Canada.

Zinck, J.M. and P.C. Ormsbee. 2001. Applying genetic analysis to the conservation and management of bat populations. Page 311 *In* 31st Annual North American Symposium on Bat Research Program and Abstracts. Victoria, British Columbia, Canada, 24-27 October.

Table 1. Means, minima and maxima for tree diameters and heights of legacy (L) and control (C) trees.

	Dbh (cm)			Height (m)		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
L	293.3	515	139	52.8	90	24.5
C	72.5	106	42	32.1	60	19.7

Table 2. Mean number of bat detections (standard deviation) for each legacy and control tree over 4, 2-day sampling periods in Mendocino County, California 2001 and 2002.

Pair #	Legacy	Control
1	23.00 (4.0)	37.25 (33.1)
2	21.88 (10.1)	22.63 (17.6)
3	7.38 (8.7)	2.88 (3.3)
4	2.25(2.6)	5.50 (4.3)
5	3.38 (5.5)	0.75 (1.5)
6	16.88 (7.4)	1.29 (1.9)
7	78.75 (27.5)	7.00 (4.5)
8	41.50 (28.4)	33.63 (29.6)
9	17.63 (16.3)	34.38 (27.4)
10	16.50 (17.1)	8.75 (5.4)
11	31.50 (27.6)	1.63 (0.8)
12	11.38 (4.3)	3.88 (2.7)
13	68.25 (40.1)	6.75 (4.1)
14	68.88 (30.6)	16.12 (24.8)
15	28.13 (33.8)	45.63 (61.5)
16	28.00 (11.9)	11.75 (8.1)
19	3.38 (3.8)	8.75 (10)
20	1.62 (1.7)	6.12 (5.1)
21	15.75 (19.9)	13.25 (8.0)
22	15.75 (17.6)	5.38 (7.1)
23	34.17 (25.4)	16.88 (15.3)
24	15.63 (23.3)	4.67 (4.2)
25	72.29 (45.3)	71.38 (111.8)
26	7.96 (8.7)	9.79 (13.6)
27	10.50 (5.1)	6.50 (12.7)
28	8.63 (2.8)	1.25 (1.2)
29	13.88 (7.0)	27.75 (30.3)
30	101.13 (29.8)	29.75 (17.3)
31	31.25 (12)	40.75 (39.8)
32	70.75 (44.3)	3.63 (3.9)
Mean	28.93 (32.5)	16.18 (29.6)

Table 3. Guano trap installation dates, monthly guano weights (g) by tree, and monthly mean guano weights (March-October) at 15 hollow-bearing legacy trees in Mendocino County, California 2001 and 2002. Means calculated for complete samples only.

		Installation Date		Guano Weights							
Tag #	Pair #	2001	2002	March	April	May	June	July	August	September	October
398	2	04-Jul-01	13-Mar-02	*0.0502	0.3811	0.4044	1.044	*0.2349	*0.4750	0.7142	0.7588
393	***3	04-Jul-01	29-Mar-02	*0.0216	0.279	0.1468	0.288	0.9766	0.5006	1.1209	0.3818
392	4	04-Jul-01	13-Mar-02	*0	0	0.0002	0.003	0.0011	0.0046	*0.0062	*0.0022
395	5	05-Jul-01	29-Mar-02	*0	0	0.009	0.135	*0.1061	0.2069	*0.0244	NA
384	7	09-Jul-01	13-Mar-02	*0.0069	0.0845	5.8841	3.039	10.304	14.6156	1.5778	0.0693
378	9	16-Jul-01	14-Mar-02	*0.0432	0.1385	0.6489	0.702	*0.1976	0.6208	1.008	*0.2696
368	***14	09-Aug-01	14-Mar-02	*0.0271	0.075	0.0761	0.372	*0.6978	1.2022	0.9544	0.2853
366	15	23-Jul-01	14-Mar-02	*0	0	0.0037	0.015	0.1124	0.1427	0.063	0.046
360	19	26-Jul-01	14-Mar-02	*0.0018	0.0015	0.03	0.0522	1.255	0.9178	0.1268	0.0529
358	20	26-Jul-01	14-Mar-02	*0.0075	0.0421	0.003	0	0.0037	0.0042	0.0043	*0.0035
354	***22	07-Aug-01	14-Mar-02	*0.0037	0.0172	0.0248	0.0232	NA	0.04338	*0.3837	*0.11
346	***23	NA	21-May-02	NA	NA	*0.0176	0.5404	0.829	1.0943	0.4569	0.1322
352	***25	NA	22-May-02	NA	NA	*0.291	0.7917	1.2754	7.1155	4.2605	1.3786
336	30	NA	23-May-02	NA	NA	*0.637	1.752	3.19	5.468	2.575	0.678
340	32	NA	12-Jul-02	NA	NA	NA	NA	*0.035	0	0.0092	0.0124
			Mean		0.0926	0.6574	0.6255	1.9941	2.2812	1.0726	0.3693

* Indicates partial trap failure or incomplete collection

*** indicates traps with consistently large amounts of bird feces

Table 4. Guano trap installation dates, monthly guano weights (g) by tree, and monthly mean guano weights (July-October) at 3 fire-scarred legacy trees in Mendocino County, California 2002.

Tag #	Pair #	Installation Date	July	August	September	October
386	6	1-Jul-02	0.0006	0.0031	0.0030	0.0009
370	12	2-Jul-02	0	0	0.0050	0.0062
350	28	14-Jul-02	0.0263	0.0248	0.0144	0.0028
		Mean	0.0090	0.0093	0.0075	0.0033

Table 5. Number of 68 guano samples collected from 15 basal hollows and 3 fire scars that could be identified to species.

	Guano Sample		Hollows		Fire-scars		Trees Total	
Species	No.	% of Samples	No.	% of Hollows	No.	% of Fire-scars	No.	% of Trees Total
Big brown bat (*Eptesicus fuscus*)	9	13	5	33	3	100	8	44
California bat (*Myotis californicus*)	17	25	11	73	1	33	12	66
Myotis 3	11	16	5	33	0	0	5	27
Long-legged bat (*Myotis volans*)	31	46	9	60	0	0	9	50

Myotis 3 – *Myotis lucifugus*, *Myotis evotis*, and *Myotis thysanodes* are not currently distinguishable, but guano from these 3 species can be distinguished from other species.

Table 6. Summary of small mammal captures by species at study sites in Mendocino County, California 2001 and 2002.

Species	Total Captures		Total Individuals Captured		Individuals Captured at Both
	Legacy	Control	Legacy	Control	Legacy and Control Pair
Trowbridge's shrew (*Sorex trowbridgii*)	33	18	30	16	0
Fog shrew (*Sorex sonomae*)	2	4	2	3	0
Shrew mole (*Neurotrichus gibbsii*)	5	0	5	0	0
Short-tailed weasel (*Mustela erminea*)	0	1	0	1	0
Dusky-footed woodrat (*Neotoma fuscipes*)	62	88	23	37	0
Redwood (yellow-cheeked) chipmunk (*Tamias ochrogenys*)	93	51	39	31	3
Deer mouse (*Peromyscus maniculatus*)	150	133	67	61	1
Western red-backed vole (*Clethrionomys californicus*)	20	37	13	19	0
	365	332	179	168	4

Table 7. Summary of visual observation results. Total survey effort, duration (minutes / hour of survey effort) that individuals were observed and the total number of incidents of wildlife observed for 3 time periods; AM (within 2 hours of sunrise), Mid (2 hours centered around mid-day) and PM (2 hours within sunset), for 2001 and 2002 combined.

	Total			Survey period: AM		Survey period: Mid		Survey period: PM	
Tree Type	Total Survey Effort	Minutes / Hour	# Incidents	Minutes / hour	# Incidents	Minutes / hour	# Incidents	Minutes / hour	# Incidents
Legacy	57.5 hours	0.0998	188	0.1035	170	0.002	4	0.1938	14
Control	57.0 hours	0.0105	34	0.0143	27	0.003	6	0.0024	1

Table 8. Species observed at legacy and control trees and the number of incidents (number of times a species was observed) during time-constrained visual observations in Mendocino County, California, 2001 and 2002 combined.

	Legacy	Control
Species at Legacy Only:		
Acorn woodpecker	12	0
Common raven	2	0
Downy woodpecker	1	0
Hairy woodpecker	3	0
Northern flicker	2	0
Osprey	1	0
Pygmy nuthatch	25	0
Red-breasted nuthatch	1	0
Turkey vulture	1	0
Unknown flycatcher	1	0
Unknown owl	1	0
Unknown swallow	11	0
Unknown woodpecker	4	0
Vaux's swift	3	0
Violet-green swallow	52	0
Winter wren	2	0
Species at Control Only:		
Golden-crowned kinglet	0	1
Hutton's vireo	0	8
Species at Both Legacy and Control:		
Brown creeper	4	2
Chestnut-backed chickadee	4	2
Hermit warbler	1	1
Pacific-slope flycatcher	1	1
Redwood chipmunk	1	1
Steller's jay	10	7
Unknown passerine	44	10
Western gray squirrel	1	1

Table 9. List of species and the number of detections (photos) at legacy and control trees during remote camera surveys in Mendocino, California, 2002. Each detection represents only one photo per species per tree per 24-hour period.

	Legacy	Control
Species at Legacy Only:		
Bat (Species Unknown)	1	0
Brush rabbit (*Sylvilagus bachmani*)	7	0
Sonoma vole (*Arborimus pomo*)	1	0
Unknown mammal	5	0
Winter wren (*Troglodytes troglodytes*)	1	0
Species at Control Only:		
Gray fox (*Urocyon cinereoargenteus*)	0	2
Raccoon (*Procyon lotor*)	0	1
Western red-backed vole (*Clethrionomys californicus*)	0	6
Species at Legacy and Control:		
Black bear (*Ursus americanus*)	4	1
Black-tailed deer (*Odocoileus hemionus*)	1	1
Bobcat (*Lynx rufus*)	4	1
Deer mouse (*Peromyscus maniculatus*)	10	25
Douglas' squirrel (*Tamiasciurus douglasii*)	5	4
Dusky-footed woodrat (*Neotoma fuscipes*)	10	25
Redwood (Yellow-cheeked) chipmunk (*Tamias ochrogenys*)	20	22
Spotted skunk (*Spilogale gracilis*)	1	1
Striped skunk (*Mephitis mephitis*)	4	3
Trowbridge's shrew (*Sorex trowbridgii*)	1	8
Western gray squirrel (*Sciurus griseus*)	9	3

Table 10. Means and standard deviations (SD) for habitat variables sampled in the immediate vicinity of legacy (L) and control (C) trees in Mendocino, County California 2001 and 2002. Legacy and control trees were excluded from calculations. T-values and p-values are from the results of matched-pair t-tests.

Vegetation characteristic	Tree type					
	L		C			
	Mean	SD	Mean	SD	t	P
Basal area (m^2/ha)	55.6	22.5	56.8	27.5	0.17	0.87
Tree Dbh (cm)	46.7	23.2	49.2	23.6	0.38	0.71
Tree height (m)	24.6	7.7	26.2	8.3	0.87	0.40
Log volume (m^2)	1.27	1.4	0.79	0.86	1.08	0.30
Canopy cover (%)	83.6	7.6	84.4	8.2	0.42	0.68
Shrub cover (%)	12.8	16.5	16.1	21.2	0.63	0.54
Herbaceous cover (%)	24.9	36.8	16.7	23.6	1.19	0.30

Table 11. Frequency of occurrence for habitat variables sampled in the immediate vicinity of legacy (L) and control (C) trees in Mendocino, County California 2001 and 2002. Legacy and control trees were excluded from calculations. Statistical values are from Chi-squared goodness of fit tests.

Vegetation characteristic		Tree type L	Tree type C		
		Frequency	Frequency	χ^2	P
Tree species	Coast redwood	22	22		
	Other conifer	15	12		
	Hardwood	20	10	2.03	0.36
Tree condition	Live	40	33		
	Declining	13	5		
	Dead	4	5	2.42	0.3
Log species	Coast redwood	31	27		
	Other conifer	10	9		
	Hardwood	4	6	0.63	0.73
Log condition	Class 1	2	1		
	Class 2	8	8		
	Class 3	15	11		
	Class 4	13	12		
	Class 5	7	9	1.05	0.9
Downed wood	High	7	8		
	Low	8	7	0.13	0.72
Duff	High	13	12		
	Low	2	3	NA	NA

Table 12. Number of individuals (small mammals) or detections (others), species richness, evenness and diversity indices by survey method for legacy (L) and control (C) trees in Mendocino County, California 2001 and 2002. Tests statistics refer to the Shannon diversity indices.

SurveyMethod	Tree Type	# Individuals or Detections	Richness (# Species)	Evenness	Shannon Diversity Index	t Statistic	df	p
	L	188	24	0.712	2.26			
Observation	C	34	10	0.815	1.88	2.497	680	0.01-0.005
	L	103	16	0.859	2.38			
TrailMaster	C	84	14	0.763	2.01	2.097	181	0.025-0.01
	L	179	7	0.824	1.6			
Mammal Trapping	C	168	7	0.815	1.58	0.258	350	>0.25
	L	451	41	0.768	2.85			
Overall	C	305	24	0.679	2.16	8.417	754	<0.001

Figure 1. Map of western Mendocino County, California indicating locations of study sites.

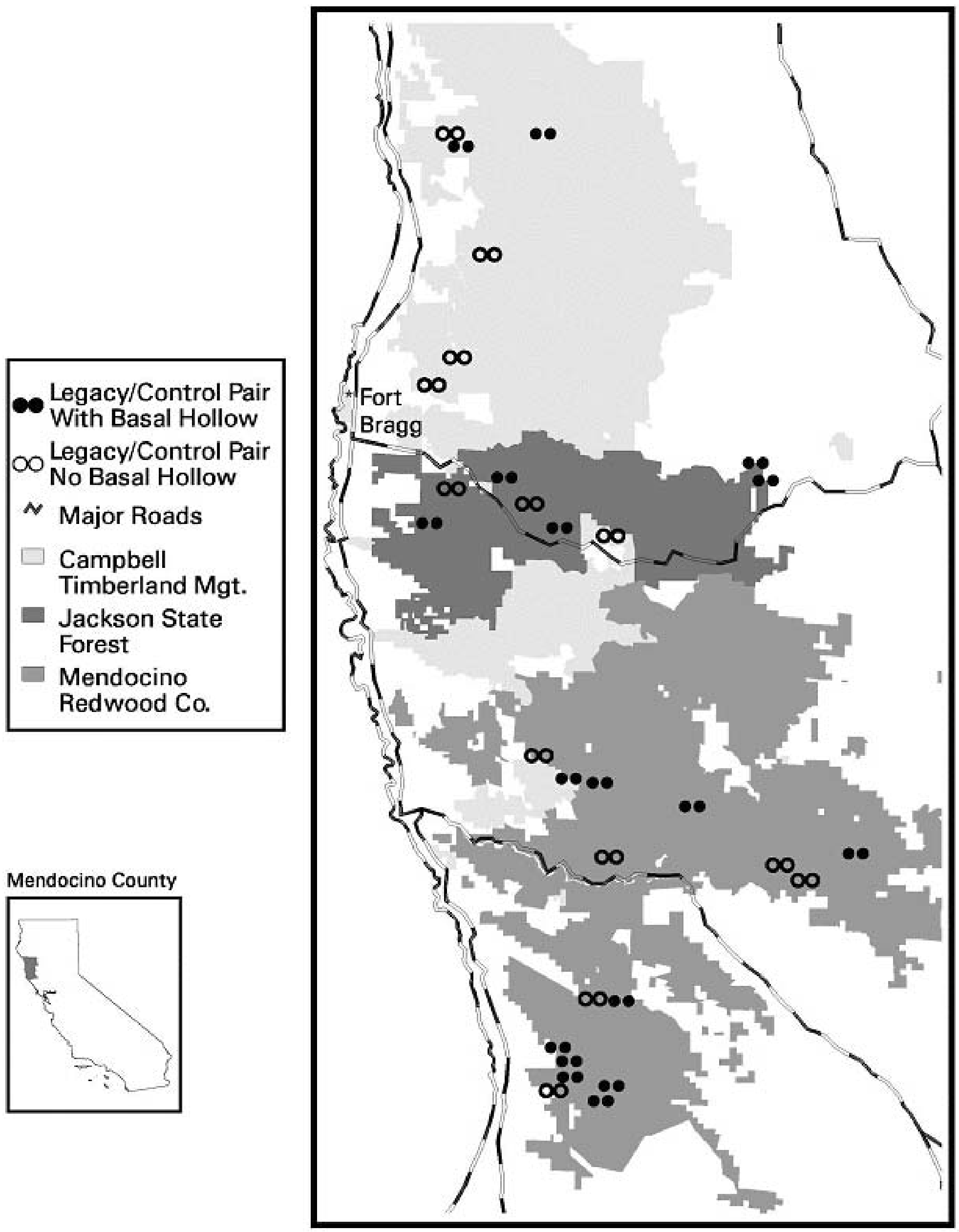


Figure 2. Mean bat detections and standard deviation for legacy and control trees ($F_{1, 45.7}$ = 17.66, P <0.0001) in Mendocino County, California 2001 and 2002.

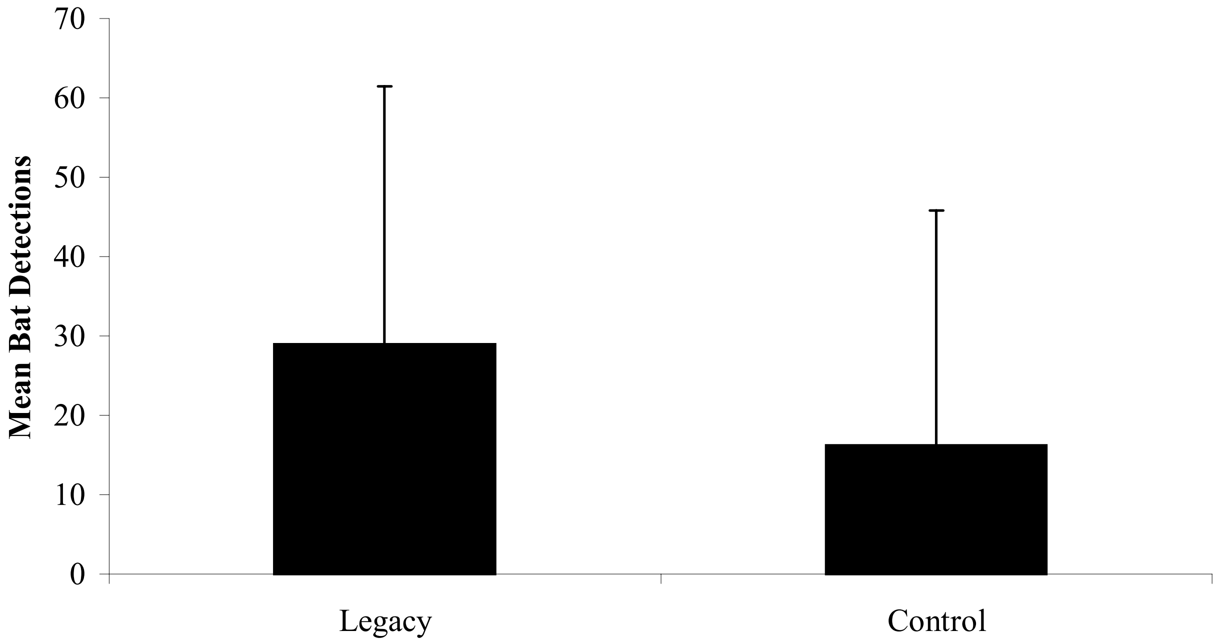
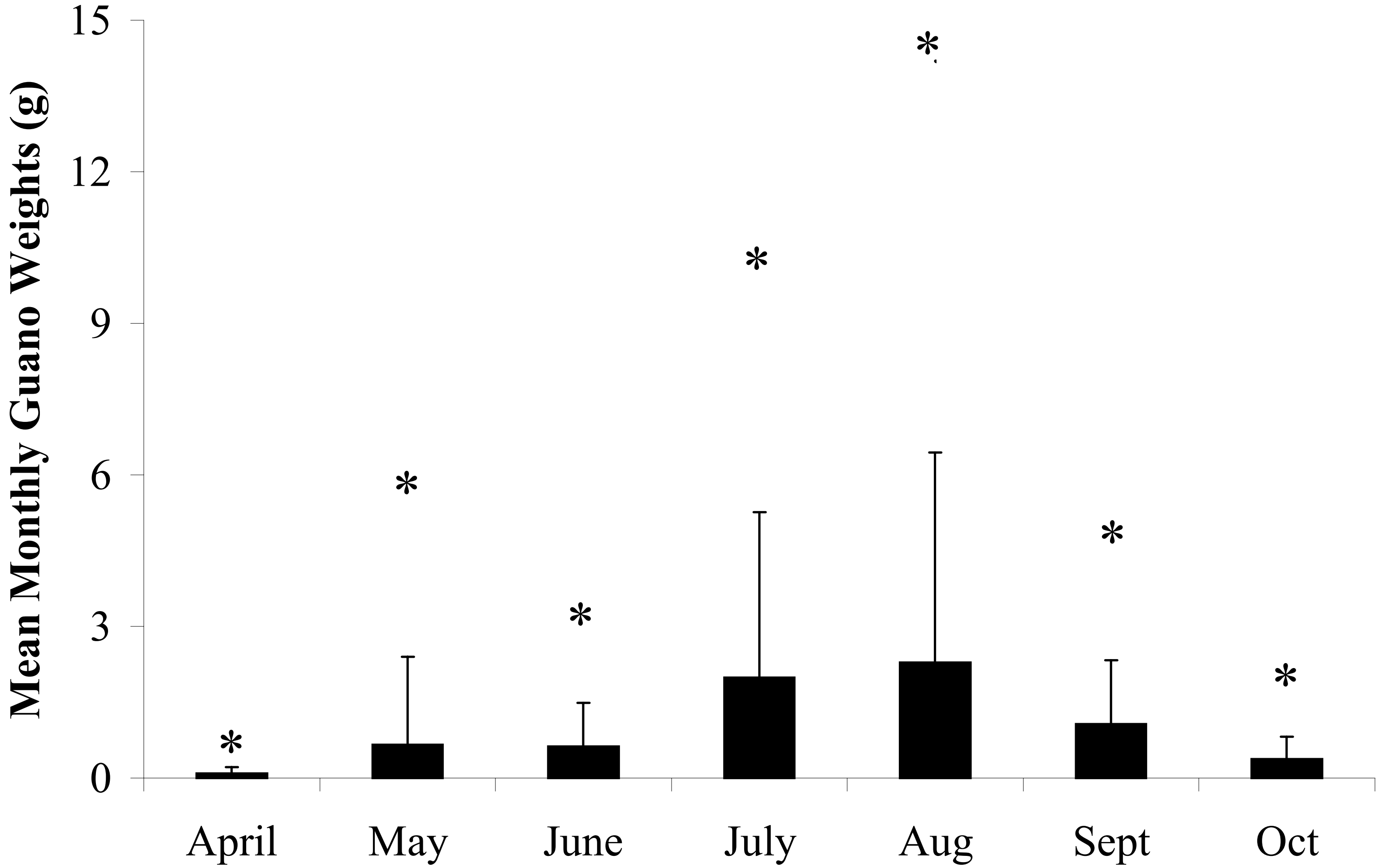


Figure 3. Mean, standard deviation, and maximum (*) monthly guano weights (g) (April – October) at 15 hollow-bearing trees in Mendocino County, California 2001 and 2002.



Appendix I.

Table IA . Physical characteristics of legacy (L) and control (C) trees. Dbh = diameter at breast height.

Tag#	Tree type	Pair#	Dbh (cm)	Height (m)	Basal structure	Guano trap
400	L	1	248.5	27.6	FIRE SCAR	N
399	C	1	88	35	NONE	N
398	L	2	315	70	HOLLOW	Y
397	C	2	82	19.7	NONE	N
393	L	3	260	67	HOLLOW	Y
394	C	3	75	19.7	NONE	N
392	L	4	184.5	40	FIRE SCAR	Y
391	C	4	80	33	NONE	N
395	L	5	335	24.5	HOLLOW	Y
396	C	5	66	24.4	NONE	N
386	L	6	260.5	42.5	FIRE SCAR	Y
385	C	6	84	22.3	NONE	N
384	L	7	262.5	57	HOLLOW	Y
383	C	7	56	34	NONE	N
382	L	8	465	64	FIRE SCAR	N
381	C	8	89	29.5	NONE	N
378	L	9	285.5	49.5	HOLLOW	Y
377	C	9	72.5	27	NONE	N
376	L	10	241.5	52.5	FIRE SCAR	N
375	C	10	74.5	36.5	NONE	N
374	L	11	188.5	90	NONE	N
372	C	11	47	25	NONE	N
370	L	12	257	34.2	FIRE SCAR	Y
371	C	12	64.5	25.5	NONE	N
362	L	13	307	47.9	FIRE SCAR	N
361	C	13	71	38	NONE	N
368	L	14	376	50.5	HOLLOW	Y
367	C	14	69	24.5	NONE	N
366	L	15	234	30.2	HOLLOW	Y
365	C	15	70.5	27.2	NONE	N
364	L	16	207	52.5	FIRE SCAR	N
363	C	16	57	23.5	NONE	N

Table I.A. (Continued) Physical characteristics of legacy (L) and control (C) trees. Dbh = diameter at breast height.

Tag#	Tree type	Pair#	Dbh (cm)	Height (m)	Basal structure	Guano trap
360	L	19	250	61	HOLLOW	Y
359	C	19	66	29	NONE	N
358	L	20	139	30	HOLLOW	Y
357	C	20	68	27	NONE	N
356	L	21	275	46	FIRE SCAR	N
355	C	21	64	29	NONE	N
354	L	22	279.5	68	HOLLOW	Y
353	C	22	95.5	53	NONE	N
346	L	23	260.5	61	HOLLOW	Y
345	C	23	106	43	NONE	N
344	L	24	359	57	FIRE SCAR	N
343	C	24	90	42	NONE	N
352	L	25	402	70	HOLLOW	Y
351	C	25	84	60	NONE	N
390	L	26	367	62	HOLLOW	N
389	C	26	91	49	NONE	N
348	L	27	380	56	FIRE SCAR	N
347	C	27	42.5	21	NONE	N
350	L	28	310	64	FIRE SCAR	Y
349	C	28	42	23.5	NONE	N
332	L	29	207	50	FIRE SCAR	N
331	C	29	76	36.5	NONE	N
336	L	30	298	58	HOLLOW	Y
335	C	30	76	46	NONE	N
338	L	31	515	62	FIRE SCAR	N
337	C	31	58	32	NONE	N
340	L	32	330	39	HOLLOW	Y
339	C	32	70	26	NONE	N

Table I.B. Physical characteristics of legacy basal hollows, fire scars and tree structures.

Pair#	External Height (m)	External Width (m)	Internal Height (m)	Internal Width (m)	Internal Depth (m)	Legacy Tree Structure
1	2.50	0.81	NA	NA	NA	SNAG-LIKE
2	3.96	0.86	4.32	1.88	1.14	SINGLE STEM
3	4.20	1.60	7.15	1.56	1.68	MULTI-STEM
4	4.10	0.36	4.10	0.71	0.84	SINGLE STEM
5	8.70	2.03	9.70	1.50	1.83	MULTI-STEM
6	2.34	2.29	NA	NA	NA	SINGLE STEM
7	5.70	1.35	6.40	1.45	0.58	SINGLE STEM
8	34.00	2.55	NA	NA	NA	MULTI-STEM
9	2.84	1.10	6.20	2.87	2.41	SINGLE STEM
10	13.70	1.13	NA	NA	NA	MULTI-STEM
11	NA	NA	NA	NA	NA	SINGLE STEM
12	1.45	0.55	NA	NA	NA	SINGLE STEM
13	47.90	2.69	NA	NA	1.45	SNAG-LIKE
14	8.62	1.47	14.09	1.50	1.85	MULTI-STEM
15	2.03	1.83	5.59	2.79	1.75	SINGLE STEM
16	1.35	1.30	NA	NA	NA	SINGLE STEM
19	3.30	1.12	4.98	1.24	1.22	SINGLE STEM
20	2.24	1.42	2.34	0.79	0.53	SINGLE STEM
21	8.00	0.86	NA	NA	NA	SINGLE STEM
22	5.90	1.90	10.90	2.30	1.00	SINGLE STEM
23	11.50	1.52	13.00	3.07	2.03	SINGLE STEM
24	1.88	0.33	NA	NA	NA	SINGLE STEM
25	4.30	1.45	7.75	3.05	2.13	SINGLE STEM
26	0.66	0.61	NA	1.75	3.35	MULTI-STEM
27	6.00	1.65	NA	NA	NA	SINGLE STEM
28	1.50	1.57	NA	NA	0.76	SINGLE STEM
29	1.47	2.39	NA	NA	NA	SINGLE STEM
30	3.35	1.27	4.27	1.68	1.07	SINGLE STEM
31	2.00	1.00	NA	NA	0.30	MULTI-STEM
32	2.70	0.25	NA	1.22	0.30	SNAG-LIKE