DRAFT
Dead Wood and Small Mammal Reponses to Three Alternative Thinning Strategies in Young Douglas-fir Forests

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INTRODUCTION

In 1990, John Tappeiner, Loren Kellogg, and Brenda McComb from OSU met with silviculturists and wildlife biologists from the Willamette National Forest at the Lowell Ranger District office. The Forest Service managers wished to establish a manipulative study designed to test the hypothesis that active management of young, even-aged Douglas-fir (*Pseudostuga menziesii*) plantations in the Oregon Cascades would accelerate the development of late-successional conditions sooner than if the plantations were left to develop without further management. This hypothesis was an outcome of similar experiments that had been initiated at McDonald-Dunn Forest in older stands, and studies that were being initiated at that time in the Oregon Coast Range on the Siuslaw National Forest and nearby BLM lands. The hypotheses were also supported by modeling simulations (McComb et al. 1993, Carey 2003; Garman 2003). Thus began the Young Stand Thinning and Diversity Study (YSS). In addition to manipulating stands to achieve habitat structure goals, the study facilitated the development of logging systems that were monitored to assess the costs and benefits of thinning in young plantations.

This report focuses on summarizing the most recent measurements of dead wood and small mammal abundance sampled 10 years after treatment of these young stands.

Background information on Coarse Woody Debris (CWD) and wildlife

One objective of the YSS was to retain and recruit dead wood, historically referred to as coarse woody debris (CWD), as a habitat element in these stands. CWD is defined as fallen trees or portions of living or dead trees > 10 cm in diameter at the largest end. CWD is used by many species of vertebrates and invertebrates as cover, foraging sites, and sites for attracting mates. In terrestrial environments, the interior of hollow logs, and the spaces beneath a log, provide a stable and often moist micro-environment that is especially important to the survival of some species of amphibians and reptiles (deMaynadier and Hunter 1995). Other species use the space between the bark and the wood and some use the interior of well-decayed CWD (e.g., clouded salamanders, *Aneides ferreus*, Stelmock and Harestad 1979).

There are several key attributes of CWD that influence its value to vertebrates, including piece size, biomass or areal cover, condition (decay stage), and the successional stage of the forest in which it occurs. CWD piece size dictates the area or volume of space available to be occupied (Maser et al. 1979). Large CWD (≥ 10 cm diameter) seems to be used by more vertebrate species than small CWD (2.5-10 cm diameter), which is probably of little value to most vertebrates. Large CWD provides more cover per piece and persists longer than small diameter CWD. Western red-backed voles (*Clethrionomys californicus*) select large CWD as cover (Hayes and Cross 1979), and CWD provides cover and a substrate for fungi which is a food source for southern red-backed voles (*C. gapperi*) (Buckmaster et al. 1996). Areal cover or biomass of CWD may influence the function of the wood as cover to both amphibians (McComb 2003) and mammals, including shrews (*Sorex* spp.), weasels (*Mustelina* spp.), mink (*M. vison*), and northern river otters (*Lontra canadensis*), among many others (Maser et al. 1981).

The physical structure of CWD is also important to some species. Maser et al. (1979) described stages of log decay that are similar to those used to describe snag decay. Each stage of decomposition can provide different resources to a suite of organisms (Maser et al. 1979).

Forest management activities that influence the frequency, severity, and pattern of disturbances in forest systems can have marked effects on the abundance of dead and dying trees and the spcies that use them. Our objectives were to synthesize data collected on CWD in the YSS to address the following questions:

1. How do different silvicultural treatments affect the amount of CWD in young Douglas-fir stands?
2. How do different silvicultural treatments influence the abundance of small mammals in young Douglas-fir stands.
3. What are chronic inputs of CWD over time in managed and unmanaged stands?
4. How are small mammal abundances associated with silvicultural treatments and coarse woody debres levels?

METHODS

Experimental Design

Planning of the experiment was truly interdisciplinary. District silviculturists, harvest planners, and wildlife biologists designed the study with guidance from Tappeiner, Kellogg, and McComb and eventually a suite of other university and agency scientists. The initial study design was based on 4 treatments in 30- to 40-year-old stands:

1. Light thin (LT) – Stand density was reduced to approximately 110 trees per acre (271/ha) and represented a typical density reduction in Douglas-fir plantations to promote rapid individual tree growth while maintaining a relatively closed canopy. This treatment tested the hypothesis that standard silivicultural practices would produce stand structure and composition more similar to old-growth over time more quickly than doing nothing at all.
2. Light thin with gaps (LTG) -- Stand density was reduced to approximately 110 trees per acre (271/ha) and in addition, 20% of the stand had 0.5-acre (0.2 ha) openings evenly spaced throughout the stand. Openings were designed to add horizontal heterogeneity, or

patchiness, to the stand similar to what might be expected from gaps formed by tree death in old-growth stands. Gaps were planted to a mixture of Douglas-fir, western hemlock (*Tsuga canadensis*), western redcedar (*Thuja plicata*), and western white pine (*Pinus monticola* ; sprouts from bigleaf maple (*Acer macrophyllum*) and golden chinkapin (*Chrysolepis chrysophylla*) also contributed to gap regeneration. This treatment tested the hypothesis that standard silivicultural practices modified to include gaps would produce stand structure and composition more similar to old-growth over time more quickly than a standard silvicultural thinning.

3. Heavy Thin (HT) – Stand density was reduced to 50 trees per acre (123 trees/ha) and seedlings of Douglas-fir, western hemlock, western redcedar, and western white pine were planted. Such a heavy thinning opened the canopy considerably allowing sunlight to strike the forest floor, presumably allowing planted trees to grow into second story in the stand, thereby increasing vertical complexity. Studies from the Oregon Coast Range indicated that natural regeneration following fires often occurred slowly and at low densities, producing stands where individual trees grew rapidly in early stand development (Poage and Tappeiner 2002). The heavy thinning and underplanting treatment was designed to set the stand on a trajectory more typical of what might have been expected following natural disturbances in the region. This treatment tested the hypothesis that widely spaced, rapidly growing trees and associated second story would produce stand structure and composition more similar to old-growth over time more quickly than any other treatment.
4. No Thin (NT) – Stands similar in density and species composition to treated stands (prior to treatment) were also sampled to understand stand development and associated habitat elements in the absence of silvicultural treatment. In addition to providing a point of comparison, this treatment tested the hypothesis that plantations without silivicultural treatment would take the longest time to produce stand structure and composition similar to old-growth, if at all.

Each of the above 4 treatments was replicated at 4 different stands, with treatments randomly assigned to locations within the stands. Stands averaged 75 acres (30 ha). In addition, 2 snags per acre were created by topping trees in each treatment area (TAC) and the tops were left on the forest floor to add to dead wood biomass.

CWD data collection

Coarse woody debris (CWD) in the YSS was sampled using the line intersect method (Marshall et al. 2000). Data were collected in 1996/97 and 2006, and there was a follow-up survey at one stand in 2007. Small CWD was defined as pieces 1-3 inches (2.5-7.6 cm) in diameter; large CWD was defined as pieces greater than 3” (7.6 cm) in diameter. Following the recommendations of S. Kim Mellen, USFS, we summarized CWD in the stands for pieces $\geq$ 10 cm in diameter that were intersected by the line transect. Although some pieces that were not included in this summary could have been larger than 10 cm somewhere along the piece, our approach provided a conservative estimate of CWD cover and volume for pieces $\geq$ 10 cm dbh.

Each of the 16 TACs was sampled with multiple line transects, each of which was associated with a sample plot. In 1996/97, transects were 50 m long (slope distance). The number of transects (plots) per treatment area ranged from 10 to 33 (Table 1). Transect direction was chosen randomly from one of five points in the plot (North, South, East, West, center). In 2006, CWD was sampled on along two, 15.24-m (slope distance) transects per plot. Each transect originated at plot center with one oriented due east and the other due west. In 2006, there were 3 transects in each of the NT, LT and HT treatments, and 6 transects in the LTG treatment. In TAC 14, two plots sampled in 2006 (12 and 13) were not sampled in 1996/97; thus for a comparison across years, transect data from plots 12 and 13 were removed from the 2006 data before analysis.

In 1996/97, small CWD was sampled along 25 m of the 50-transect (from 25-50 m). The number of intersections with small CWD were tallied along the line transect, and diameters of individual small CWD pieces were not recorded. For large CWD (logs), the data collected in 1996/97 included log diameter at the point of intersection, an estimate of decay class (1-5), and tree species if identifiable (about 82% of logs were identified to species in 1996/97). Diameters of elliptical- or other-shaped logs were measured in two dimensions which were then averaged to get a single value. In 1996/97, pre-treatment down wood (debris type = D) was distinguished from post-treatment slash (debris type = S) for both small and large CWD.

In 2006, small CWD was sampled along the entire length of the two 15.24 m transects. Data collected on individual pieces of large CWD included diameter at the point of intersection, species if identifiable (about 8% of the logs in 2006), and a species/decay category when logs were not identifiable to species (888 = sound and unidentifiable, 999 = rotten and unidentifiable). Logs identified to species were sound. Debris type (origin) was not distinguished in 2006.

Data in the Forest Science Data Bank were checked for errors and the results of that data screening are described in Appendix 1.

Dead wood data summaries

Volume, projected area, and surface area of small and large CWD were calculated using the following equations (Marshall et al. 2000; Marshall et al. 2003):

$$\text{Volume/ha (m}^3\text{/ha)} = (\pi^2/(8*\text{transect length})) * \sum(\text{log diameters}^2)$$
$$\text{Total projected area/ha (m}^2\text{/ha)} = ((50*\pi)/\text{transect length}) * \sum(\text{log diameters})$$
$$\text{Total surface area (m}^2\text{/ha)} = ((50*\pi^2)/\text{transect length}) * \sum(\text{log diameters}),$$

where transect length is in meters and log diameter is in centimeters.

Volumes and area of large logs were calculated at the piece level, thus the terms for log diameter in the equations are not a sum but the individual log diameter. Furthermore, the treatment area (TAC) was considered the unit of interest rather than individual transects within a TAC, so the term for transect length was the sum of all slope-corrected transect lengths in a given treatment area. This piece-level information permits summing the volumes or areas to whatever level of interest (e.g., TAC by Decay Class), while transects with no CWD intersections (i.e., valid 0 values) are accounted for because all transects are included when summing transect lengths.

Data were summarized for three sets of data:

1. 1996/97 (all transects)
2. 1996/97 (subset of transects sampled in 2006)
3. 2006 (subset).

As mentioned previously, two plots in TAC 14 (12 and 13) that were sampled in 2006 were not sampled in 1996/97, thus for a comparison across years the data from transects in plots 12 and 13 were removed from the 2006 data before analysis. In addition, the 1996/97 data were collapsed into broader decay categories to be compatible with 2006, with decay classes 1-2 considered **sound**, and decay classes 3-5 **rotten**.

Biomass was not calculated, because we would have needed species- and decay-class-specific density constants. And since species was not identified for a significant number of logs (811 of 4,464 logs in 1996/97 and 250 of 271 in 2006), biomass could only be calculated by assigning a species and decay class to each unidentified log. This could be done using a frequency (probability) distribution of logs identified by species, size and decay class. Alternatively, the rule set used by Buford and Boyle (1999) could be applied, in which most unidentified logs were assigned the constants for Douglas-fir. However, neither of these approaches were employed.

Mammal sampling methods

We sampled small mammals during fall 2007 and 2008 using the following methods:

- 50 Sherman live traps in variable-length transects, 60-m spacing
- 25 Tomahawk live traps (for larger mammals) set on the ground at alternating stations along every other transect.
- 25 Tomahawk live traps (for northern flying squirrels) attached to tree boles at alternating stations along every other transect (Lehmkuhl et al. 1999).

Trapping at each site occurred over a 4-day period during fall after the onset of the fall rains but before snowfall, approximately mid September through mid November. Traps were checked twice daily (morning and afternoon) to minimize trap-induced mortality. All traps were baited with rolled oats, peanut butter and sunflower seeds; cotton batting was placed in all traps to provide thermal cover for captured mammals. Animals were weighed, marked with individual tags, and then released at the point of capture. Dead animals were stored for future analyses and donated to the Burke Museum at the University of Washington. Two grids in each block were sampled simultaneously and the other two grids in the same block were sampled in the following week. The order for sampling grids within blocks was random and blocks were sampled sequentially. Trapping was in concordance with an approved Institutional Animal Care and Use Committee protocol. We estimated populations of abundant species using Program MARK (see Appendix 2), and used capture rates (captures per 1000 trap nights) as indices of abundance as the basis for analysis for all species.

Statistical Analyses

Dead wood sample plots within TACs were considered sub-samples, with TACs being considered independent observations for the purposes of analyses. Hence, Analysis of Variance was used (n=4 stands per treatment) to assess differences in dead wood among treatments. Scheffe's multiple means comparison was used to identify differences among treatment means. We used a significance level (α) of 0.05. We used a similar ANOVA model to assess response of various small mammals species to treatments (n=4 stands per treatment) in each year sampled. In addition, we explored habitat relationships between small mammal capture rates and dead wood amounts and included a dummy variable in the regression models to understand the effect of thinning on dead wood relationships.

RESULTS – DEAD WOOD

Additions of CWD from Thinning

The contribution of new CWD volume from thinning was significantly ($P < 0.05$) greater in thinned stands with gaps than in control areas where new CWD would only have come from tree mortality or snag fall during the period prior to and following thinning in the other stands. The area of new CWD contributed following light thinning was significantly higher than control stands and the projected surface area of CWD added following heavy thinning was significantly greater than in control areas. Hence, depending on how CWD is measured and summarized, thinning did indeed add CWD to the sites, but due to the high variability in CWD among TACs within treatments, the ability to detect differences was severely compromised (Table 2). Further, contributions from thinning were usually 5-10% of the total log volume already in the TAC. Volume of decay class 1-2 logs increased on lightly thinned stands following thinning, but we were unable to detect changes in CWD area and projected cover for decay class 1-2 logs (Table 3). And we were unable to detect any changes in volume or area of decay class 3-5 logs following thinning (Table 4).

Effectiveness of the 2006 subsample of transects

The 1996 estimates of CWD from the subsample of transects measured in 2006 did not differ from the estimates derived from all transects sampled in 1996, although the variance of the subsample estimates was very high (Tables 5-7). Indeed, the coefficients of variation associated with the difference in CWD estimates between the full set of transects and the subsample were extremely high, leading us to believe that the precision of the subsample was very low. Nonetheless, because the subsampled transects were sampled in both time periods, the difference in CWD between 1996 and 2006 should provide some indication of change in CWD over that 10-year period. The precision in the estimated CWD volume or area in 2006 however may be quite low.

Changes in CWD from 1996 to 2006

We were unable to detect any significant changes in CWD volume or area from the subsample of transects between 1996 and 2006 (Tables 8-10). Coefficients of variation associated with the differences in volume and area between 1996 and 2006 were often greater than 100%, indicating that the precision of these estimates were very low. One possibility for this low precision was the smaller number of subsamples in each TAC, or other factors confounding the detection of CWD. Nonetheless the data suggests declines in CWD volume and area coverage from 1996-2006 at levels that would not be explained soley by decomposition.

2007 sampling: checking 2006 CWD estimates

To explore the reasons for the low precision and decline in CWD estimates between 1996 and 2006, a follow-up survey was conducted in 2007 by Rob Pabst and Tim Fox (Willamette National Forest). We sampled 15 transects in TACs 1-4 at the Tap Thin (Cougar) stand located in the same plots that were sampled in 2006. However, transect length was 50 m (same as 1996/97, rather than 30.48 m, as was used in 2006), and the 2007 transects started from the same point using the same azimuth as in 1996/97, with one exception. In TAC 3, Plot 8, the transect began at the South point instead of the East point (although the same azimuth was used as in 1996/97, so the slope-corrected transect length should be similar to 1996/97). In many of the plots there were remnant bits of blue-and-white striped flagging marking the 1996/97 transect lines, and occasionally we found the original blue pin flags used to mark the 25 m and 50 m points. We didn't realize this until after the first transect, which at 50 meters was about 2 m west of the 50-m pin flag. On that first transect, we checked what logs would and wouldn't have been intersected if we'd been in the exact same location as in 1996/97. The summary data reflect these adjustments (which added two large logs that our original transect did not intersect). On the remaining plots, we took more care in following the bearing and looking for flagging and pin flags. In some plots,transects ended up within a half-meter of a pin flag that had not been noticed previously.

On almost every plot we tallied fewer pieces of large (≥7.5 cm) CWD than in 1996/97. It is possible that some pieces were not found under sword fern (*Polystichum munitum*) or Oregon grape (*Berberis oreganum*), but on some plots we could not find very large pieces of wood that the crew tallied in 1996/97. Some of these pieces were decay class 3 in 1996/97, so it seems like they should have been easy to find in 2007. The most extreme example is from TAC 4, Plot 30. In 1996 the crew recorded a piece of CWD with a diameter of 290 cm. The comment column for this entry reads "130 cm stem (base) root wad." Why they recorded 290 and not 130 is not clear. Regardless, this was one of the very large pieces we did not find, and which would add 354 m^3/ha of wood volume (based on a total transect length of 292 meters from the 6 plots sampled in TAC 4). In general, it seems possible that litter accumulation and moss growth in the past 10 years could have obscured some pieces of wood. We did not comb through the litter or moss looking for buried wood. This is not addressed in the protocol as far as We can tell and raises a question about long-term monitoring of wood. Consideration should be given to the effects of litter accumulation and growth of moss and understory vegetation when estimating wood volumes and decomposition rates over time.

We recorded decay class (1-5) for large CWD pieces, but found very few pieces of "sound" wood (classes 1-2), and the proportions of sound to rotten wood volumes in our sample were much less than in 1997 or even 2006. Standardized definitions for assigning decay classes or for distinguishing "sound" from "rotten" will help in future surveys.

Volume of CWD ≥ 10 cm diameter was higher in 2007 than in 2006 in three of the four TACs (Table 11). There were no clear trends in the comparison of 2007 data to 1996/97 data.

Estimating Sampling Intensity Needed for Future monitoring Efforts.

We used the CWD data available to develop charts of mean and variance stabilization for each of the CWD variables measured in order to provide guidance to managers and researchers designing future CWD sampling efforts. By randomly sorting all plots sampled in all TACs and then plotting the mean and variance over number of plots in the sample, we can see that a reasonably consistent estimate of CWD volume per ha can be achieved with between 50-70 plots. This range encompasses an inflection point in figures 1 and 2. Based on these data, sampling more than 70 plots is unlikely to change the estimated mean or variance significantly and would represent the most economical sampling strategy to achieve an estimate of dead wood volume. Similar charts are available by treatment among blocks and by TAC. See Appendix 2 for treatment level summaries.

SMALL MAMMALS

Although total abundance of small mammals seemed to be greater on the thinned sites (Table 12), there were important differences in patterns of abundance of individual species among treatments. Flying squirrels, deer mice and Trowbridge’s shrew capture rates differed among treatments in one or more of the years sampled (Table 13). During the 2007 and 2008 sampling sessions, several species showed a generally positive association with thinning, such as deer mice (*Peromyscus maniculatus*), creeping voles (*Microtus oregoni*) and Townsend’s chipmunks (*Tamias townsendii*) (Figure 3), though only deer mouse and vole captures differed significantly among treatments ($P<0.10$). However, other species such as northern flying squirrels (*Glaucomys sabrinus*), Trowbridge’s shrews (*Sorex trowbridgii*), and (not significantly) California red-backed voles (*Clethrionomys californicus*) showed a general negative trend to one of more treatments and were generally more abundant on uncut control sites (Figure 4). This information is very useful to managers deciding how to thin young dense stands to improve habitat for late seral associated species because although the thinning treatments may have long term benefits for some species, the short term impacts must be considered.

Small mammal populations are notoriously variable from year to year. High populations in one year could mask patterns of abundance in other years. To assess if patterns of captures were consistent from one year to the next we examined correlations in captures per TAC between the samples collected in 2007 and in 2008 for the 7 most commonly captured species (Table 14). Of note is the consistency in data patterns from one year to the next for flying squirrels, chipmunks, deer mice and Pacific shrews. Since flying squirrels seem to be less abundant in thinned than unthinned stands for the first 10 years after thinning, we suggest that thinning in a manner that maintains an uncut matrix of young forest within which stands of thinned stands are embedded may be necessary if we are to maintain high populations of species such as northern flying squirrels, an important prey species for the northern spotted owl (*Strix occidentalis caurina*). Further, in order to provide habitat for a full suite of small mammal species, uncut stands supported 12 species, while thinned stands supported 10-11 species. Finally, of the thinning treatments, the gap-cut stands seemed to have the least impact on the small mammal community. Consequently these patterns need to be confirmed through another season of sampling. If these patterns are consistent then the type of thinning and arrangement of thinned stands should be given careful consideration in order to maintain habitat for the full suite of mammal species detected thus far in this study.

Capture rates are often considered unreliable indicators of abundance so we also estimated abundance using program MARK for several common species to assess the relationship between estimated abundance and standardized capture rates. Specific approaches to estimating abundance using MARK are provided in Appendix 3. Correlations between Mark-Recapture estimates per site using Program MARK and capture rates per site for the four most commonly captured species were very high (r=0.81-1.00) (Table 15). Hence we feel that capture rates probably reasonably reflect abundance for the other species as well.

Associations with dead wood

Correlations between capture rates for common species and dead wood availability were highly variable among species and among years (Table 16, Appendix 5). Given the high degree of inconsistency in associations within species, the regression approach that we took may not be fully detecting meaningful relationships between dead wood and mammal abundance, but previous compilations of studies shows similar patterns of variability (McComb 2003). Very general patterns can be inferred from Table 16:

- Flying squirrels were more affected by thinning than by dead wood
- Deer mice and creeping voles were more associated with sound dead wood and thinning
- Townsend’s chipmunks and California red-backed voles were more associated with dead wood than with thinning.

CONCLUSIONS AND RECOMMENDATIONS

1. Thinning generated pieces of dead wood that increased CWD volume by nearly 10% in some treatments and increased areal cover by nearly 20% following thinning (Figure 5). Ten year remeasurements showed a drastic decline in CWD volume and area which may be in part caused by decomposition and in part by inconsistencies in sampling from one time period to the next.

2. Spatial distribution of wood is highly variable, so for long-term monitoring it may be best to sample 50-70 plots using the same transect length and location as in previous measurements.

3. The 25- and 50-m points along the CWD transects in the YSS should be marked permanently to facilitate accurate tallies of CWD pieces in the future.

4. Resampling the same transect line may not always translate to accurate tallies. In general we found fewer pieces of wood than were found in 1996/97, including some very large pieces. Accumulation of litter, moss and understory vegetation (especially sword fern and Oregon grape) may make detection of some pieces more difficult over time. Clarification to the original protocol is needed to describe how crews should detect wood pieces (e.g., should they lift up dead fern fronds or comb through moss looking for wood?).

5. Standardized definitions for assigning decay classes or for distinguishing "sound" from "rotten" will help in future surveys.

6.Future field crews (vegetation, trees, wildlife, etc.) should be cognizant of their potential impact on CWD in the YSS TACs. It seems possible that stepping on rotting pieces of large CWD may accelerate their decay.

7.Thinning resulted in more captures of deer mice, creeping voles and Townsned’s chipmunks, but fewer captures of flying squirrels, Trowbridge’s shrews, and red-backed voles in 2007 and 2008. Flying squirrels seem particularly sensitive to any form of thinning. Thinned patches should be set within unthinned forest matrices should be considered in order to maintain northern flying squirrel populations until populations recover in adjacent thinned stands.

8. Dead wood abundance was associated with some small mammal species such as Townsend’s chipmunks and red-backed voles. Other species were more associated with thinning or a combination of dead wood and thinning. Changes in the understory vegetation as a result of thinning was probably a more important than dead wood as a determinant of abundance for creeping voles and deer mice.

Although thinning prescriptions should consider a suite of other organisms, such as amphibians (data are still be collected using cover boards), birds, invertebrates, and vascular and non-vascular plants, we offer the following suggestions pertinent to dead wood and small mammals.

1. Fluxes in dead wood in thinned stands are more likely to come from damage to pre-existing dead wood pieces (loss) with only a modest increase in dead wood from suppression mortality and slash. Because piece sizes are small in young stands, it is the larger pre-existing pieces resulting from different utilization standards during harvesting that are the most likely to be associated with small mammal abundance. Care in working around and not disturbing or destroying pre-existing pieces is hence key to maintaining high levels of dead wood in these stands until large trees begin to die (or can be killed) decades into the future.
2. Thinning had a marked and consistent negative effect on northern flying squirrels. Since this is a primary food source for northern spotted owls, thinned stands should be strategically placed within a matrix of unthinned stands. Although we anticipate that flying squirrel populations will recover as the thinned stands close canopy and mature, unthinned stands will be an important bridge until that time.
3. Monitoring of dead wood must be intensive, with 50-17 plots per sample area to capture means and variances in stands similar to the ones that we worked in. New techniques should be explored to ensure that pieces measured at one time period can be accurately tracked into the future by different field crews.
4. Monitoring of small mammals should continue on 10-year intervals to assess when populations of flying squirrels begin recovering in the thinned stands. At the community level, it would be informative to know when community similarity between the mammal community in these young stands approximates the community composition and structure in old-growth stands.

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Table 1. Number of transects sampled for CWD in each treatment area in 1996/97 and 2006.

TAC	Location	Treatment	# Transects / TAC	
			1996/97	2006
1	Cougar Reservoir	Control	23	3
2	Cougar Reservoir	Heavy	13	3
3	Cougar Reservoir	Light	19	3
4	Cougar Reservoir	Gaps	30	6
5	Mill Creek	Control	25	3
6	Mill Creek	Heavy	18	3
7	Mill Creek	Light	26	3
8	Mill Creek	Gaps	33	6
9	Christy Flats	Control	23	3
10	Christy Flats	Heavy	15	3
11	Christy Flats	Light	24	3
12	Christy Flats	Gaps	30	6
13	Sidewalk Creek	Control	17	3
14	Sidewalk Creek	Heavy	10	3
15	Sidewalk Creek	Light	15	3
16	Sidewalk Creek	Gaps	30	6
Total number of transects:			351	60

Table 2. Means (and standard errors indicated parenthetically) of total CWD in 1996 in which pre-treatment volumes and areal coverages were tallied separately to estimate the effects of thinning on adding CWD to the site. (n=4).

CWD Characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of preexisting pieces	228.0 (49.3)	156.3 (58.6)	224.3 (49.3)	117.8 (46)	**0.0253**
No. of pieces added	1.5 (3.0)	84.3 (51.2)	92.3 (60.1)	42.0 (29.2)	**0.0355**
Total no. of pieces	229.5 (51.1)	240.5 (75.3)	316.5 (85.8)	159.5 (74.7)	0.0607
Pre-existing pieces/m	0.21 (0.02)	0.15 (0.03)	0.15 (0.04)	0.17 (0.05)	0.1167
New pieces/m	0.001 (0.003)	0.079 0.053	0.060 (0.036)	0.056 (0.036)	0.0586
Total pieces/m	0.21 (0.03)	0.228 (0.029)	0.208 (0.054)	0.225 (0.080)	0.9285
Pre-existing piece volume(m3/ha)	425 (131)	402.3 (131.8)	380.6 (95.3)	370.0 (54.4)	0.8912
New piece volume	4.8 (9.50)B	28.5 (19.0)AB	36.4 (10.6)A	22.8 (7.0)AB	**0.0211**
Total piece volume	429.7 (133.3)	430.8 (126.1)	417.0 (84.8)	392.8 (57.0)	0.9507
Projected area of pre-existing pieces(m2/ha)	1127 (223)	923 (263)	856 (173)	938 (193)	0.3632
Projected area of new pieces	10.9 (21.7)B	182.5 (110.3)A	157.0 (63.3)AB	135.5 (70.9)AB	**0.0283**
Total projected area of pieces	1138 (235)	1105 (194)	1013 (189)	1074 (255)	0.8701
Surface area of pre-existing pieces (m2/ha)	3541 (700)	2900 (825)	2689 (545)	2947 (605)	0.363
Surface area of new pieces	34 (68)B	573 (347)AB	493 (199)AB	426 (223)A	**0.0283**
Total surface area of pieces	3575 (737)	3473 (610)	3183 (592)	3373 (801)	0.8700

Table 3. Means (and standard errors indicated parenthetically) of CWD in decay classes 1-2 in 1996 in which pre-treatment volumes and areal coverages were tallied separately to estimate the effects of thinning on adding CWD to the site. (n=4).

CWD Characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of preexisting pieces	62.5 (28.4)	37.3 (19.3)	52.3 (22.6)	29.5 (17.4)	0.2078
No. of pieces added	0 (0)	80.8 (49.2)	83.3 (61.7)	40.3 (31.1)	0.0519
Total no. of pieces	62.5 (28.4)	118.0 (46.7)	135.5 (74.7)	69.8 (47.8)	0.1845
Pre-existing pieces/m	0.06 (0.02)	0.04 (0.01)	0.03 (0.02)	0.04 (0.02)	0.4108
New pieces/m	0 (0)	0.08 (0.05)	0.05 (0.04)	0.05 (0.04)	0.0765
Total pieces/m	0.06 (0.05)	0.13 (0.07)	0.10 (0.06)	0.08 (0.05)	0.3739
Pre-existing piece volume(m3/ha)	42.2 (23.6)	51.9 (45.0)	55.5 (49.2)	47.0 (27.6)	0.962
New piece volume	0 (0)B	19.9 (9.5)A	19.0 (6.5)AB	14.5 (12.6)AB	0.022
Total piece volume	42.2 (23.6)	71.8 (35.9)	74.5 (42.7)	61.5 (35.5)	0.5711
Projected area of pre-existing pieces(m2/ha)	167.6 (64.2)	142.9 (95.4)	126.8 (58.1)	144.8 (71.0)	0.8891
Projected area of new pieces	0 (0)	162.9 (96.7)	120.6 (73.7)	116.5 (92.6)	0.0556
Total projected area of pieces	167.6 (64.2)	305.8 (24.8)	247.4 (90.9)	261.3 (158.6)	0.2924
Surface area of pre-existing pieces (m2/ha)	526 (202)	449 (300)	398 (183)	455 (223)	0.8892
Surface area of new pieces	0 (0)	512 (304)	379 (231)	366 (291)	0.0556
Total surface area of pieces	526 (202)	961 (78)	777 (286)	821 (498)	0.2921

Table 4. Means (and standard errors indicated parenthetically) of CWD in decay classes 3-5 in 1996 in which pre-treatment volumes and areal coverages were tallied separately to estimate the effects of thinning on adding CWD to the site. (n=4).

CWD Characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of preexisting pieces	165.5 (28.1)AB	119.0 (42.6)AB	172.0 (31.1)A	88.3 (30.2)B	**0.0120**
No. of pieces added	1.5 (3.0)B	3.5 (3.4)AB	9.0 (3.9)A	1.8 (2.4)AB	**0.0217**
Total no. of pieces	167.0 (30.8)AB	122.5 (44.6)AB	181.0 (32.4)A	90.0 (28.8)B	**0.0111**
Pre-existing pieces/m	0.15 (0.02)	0.11 (0.02)	0.02 (0.09)	0.13 (0.03)	0.1275
New pieces/m	0.001 (0.003)	0.003 (0.003)	0.006 (0.003)	0.003 (0.005)	0.3244
Total pieces/m					
Pre-existing piece volume(m3/ha)	382.9 (107.7)	350.4 (105.7)	325.2 (65.4)	323.0 (38.9)	0.7309
New piece volume	4.8 (9.5)	8.6 (10.7)	17.4 (6.8)	8.3 (9.6)	0.3021
Total piece volume	388.0 (110.8)	359.0 (108)	342.6 (58.6)	331.3 (30.3)	0.798
Projected area of pre-existing pieces(m2/ha)	959.7 (182.3)	780.3 (198.4)	729.2 (130.5)	793.2 (150.4)	0.2839
Projected area of new pieces	10.9 (21.7)	19.6 (23.1)	36.5 (14.9)	19.0 (24.7)	0.4235
Total projected area of pieces	970.6 (194.8)	800.0 (205.1)	765.6 (123.1)	812.2 (139.6)	0.3655
Surface area of pre-existing pieces (m2/ha)	3015 (573)	2451 (623)	2291 (410)	2492 (472)	0.2839
Surface area of new pieces	34 (68)	62 (73)	115 (47)	60 (78)	0.4237
Total surface area of pieces	3049 (612)	2513 (644.4)	2405 (387)	2552 (439)	0.3655

Table 5. Means (and standard errors indicated parenthetically) of total CWD in the full set of 1996 samples of CWD compared to the subsample of transects that were subsequently used to sample CWD (but sampled in 1996). (n=4).

CWD Characteristic	Control	Light thin	Thin with gaps	Heavy thin	P
No. of pieces in 1996 sample	229.5 (51.1)	240.5 (75.3)	316.5 (85.8)	159.8 (74.7)	0.067
No. of subsample pieces	32.3 (1.9)B	36.5 (11.0)B	68.5 (17.9)A	24.5 (10.8)B	**0.0011**
Difference in no. of pieces	-197.3 (50.8)	-204.0 (73.5)	248.0 (68.2)	135.3 (66.8)	0.1657
No of pieces in 1996 sample/m	0.21 (0.03)	0.228 (0.029)	0.208 (0.054)	0.225 (0.080)	0.9285
Subsample pieces/m	0.22 (0.02)	0.243 (0.068)	0.230 (0.062)	0.210 (0.074)	0.8743
Difference in pieces/m	0.007 (0.035)	0.015 (0.055)	0.022 (0.008)	0.015 (0.104)	0.8473
!996 piece volume(m3/ha)	429.7 (133.3)	430.8 (126.1)	417.0 (84.8)	392.8 (57.0)	0.9507
Subsample piece volume	449.3 (32.2)	314.7 (122.8)	586.7 (289.2)	397.7 (254.7)	0.3304
Difference in piece volume	19.6 (122.2)	-116.0 (197.0)	169.7 (251.1)	4.9 (283.6)	0.3823
Projected area of 1996 pieces(m2/ha)	1138 (234)	1106 (194)	1013 (189)	1073 (255)	0.8701
Projected area of subsample pieces	1189 (64)	996 (226)	1156 (213)	1090 (546)	0.8327
Difference in projected area of pieces	51 (219)	-109 (381)	143 (198)	17 (625)	0.8391
Surface area of 1996 pieces (m2/ha)	3575 (736)	3475 (610)	3182 (592)	3372 (801)	0.87
Surface area of subsample pieces	3735 (201)	3130 (710)	3632 (669)	3425 (1717)	0.8327
Difference in surface area of pieces	159 (688)	-343 (1197)	449 (624)	52.2 (1964)	0.8391

Table 6. Means (and standard errors indicated parenthetically) of decay class 1-2 CWD in the full set of 1996 samples of CWD compared to the subsample of transects that were subsequently used to sample CWD (but sampled in 1996). (n=4).

CWD Characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of pieces in 1996 sample	62.5 (28.4)	118.046.7)	135.5 (74.7)	69.8 (47.8)	0.1845
No. of subsample pieces	8.5 (7.7)	19.8 (9.4)	31.8 (19.2)	10.8 (8.1)	0.069
Difference in no. of pieces	54.0 (22.8)	98.3 (39.3)	103.8 (57.2)	59.0 (40.4)	0.2556
No of pieces in 1996 sample/m	0.06 (0.02)	0.11 (0.04)	0.09 (0.05)	0.09 (0.06)	0.3784
Subsample pieces/m	0.06 (0.05)	0.13 (0.07)	0.10 (0.06)	0.08 (0.05)	0.3739
Difference in pieces/m	0.00 (0.04)	-0.02 (0.03)	0.01 (0.02)	0.02 (0.02)	0.3654
!996 piece volume(m3/ha)	42.2 (23.6)	71.8 (35.9)	74.5 (42.7)	61.5 (35.5)	0.5711
Subsample piece volume	47.6 (41.2)	44.8 (7.7)	156.9 (161.5)	72.4 (91.0)	0.3454
Difference in piece volume	5.5 (24.3)	27.0 (39.5)	82.4 (126.1)	11.0 (67.1)	0.2626
Projected area of 1996 pieces(m2/ha)	167.6 (64.2)	305.8 (24.8)	247.4 (90.9)	261.3 (158.6)	0.2924
Projected area of subsample pieces	182.6 (136)	311.6 (92.0)	319.0 (41.6)	247.3 (216.9)	0.4888
Difference in projected area of pieces	15.1 (105.5)	5.8 (89.8)	71.6 (52.3)	14.0 (115.3)	0.6197
Surface area of 1996 pieces (m2/ha)	526 (202)	961 (78)	777 (286)	821 (498)	0.2921
Surface area of subsample pieces	183 (136)	979 (289)	1002 (131)	777 (681)	0.4888
Difference in surface area of pieces	47 (331)	18 (282)	225 (164)	44 (362)	0.6199

Table 7. Means (and standard errors indicated parenthetically) of decay class 3-5 CWD in the full set of 1996 samples of CWD compared to the subsample of transects that were subsequently used to sample CWD (but sampled in 1996). (n=4).

CWD Characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of pieces in 1996 sample	167.0 (30.8)AB	122.5 (44.6)AB	181.0 (32.4)A	90.0 (28.8)A	0.0111
No. of subsample pieces	23.8 (5.9)B	16.8 (2.5)B	8.1 (26.0)A	13.8 (3.6)B	0.0003
Difference in no. of pieces	143.3 (31.5)	105.8 (46.8)	144.3 (29.5)	76.3 (28.1)	0.0481
No of pieces in 1996 sample/m	0.15 (0.02)	0.116 (0.024)	0.120 (0.024)	0.131 (0.028)	0.1866
Subsample pieces/m	0.16 (0.04)	0.115 (0.017)	0.123 (0.025)	0.135 (0.087)	0.6504
Difference in pieces/m	0.003 (0.026)	0.001 (0.041)	0.002 (0.023)	0.004 (0.087)	0.9989
!996 piece volume(m3/ha)	387.6 (110.8)	359.0 (107.9)	342.6 (58.6)	331.4 (30.3)	0.798
Subsample piece volume	401.6 (20.8)	684.7 (188.0)	429.8 (152.9)	325.2 (269.0)	0.5391
Difference in piece volume	14.0 (125.1)	89.1 (193.8)	87.2 (142.3)	6.1 (277.9)	0.6525
Projected area of 1996 pieces(m2/ha)	970.6 (194.8)	800.0 (205.1)	765.6 (123.1)	812.2 (139.6)	0.3655
Projected area of subsample pieces	1006.1 (158.8)	684.7 (188.0)	836.9 (204.7)	842.8 (604.9)	0.634
Difference in projected area of pieces	35.6 (193.4)	115.1 (354.7)	71.3 (204.1)	30.6 (596.6)	0.8983
Surface area of 1996 pieces (m2/ha)	3049 (612)	2513 (644)	2405 (387)	2552 (439)	0.3655
Surface area of subsample pieces	3161 (499)	2151 (591)	2629 (643)	2648 (1900)	0.634
Difference in surface area of pieces	112 (608)	362 (1114)	224 (641)	96.2 (1874)	0.8984

Table 8. Means (and standard errors indicated parenthetically) of total CWD in the subset of 1996 samples of CWD compared to the same transects in 2006. (n=4).

CWD characteristic	**Control**	**Light thin**	**Thin with gaps**	**Heavy thin**	**P**
No. of pieces in 1996	32.3 (1.9)AB	36.5 (11.0)AB	68.5 (17.9)A	24.5 (10.8)B	**0.0011**
No. of pieces in 2006	14.5 (7.9)	11.5 (4.8)	30.0 (6.4)	10.8 (7.9)	**0.0059**
Change from 1996-2006	-17.8 (7.8)	-25.0 (12.1)	-38.5 (12.3)	13.8 (11.3)	0.0372
Pieces/m in 1996	0.22(0.02)	0.243 (0.068)	0.23 (0.06)	0.21	0.8743
Pieces/m in 2006	0.16 (0.08)	0.128 (0.052)	0.16 (0.03)	0.12 (0.09)	0.7387
Change from 1996-2006	-0.06 (0.09)	-0.115 (0.089)	-0.07 (0.03)	0.09 (0.16)	0.8267
Piece volume 1996 (m^3/ha)	449.3(32.2)	314.7 (122.8)	586.7 (289.2)	397.7 (255.7)	0.3304
Piece volume 2006	248.4 (67.3)	106.5 (84.3)	229.9 (76.8)	270.0 (220.5)	0.3201
Change from 1996-2006	-200.9 (42.7)	208.3 (163.0)	356.8 (273.7)	128.0 (403.6)	0.6554
Projected area of 1996 pieces(m^2/ha)	1189(64)	996 (226)	1156 (213)	1090 (546)	0.8237
Projected area of 2006 pieces	730 (274)	410 (211)	674 (48)	560 (394)	0.3682
Change from 1996-2006	-459 (241)	-586 (294)	-482 (203)	-531 (883)	0.9833
Surface area of 1996 pieces (m^2/ha)	3734 (201)	3130 (710)	3632 (669)	3425 (1717)	0.8237
Surface area of 2006 pieces	2292 (859)	1289 (664)	2118 (151)	1758 (1237)	0.3682
Change from 1996-2006	-1442 (758)	-1841 (922)	-1514 (639)	1667 (2777)	0.9833

Table 9. Means (and standard errors indicated parenthetically) of decay class 1-2 CWD in the subset of 1996 samples of CWD compared to the same transects in 2006. (n=4).

CWD characteristic	Control	Light thin	Thin with gaps	Heavy thin	P
No. of pieces in 1996	8.5 (7.7)	19.8 (9.4)	31.8 (19.2)	10.8 (8.1)	0.069
No. of pieces in 2006	9.0 (7.1)	9.0 (5.4)	20.0 (8.8)	8.8 (8.0)	0.1362
Change from 1996-2006	0.5 (8.5)	10.8 (9.3)	-11.8 (11.1)	-2.0 (9.5)	0.2335
Pieces/m in 1996	0.06 (0.05)	0.13 (0.07)	0.10 (0.06)	0.08 (0.05)	0.3739
Pieces/m in 2006	0.10 (0.08)	0.10 (0.06)	0.11 (0.05)	0.10 (0.09)	0.9884
Change from 1996-2006	0.04 (0.08)	-0.03 (0.08)	0.01 (0.02)	0.02 (0.09)	0.6003
Piece volume 1996 (m^3/ha)	47.6 (41.2)	44.8 (7.7)	156.9 (161.5)	72.4 (91.0)	0.3454
Piece volume 2006	55.3 (52.3)	85.5 (85.3)	121.7 (38.2)	128.9 (109.3)	0.52
Change from 1996-2006	7.7 (34.8)	40.7 (77.6)	35.2 (187.5)	56.5 (140.8)	0.7403
Projected area of 1996 pieces(m^2/ha)	182.6 (135.9)	311.6 (92.0)	319.0 (41.6)	247.3 (216.9)	0.4888
Projected area of 2006 pieces	278.6(227.2)	318.4 (212.3)	390.2 (100.3)	354.8 (314.3)	0.9085
Change from 1996-2006	95.9 (156.7)	6.7 (192)	71.2 (85.8)	107.5 (380.7)	0.9266
Surface area of 1996 pieces (m^2/ha)	574 (427)	979 (289)	1002 (131)	777 (681)	0.4888
Surface area of 2006 pieces	875 (714)	1000 (667)	1226 (315)	1115 (988)	0.9085
Change from 1996-2006	301 (492)	21.2 (602)	224 (269)	338 (1196)	0.9266

Table 10. Means (and standard errors indicated parenthetically) of decay class 3-5 CWD in the subset of 1996 samples of CWD compared to the same transects in 2006. (n=4).

CWD characteristic	Control	Light thin	Thin with gaps	Heavy thin	P
No. of pieces in 1996	23.8 (5.9)B	16.8 (2.5)B	36.8 (8.1)A	13.8 (3.6)B	**0.0003**
No. of pieces in 2006	5.5 (1.7)AB	2.5 (1.3)B	10.0 (2.9)A	2.0 (2.5)B	**0.0009**
Change from 1996-2006	18.3 (5.9)AB	14.3 (3.4)B	26.8 (6.4)A	11.8 (2.2)B	**0.0044**
Pieces/m in 1996	0.158(0.038)	0.12 (0.02)	0.12 (0.03)	0.14 (0.09)	0.6504
Pieces/m in 2006	0.060(0.023)	0.03 (0.01)	0.06 (0.02)	0.02 (0.03)	0.0545
Change from 1996-2006	0.098(0.043)	0.09 (0.03)	0.07 (0.02)	0.11 (0.10)	0.7307
Piece volume 1996 (m^3/ha)	401.6 (20.8)	269.9 (125.2)	429.8 (152.9)	325 (269)	0.5391
Piece volume 2006	193.1 (17.2)	20.9 (10.0)	108.2 (63.8)	140.8 (192)	0.1648
Change from 1996-2006	208.6 (31.1)	249.0 (121)	321.6 (112.9)	184.5 (374)	0.7949
Projected area of 1996 pieces(m^2/ha)	1006.1(158.8)	684.7 (188)	836.9 (204.7)	843.0(605.0)	0.634
Projected area of 2006 pieces	451.1 (76.6)	91.9 (5.1)	283.9 (136.4)	204.9(283.6)	0.0506
Change from 1996-2006	555.0 (180.1	592.9 (192.6)	553.0 (145.2)	638.0(735.0)	0.9886
Surface area of 1996 pieces (m^2/ha)	3161 (499)	2151 (590)	2629 (643)	2648 (1900)	0.634
Surface area of 2006 pieces	1417 (241)	289 (16)	892 (428)	644 (891)	0.0506
Change from 1996-2006	1744 (566)	1863 (605)	1737 (456)	2004 (2309)	0.9886

Table 11. A resample of CWD on the Cougar reservoir sites conducted in 2007 compared to 1996/97 samples and the 2006 sample.

		1997 (50-m transects)				**2006 (30.5-m transects)**				**August 2007 (50-m transects)**			
Treatment	**# plots**	**Tr length (m)**	**# Logs ge 10 cm**	**Logs per meter**	**Volume (m3/ha)**	**Tr length (m)**	**# Logs ge 10 cm**	**Logs per meter**	**Volume (m3/ha)**	**Tr length (m)**	**# Logs ge 10 cm**	**Logs per meter**	**Volume (m3/ha)**
Control	3	149.2	31	0.2077	**418.0**	91.3	10	0.1095	**186.9**	149.2	30	0.2010	**469.6**
Heavy	3	146.1	30	0.2053	**439.6**	90.9	11	0.1210	**540.0**	146.1	22	0.1506	**425.4**
Light	3	149.6	52	0.3475	**359.6**	91.1	9	0.0988	**72.4**	149.6	31	0.2072	**140.8**
Light w/ Gaps	6	292.8	63	0.2152	**1016.7**	181.8	25	0.1375	**253.5**	292.8	44	0.1503	**368.4**

Table 12. Total captures (uncorrected for trap effort) by species and thinning treatment, Willamette National Forest, Young Stand Thinning and Diversity study, 2007 and 2008 combined.

Species	Control	Heavy	Light	Gaps	TOTAL
Deer mouse	255	724	609	619	2207
Townsend's chipmunk	444	774	811	803	2832
Trowbridge's shrew	132	34	60	71	297
N. Flying squirrel	202	22	78	45	347
Red-backed vole	62	27	40	30	159
Creeping vole	4	11	24	21	60
Pacific shrew	46	6	22	16	90
W. spotted skunk	16	2	3	3	24
Coast mole	14	0	0	0	14
Vagrant shrew	1	1	1	2	5
Douglas' squirrel	1	5	11	6	23
Snowshoe hare	2	0	0	0	2
California ground squirrel	0	0	2	9	11
Ermine	1	0	3	1	5
Shrew-mole	4	0	0	1	5
Bushy-tailed woodrat	0	4	3	0	7
Pacific Jumping Mouse	0	2	0	0	2
Brush rabbit	0	1	0	0	1
TOTAL CAPTURES	1184	1613	1667	1627	6091
TOTAL SPECIES	14	13	13	13	18

Table 13. Comparisons of capture rates (mean and SE) for the six most commonly captured small mammal species. Bolded lines represent a significant difference among treatments.

Species	Year	Control	Light thin	Thin w/ gaps	Heavy thin	P
Red-backed vole	1991	4.8 (3.2)	4.9 (3.1)	5.1 (3.4)	6.8 (3.5)	0.9680
	1992	8.9 (4.4)	16.2 (7.8)	21.5 (14.4)	16.6 (7.3)	0.8133
	1998	1.1 (0.5)	0.3 (0.3)	0.8 (0.5)	2 (1.2)	0.4215
	1999	1.9 (1.1)	0 (0)	0 (0)	0 (0)	0.0769
	2001	2.6 (0.8)	1.3 (0.4)	1.3 (0.8)	1.4 (0.8)	0.5359
	2007	12.8 (5.6)	3.8 (2.9)	7.7 (7.7)	10.8 (8.1)	0.7725
	2008	28.4 (7.5)	22.2 (13.7)	13.9 (9.0)	9.7 (4.1)	0.5092
Flying squirrel	1991	0 (0)	6.2 (5.0)	4.5 (4.0)	0.3 (0.3)	0.4599
	1992	0.9 (0.9)	4.5 (4.5)	3.5 (3.5)	2.5 (2.1)	0.8657
	1998	0.7 (0.7)	0.3 (0.3)	0 (0)	0 (0)	0.5525
	1999	4.3 (2.8)	1.0 (0.2)	0.3 (0.3)	0 (0)	0.1959
	2001	**7.3A (3.0)**	**0.8B (0.8)**	**0.3B (0.3)**	**0B (0)**	**0.0171**
	2007	**29.8A (10.2)**	**10.2AB (6.7)**	**8.6AB (5.3)**	**2.3B (1.3)**	**0.0638**
	2008	**29.9A (10.4)**	**12.4AB (6.7)**	**7.1AB (1.5)**	**4.5B (2.2)**	**0.0607**
Creeping vole	1991	0 (0)	0 (0)	0 (0)	0 (0)	
	1992	0 (0)	0 (0)	0.3 (0.3)	0 (0)	0.4262
	1998	0.8 (0.5)	0.9 (0.5)	1.2 (0.5)	1.4 (0.7)	0.8687
	1999	0 (0)	1.9 (1.3)	2.1 (1.3)	1.7 (0.6)	0.4135
	2001	2.0 (1.7)	1.1 (0.2)	2.0 (0.9)	2.3 (0.8)	0.8558
	2007	0.7 (0.7)	10.4 (5.1)	6.8 (2.3)	2.9 (2.0)	0.1595
	2008	2.2 (0.70)	5.9 (2.4)	10.4 (2.8)	3 (2.1)	0.0795
Deer mouse	1991	26.2 (14.2)	44.1 (2.2)	48.5 (17.4)	51.2 (12.7)	0.5254
	1992	39.8 (8.0)	62.9 (13.5)	76.5 (27.6)	100.2 (35.9)	0.3837
	1998	**41.9B (10.7)**	**144.3A (28.5)**	**124.3A (13.3)**	**116.4AB (18.6)**	**0.0128**
	1999	6.4 (6.4)	25.9 (21.6)	25.3 (11.8)	48.5 (29.5)	0.5249
	2001	16.7 (6.8)	36.1 (3.6)	25.4 (4.5)	34.4 (4.4)	0.0595
	2007	**109B (19.4)**	**266.0A (42.3)**	**294.2A (36.1)**	**289A (25.9)**	**0.0045**
	2008	38.1 (10.4)	95.9 (28.8)	103.1 (26.4)	108.9 (14.5)	0.1273
Trowbridge's shrew	1991	15.1 (4.3)	13.9 (2.8)	11.1 (2.5)	18.4 (7.0)	0.7248
	1992	14.2 (6.7)	20.0 (7.1)	17.0 (10.4)	20.2 (8.3)	0.9474
	1998	41.5 (4.2)	40.9 (13.9)	31.0 (3.0)	24.7 (3.5)	0.3701
	1999	31.6 (13.4)	13.3 (3.0)	29.7 (9.3)	12.4 (3.2)	0.2667
	2001	26.3 (6.7)	20.8 (6.5)	22.8 (6.0)	17 (4.7)	0.7385
	2007	39.5 (17.3)	19.3 (4.7)	23.7 (10.4)	10.3 (3.8)	0.3058
	2008	**45.5A (9.2)**	**22.6AB (7.4)**	**27.6AB (8.6)**	**10.5B (2.0)**	**0.0373**
Townsend's chipmunk	1991	0 (0)	6.3 (5.8)	18.2 (15.7)	18.4 (16.7)	0.6314
	1992	7.2 (4.1)	14.2 (11.3)	26.5 (20.6)	15.3 (8.5)	0.7560
	1998	41.0 (26.6)	53.8 (27.6)	45.3 (13.9)	43.8 (10.1)	0.9758
	1999	28.2 (13.3)	60.8 (28.5)	80.3 (25.4)	73.6 (15.3)	0.3704
	2001	84.5 (25.7)	125.8 (58.6)	180.3 (54.2)	159.3 (33.3)	0.4878
	2007	50.6 (11.6)	136.2 (45.1)	152.9 (83.3)	113.6 (28.9)	0.5135
	2008	40.6 (7.2)	65.6 (12.6)	63.4 (15.0)	66.9 (7.7)	0.3343

Table 14. Correlations in capture rates between 2007 and 2008 for the 7 most abundant species sampled in both years.

Species	**r**
Red-backed vole	0.58
Flying Squirrel	0.83
Deer mouse	0.72
Trowbridge's shrew	0.52
Townsend's chipmunk	0.76
Creeping vole	0.25
Pacific shrew	0.71

Table 15. Correlations between estimated abundance using Program MARK and capture rates for the four species with enough captures to develop reliable estimates of abundance.

	2007	2008
Flying Squirrel	0.96	0.97
Townsend's chipmunk	0.85	0.92
Deer mouse	0.81	0.95
Red-backed vole	0.99	1.00

Table 16. Correlations of capture rates for each species with estimates of dead wood availability (n=16) by species and year. Thinning was entered as a dummy variable (thin) in the post-treatment year models to account for effects due to cutting that may otherwise be confounded with dead wood availability.

Species	**Year**	**CWD Variable**	**Partial R^2**	**Overall R^2**	**P**
Townsend's chipmunk	2008	Area of rotten logs	0.41	0.41	0.0074
		Number of logs	0.16	0.57	0.0451
	2007	Number of logs	0.29	0.29	0.0318
	1999	Thin	0.20	0.20	0.0865
		Area of rotten logs	0.16	0.35	0.0980
	1998	Volume of rotten logs	0.30	0.30	0.0290
		Area of pretreatment logs	0.22	0.52	0.0280
		Volume of sound logs	0.10	0.62	0.1035
	1992	Area of rotten logs	0.36	0.36	0.0143
	1991	No model			
Trowbridge's shrew	2008	Thin	0.37	0.01	0.0120
	2007	Area of all logs	0.30	0.30	0.0266
		Volume of sound logs	0.15	0.46	0.0782
		Area of rotten logs	0.14	0.60	0.0653
	1999	Thin	0.54	0.54	0.0012
	1998	Thin	0.54	0.54	0.0012
	1992	Area of rotten logs	0.23	0.23	0.0629
		Number of sound logs	0.16	0.39	0.0869
	1991	Number of sound logs	0.42	0.42	0.0069
Deer mouse	2008	Thin	0.36	0.36	0.0145
	2008	Area of sound logs	0.16	0.52	0.0559
	2008	Cover of sound logs	0.17	0.69	0.0273
	2007	Thin	0.64	0.64	0.0002
	2007	Area of all logs	0.06	0.70	0.1255
	1999	No model			
	1998	Thin	0.54	0.54	0.0012
	1992	Volume of sound logs	0.26	0.26	0.0425
		Cover of rotten logs	0.13	0.40	0.1140
	1991	Volume of sound logs	0.26	0.26	0.0427
Creeping vole	2008	No model			
	2007	Thin	0.16	0.16	0.1199
	1999	Volume of sound logs	0.29	0.29	0.0298
		Area of sound logs	0.16	0.46	0.0709
		Volume of sound logs	0.09	0.55	0.1417
	1998	No model			
	1992	No model			
	1991	No model			
Flying Squirrel	2008	Thin	0.41	0.41	0.0076
	2007	Thin	0.41	0.41	0.0080
	1999	Thin	0.30	0.30	0.0287
	1998	Volume of pretreatment logs	0.23	0.23	0.0630

		Number sound logs	0.39	0.61	0.0032
		Number of rotten logs	0.08	0.70	0.0929
		Thin	0.06	0.75	0.1386
	1992	No model			
	1991	No model			
Red-backed vole	2008	No model			
	2007	Cover of rotten logs	0.50	0.50	0.0021
		Area of rotten logs	0.13	0.63	0.0523
	1999	Cover of sound logs	0.19	0.19	0.0927
		Area of rotten logs	0.17	0.36	0.0880
		Cover of rotten logs	0.11	0.47	0.1454
	1998	No model			
	1992	Number of sound logs	0.33	0.33	0.0206
		Number of rotten logs	0.13	0.45	0.1051
	1991	Number of sound logs	0.22	0.22	0.0639
		Area of logs	0.12	0.35	0.1432

Figures

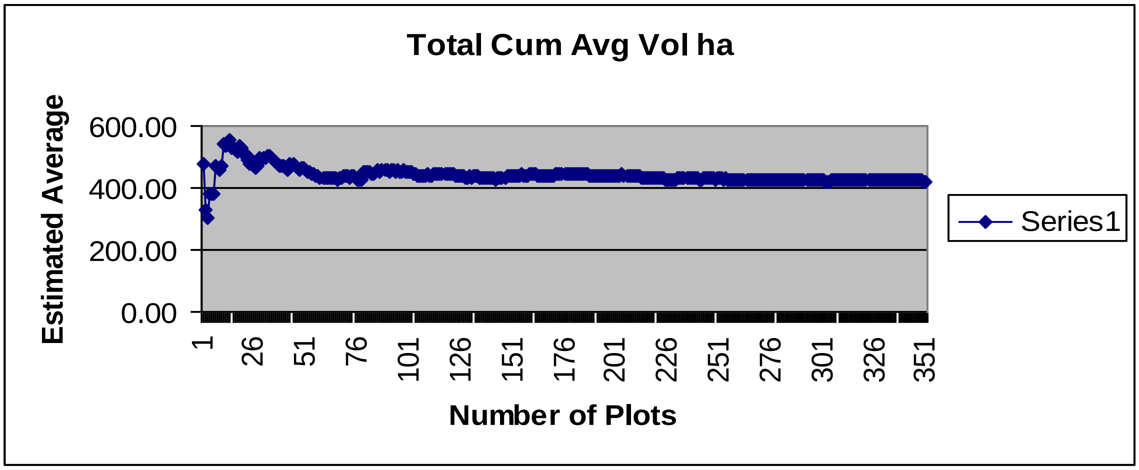

Figure 1. Stabilization of the estimated mean of the volume per ha for total coarse woody debris as number of plots increase.

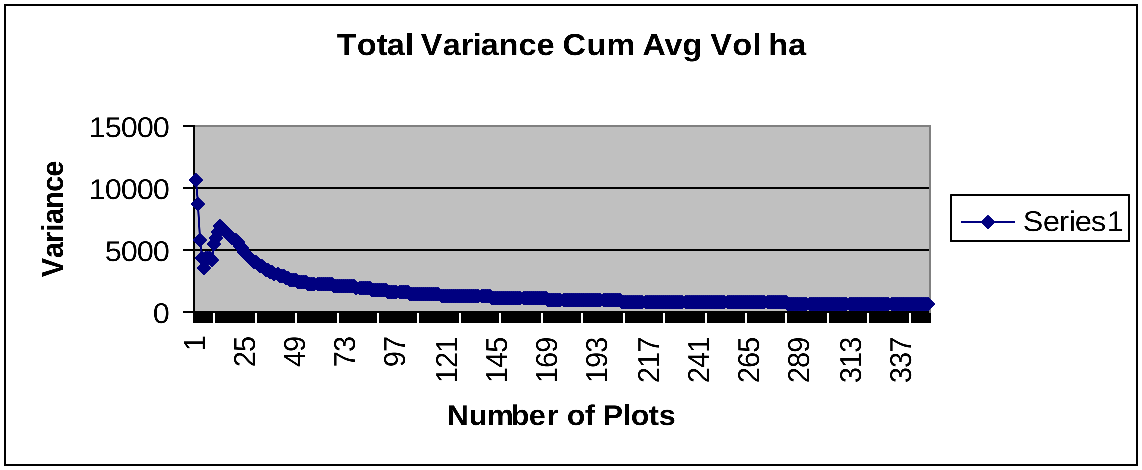

Figure 2. Stabilization of the variance of the estimated mean of the volume per ha for total coarse woody debris as number of plots increase

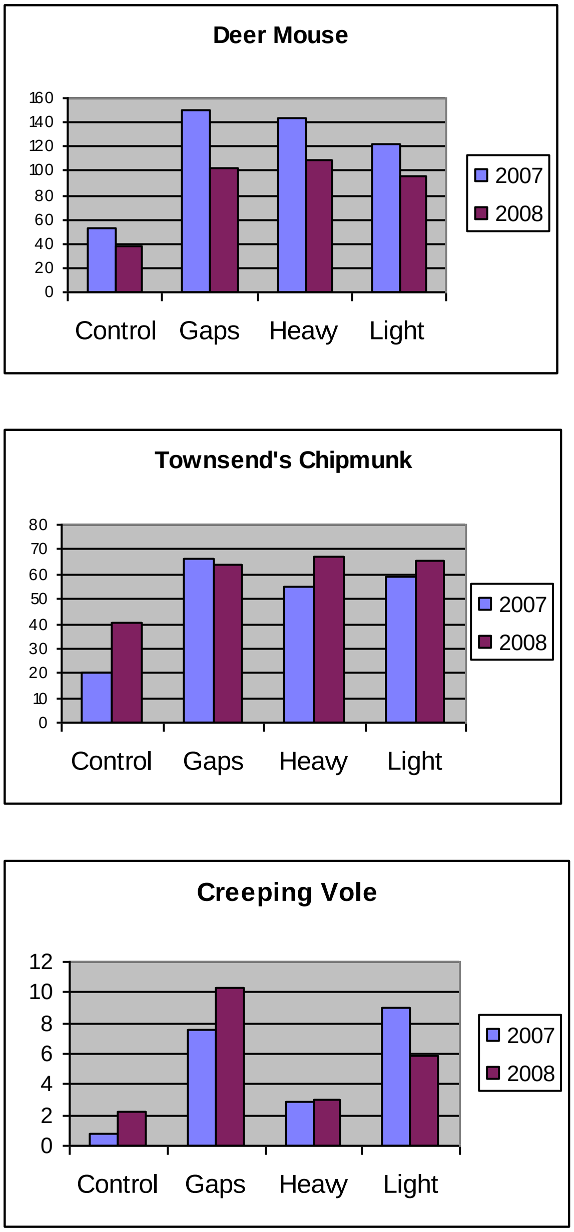

Figure 3. Species of mammals that apparently respond positively to one or more thinning treatments 10 years post treatment, young stand thinning and diversity study, Willamette National Forest, Oregon, 2007. Captures are standardized as captures per 1000 trap nights.

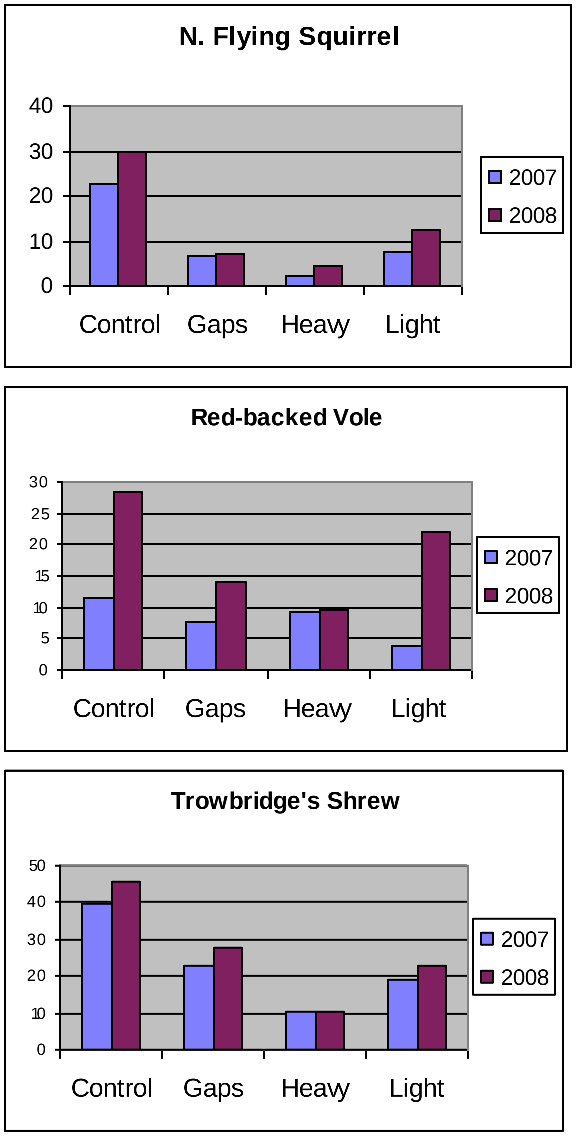

Figure 4. Species of mammals that apparently respond negatively to one or more thinning treatments 10 years post treatment, young stand thinning and diversity study, Willamette National Forest, Oregon, 2007. Captures are standardized as captures per 1000 trap nights.

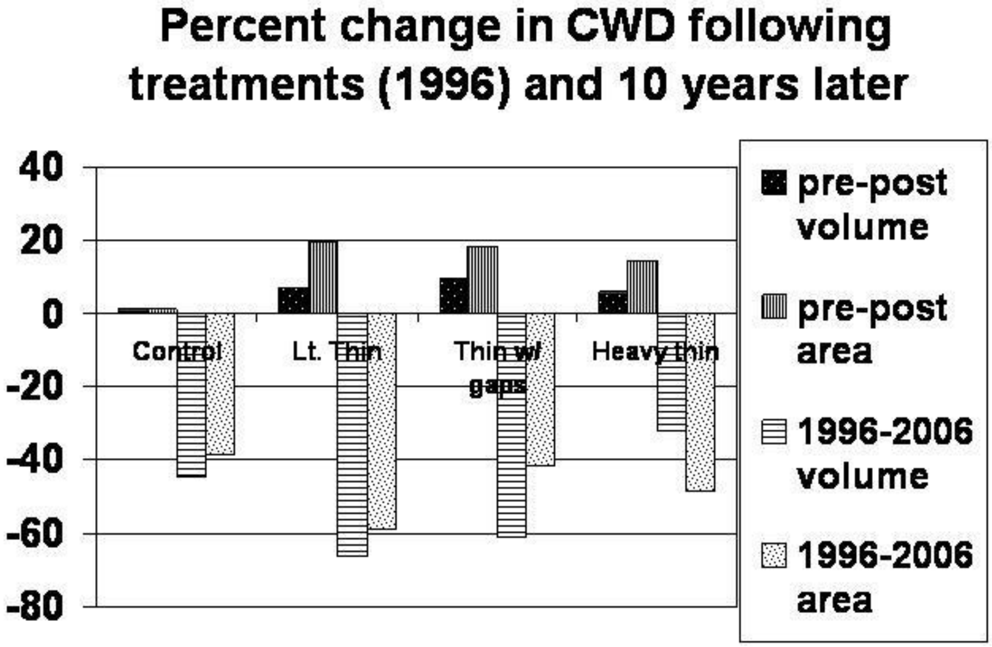

Figure 5. Percent change in CWD volume and area following three silvicultural treatments and a control on the Willamette National Forest (N=4 replicates per treatment). Lt thin = Light thinning, Thin w/ gaps = light thinning with gaps.(n=4 per treatment)

Appendix 1. Data checks of the 1996/97 and 2006 data. Conducted and written by Rob Pabst.

- The Forest Science Data Bank file for large CWD (FS11810.dat) in 1996/97 had 748 logs with diameter = 0. The original data sheets from 1996/97 (courtesy of Jim Boyle) showed that these are records for logs that are elliptical- or other-shaped in cross section. The crew did not record a diameter for those logs; instead, they noted diameters in two dimensions in the comment column. In the FS118 file, those records were assigned a log diameter of 0, rather than the average of the two dimensions. A file with the average diameters for those records was obtained from Jim Boyle and used for analysis instead of the FSDB file.

- Data sheets from 1996/97 are in a file cabinet next to Jim Boyle's desk in Peavy 274. Copies of the data sheets should be made and stored in a binder with the rest of the YSTDS data sheets in Klaus Puettmann's lab in Richardson Hall.

- Data from Jim Boyle had 7 missing values for log diameter and 6 missing values for decay class. Most of these were filled in by referencing the original data sheets. One log (a decay class 4 PSME) in TAC 6, Plot 22 was not measurable because it was underneath other debris. It was assigned the average diameter (31 cm) of other decay class-4 PSME logs in TAC 6. Another log (TSHE in TAC 9, Plot 21) did not have decay class recorded and was assigned a decay class 2 (sound), given that the species was identified.

- 117 logs in the Boyle data have diameter less than the minimum (8 cm) and were deleted prior to analysis.

- 20 records with missing values for species were set to "UNKN" (unknown).

- One record with decay class=22 and another with decay class=23 were changed to 2 and 3, respectively.

- For small CWD, two plots have two records for DEBTYPE=S and no records for DEBTYPE=D. The plots are TAC=10, Plot=1 and TAC=14, Plot=6. The original data sheets show that TAC 10, Plot 1 has D=1 and S=13, and that TAC 14, Plot 6 has D=1 and S=6.

- Some control plots have records for post-treatment slash (S): TAC=1, Plot=13 for large CWD, and TAC=1, Plot=4 and TAC=13, Plot=4 for small CWD. These are legitimate according to the protocol.

- TAC 8, Plot 15 had missing values for small CWD in data provided by Jim Boyle. Missing values were replaced with data from original data sheets which show 3 intersections for debris type D and 11 intersections for debris type S.

- The number of transects (plots) sampled for small CWD and large CWD is the same for all TACs except TAC 7, where small CWD was sampled in 33 plots and large CWD in 26 plots. The 26 plots in common to the small and large CWD sampling were used in summarizing the 1996/97 data.

- For 2006 data, plot “5A” in TAC 8 was renamed “A5” so it matches 1996/97.

- Two plots sampled in TAC 14 in 2006 (12 and 13) were not sampled in 1996/97, thus for a comparison across years the data from line transects in plots 12 and 13 were removed from the 2006 data before analysis.

Appendix 2. Variance stabilization estimations of sampling effort needed for future monitoring efforts. Charts developed by Chris Jordan.

PATTERNS AMONG ALL TREATMENTS COMBINED

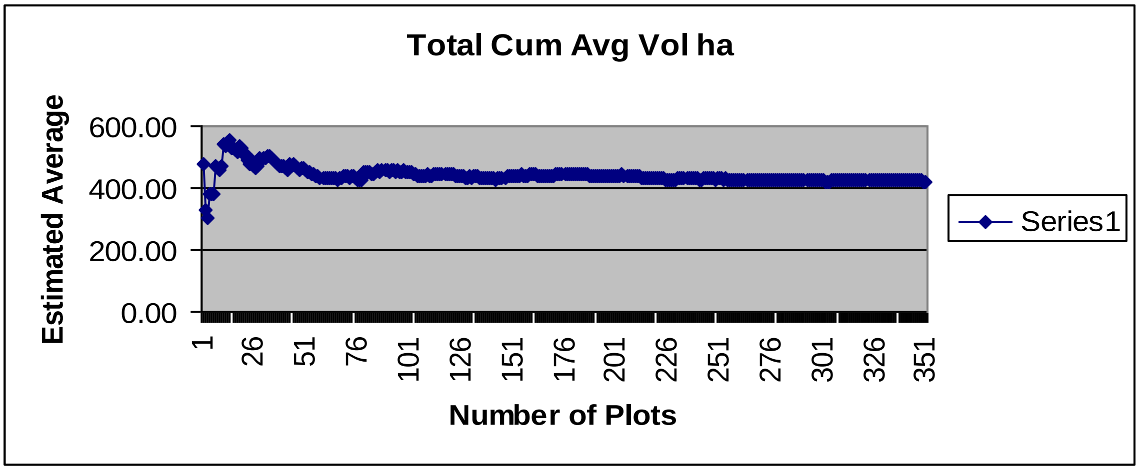

Figure 2.1 Graph showing the stabilization of the estimated mean of the Volume per ha for Total Coarse Woody Debris as number of plots increase

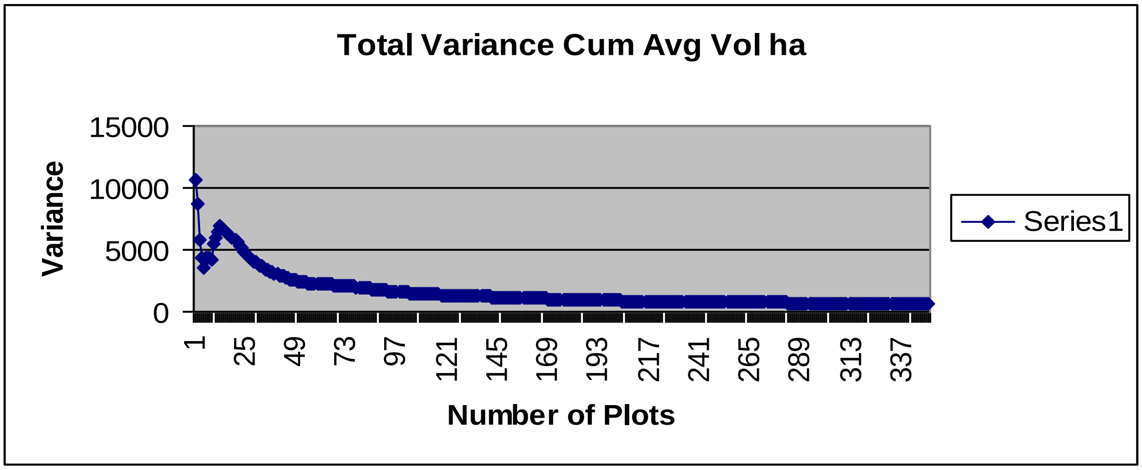

Figure 2.2 Graph showing the stabilization of the variance of the estimated mean of the Volume per ha for Total Coarse Woody Debris as number of plots increase

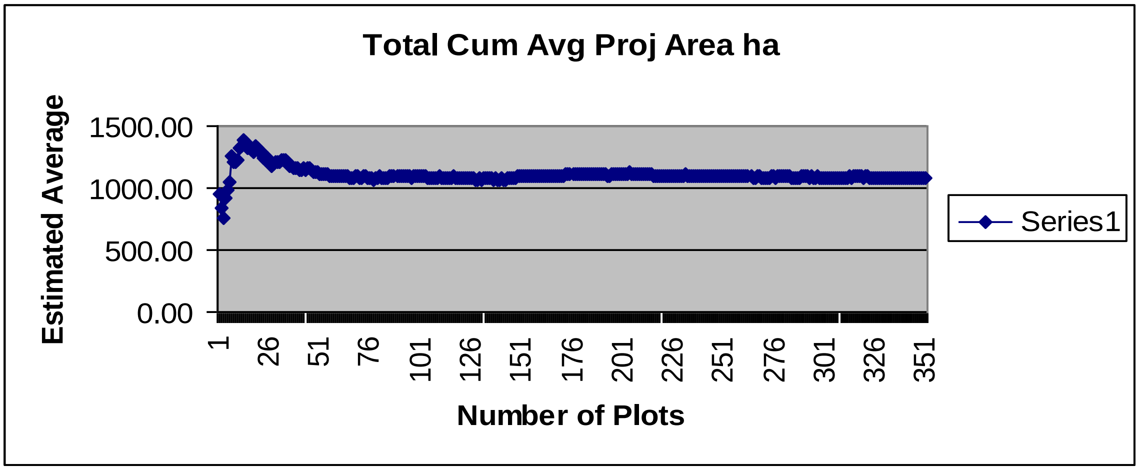

Figure 2.3 Graph showing the stabilization of the estimated mean of the Projected Area per ha for Total Coarse Woody Debris as number of plots increase

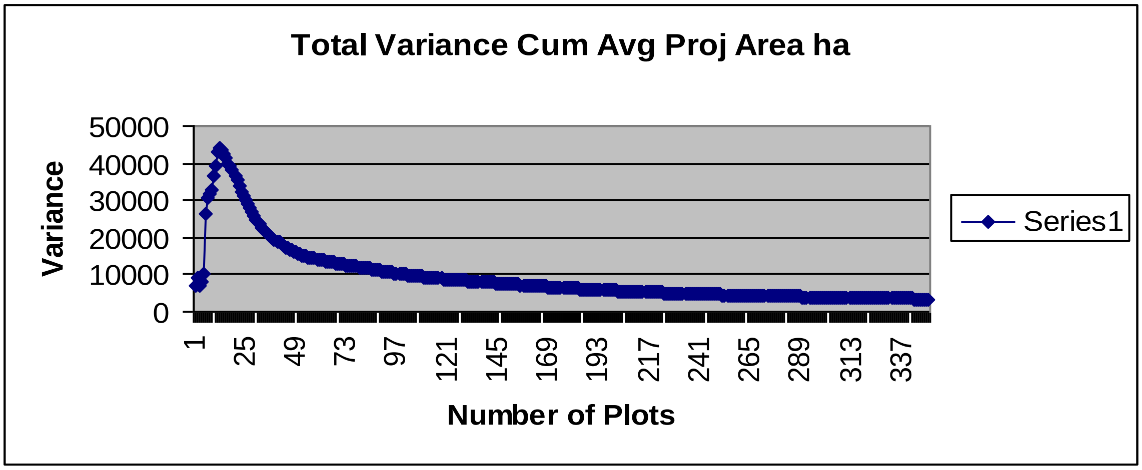

Figure 2.4 Graph showing the stabilization of the variance of the estimated mean of the Projected Area per ha for Total Coarse Woody Debris as number of plots increase

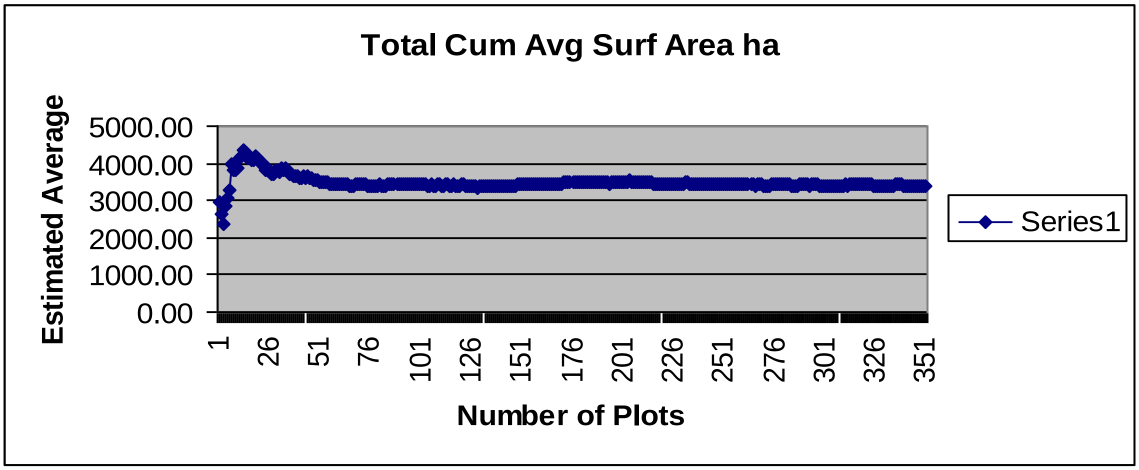

Figure 2.5 Graph showing the stabilization of the estimated mean of the Surface Area per ha for Total Coarse Woody Debris as number of plots increase

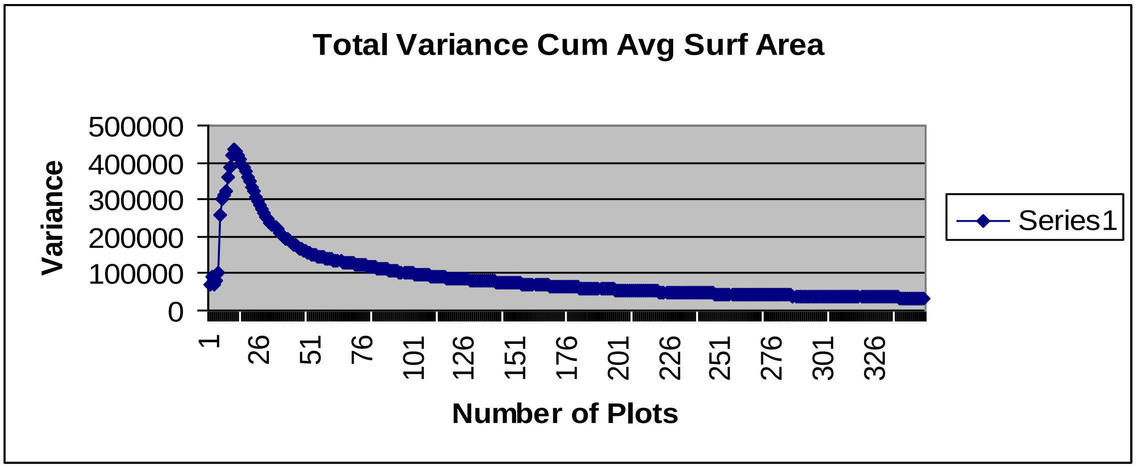

Figure 2.5 Graph showing the stabilization of the variance of the estimated mean of the Surface Area per ha for Total Coarse Woody Debris as number of plots increase

PATTERNS BY TREAETMENT

Light:

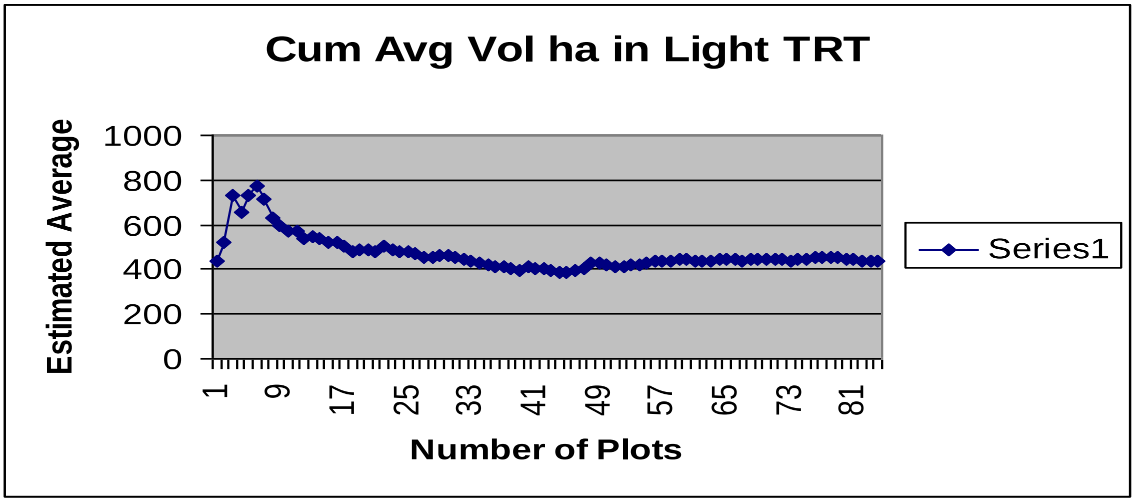

Figure 2.6 Graph showing the stabilization of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

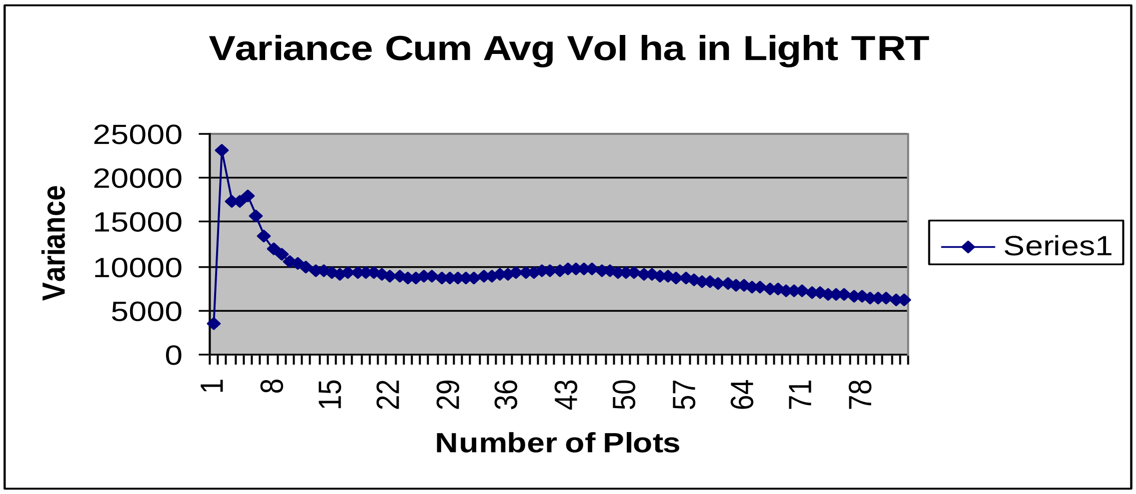

Figure 2.7 Graph showing the stabilization of the variance of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

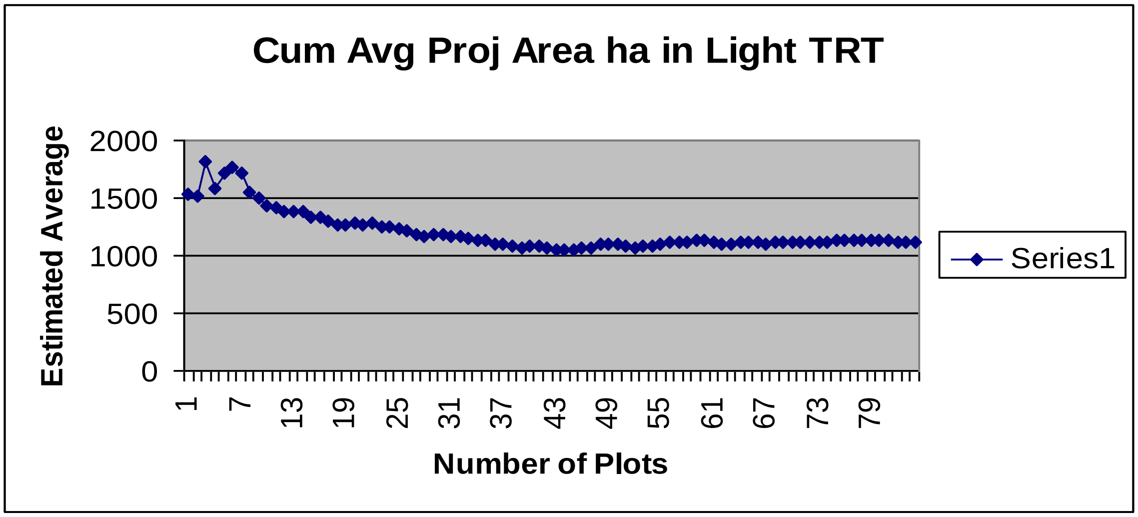

Figure 2.8 Graph showing the stabilization of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

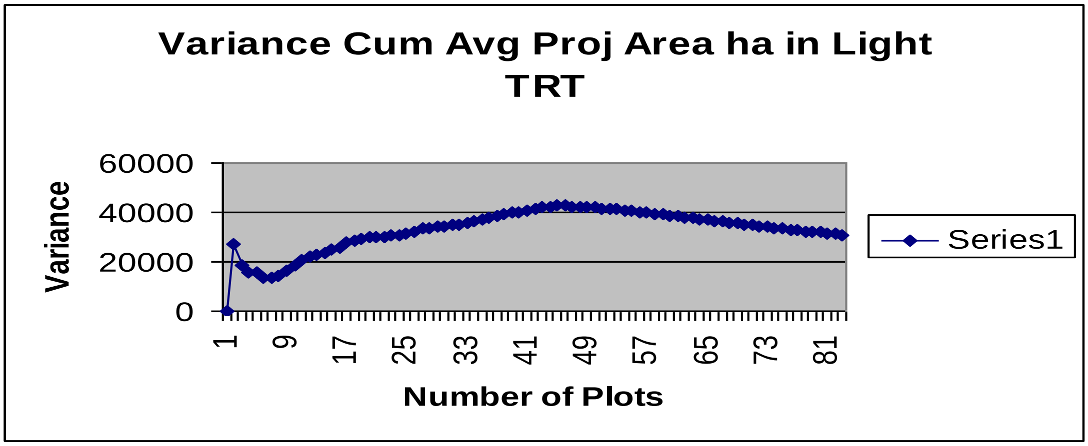

Figure 2.9 Graph showing the stabilization of the variance of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

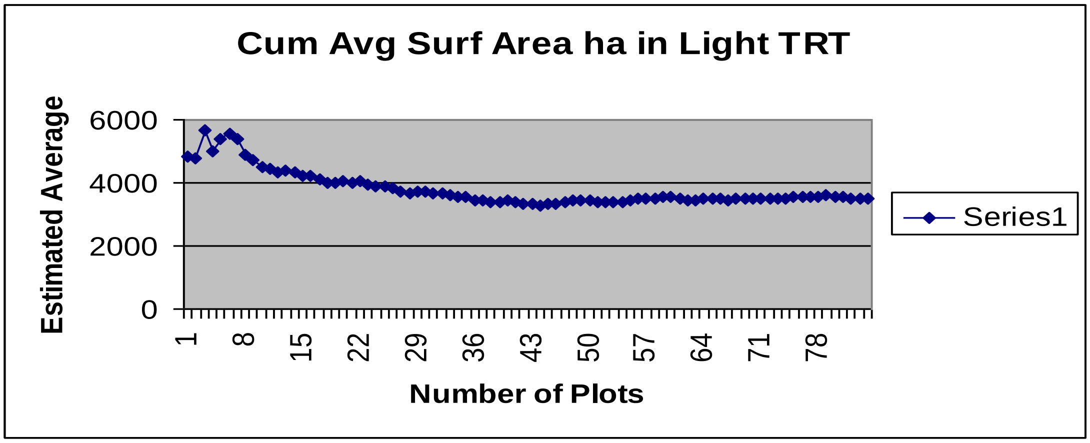

Figure 2.10 Graph showing the stabilization of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

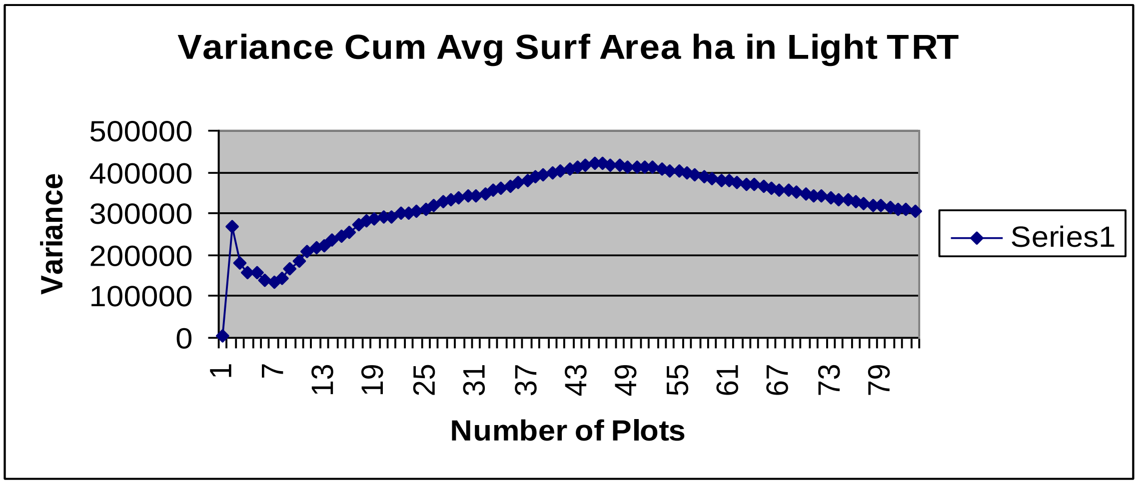

Figure 2.11 Graph showing the stabilization of the variance of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Light Treatment TACs as number of plots increase

Light w/ Gaps:

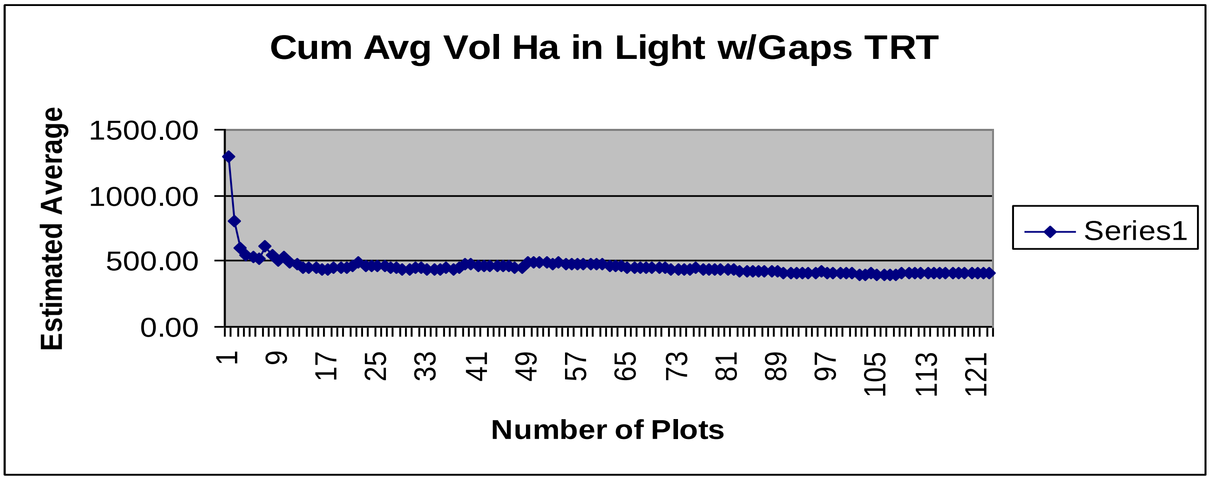

Figure 2.12 Graph showing the stabilization of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Light Treatment w/ Gaps TACs as number of plots increase

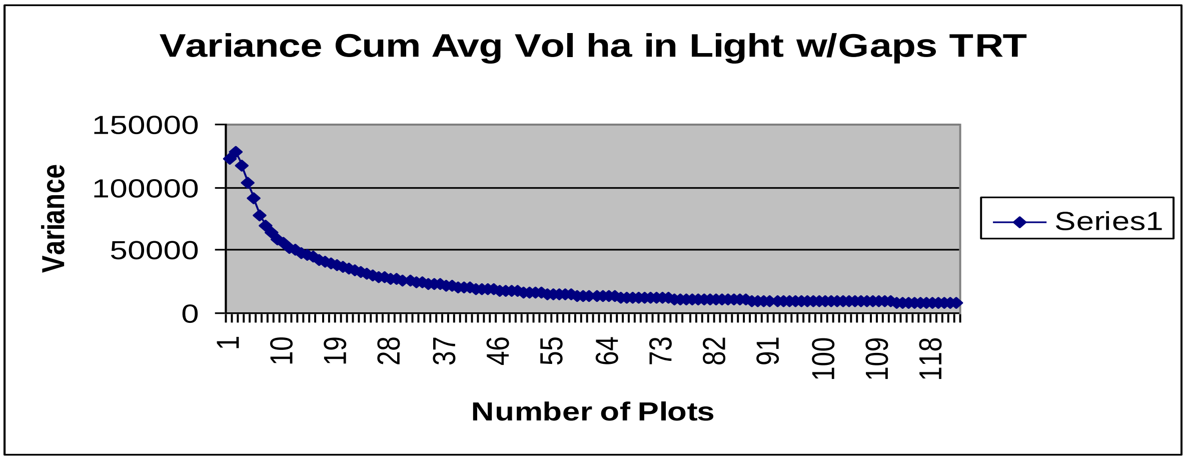

Figure 2.13 Graph showing the stabilization of the variance of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Light Treatment with Gaps TACs as number of plots increase

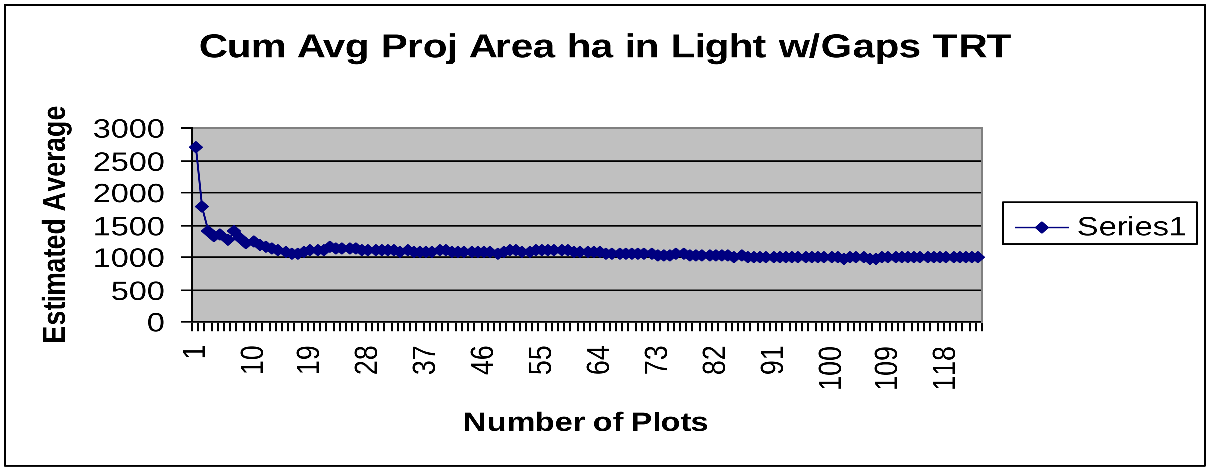

Figure 2.14 Graph showing the stabilization of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Light Treatment with Gaps TACs as number of plots increase

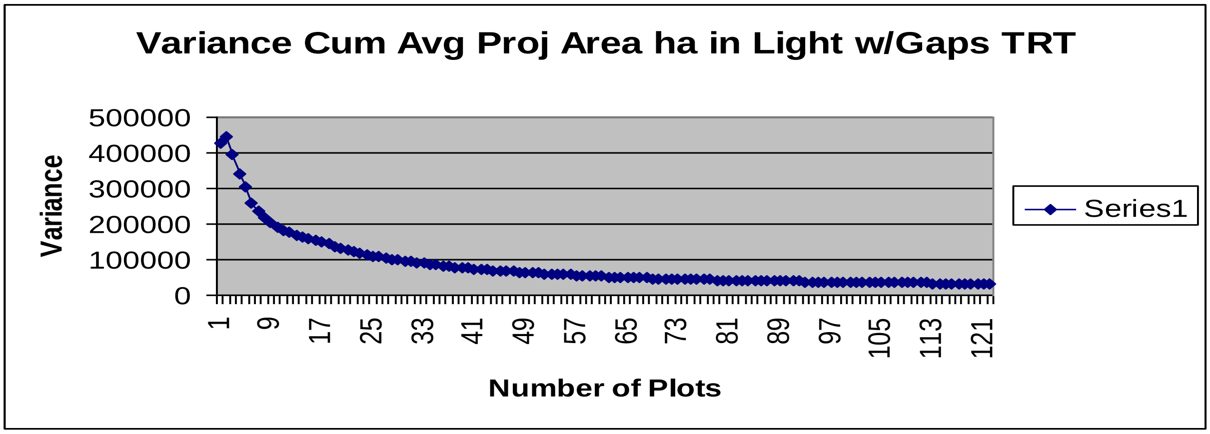

Figure 2.15 Graph showing the stabilization of the variance of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Light Treatment w/ Gaps TACs as number of plots increase

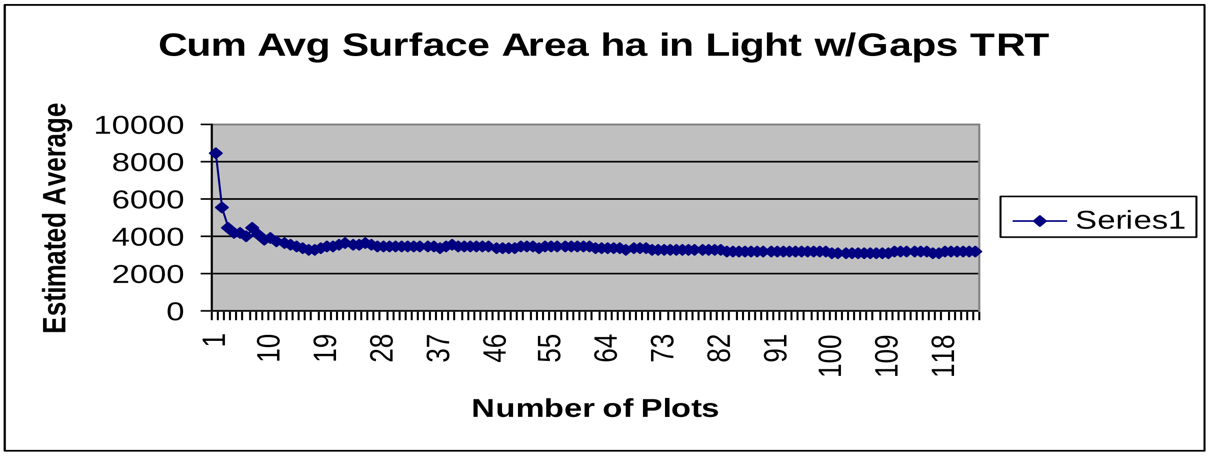

Figure 2.16 Graph showing the stabilization of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Light Treatment w/ Gaps TACs as number of plots increase

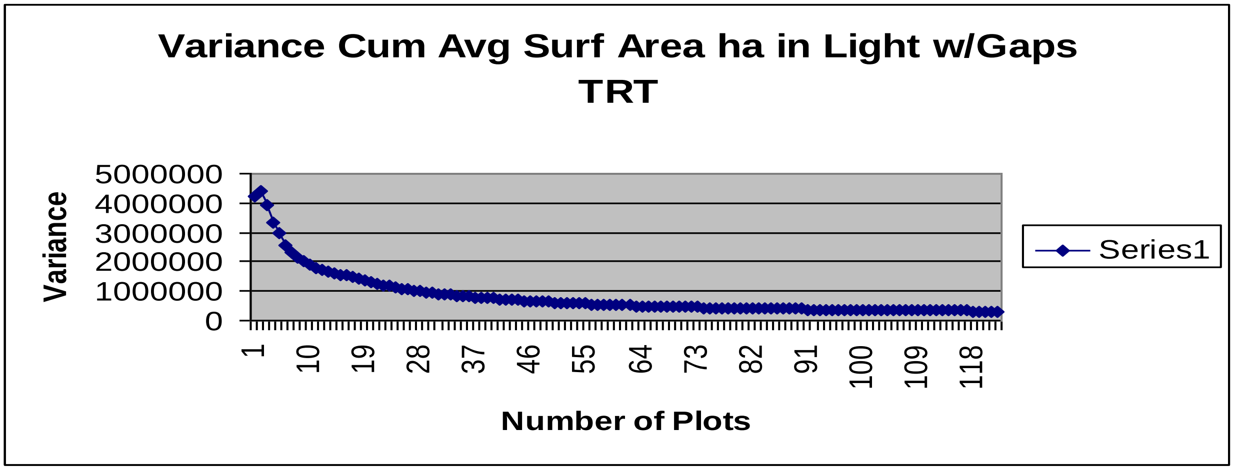

Figure 2.17 Graph showing the stabilization of the variance of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Light Treatment w/ Gaps TACs as number of plots increase

Heavy

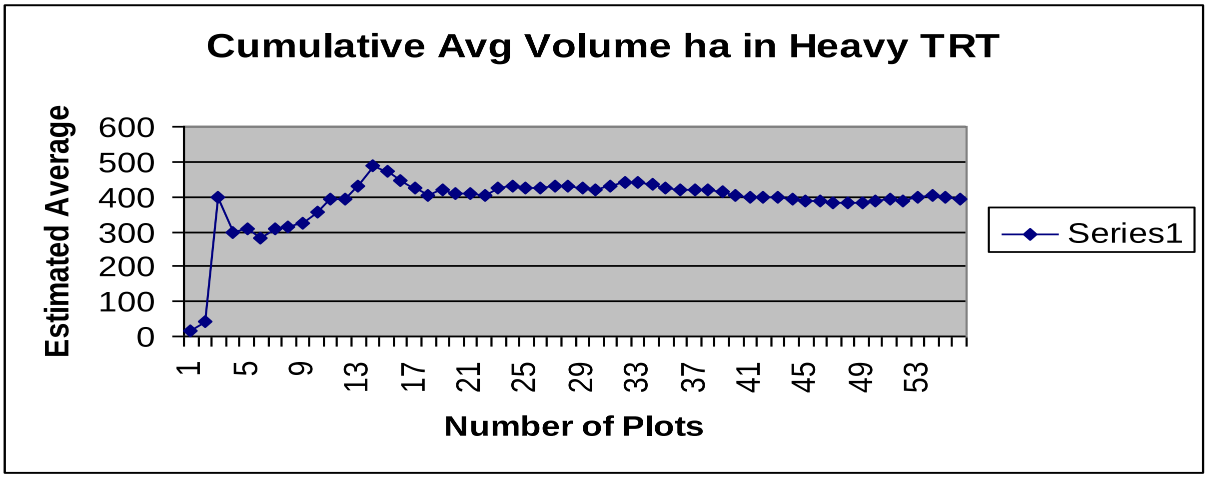

Figure 2.18 Graph showing the stabilization of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

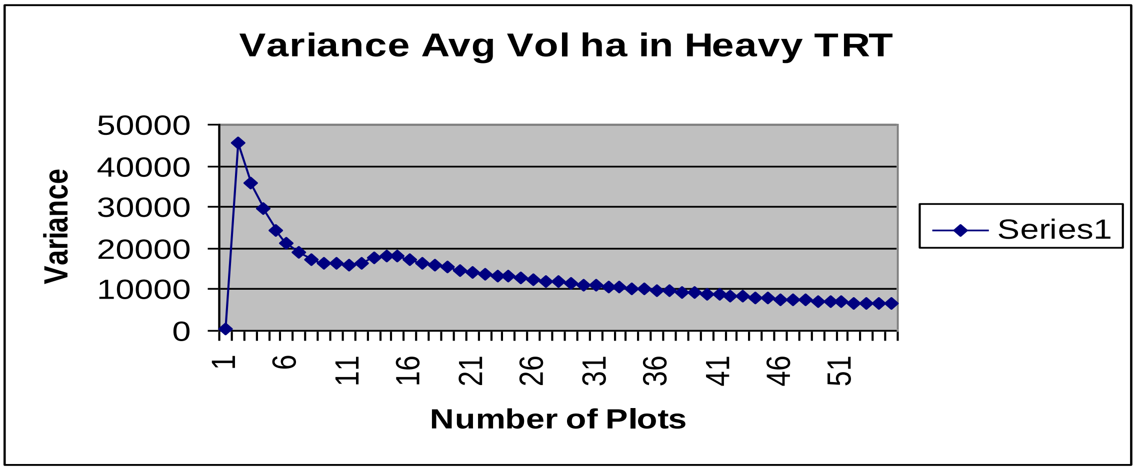

Figure 2.19 Graph showing the stabilization of the variance of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

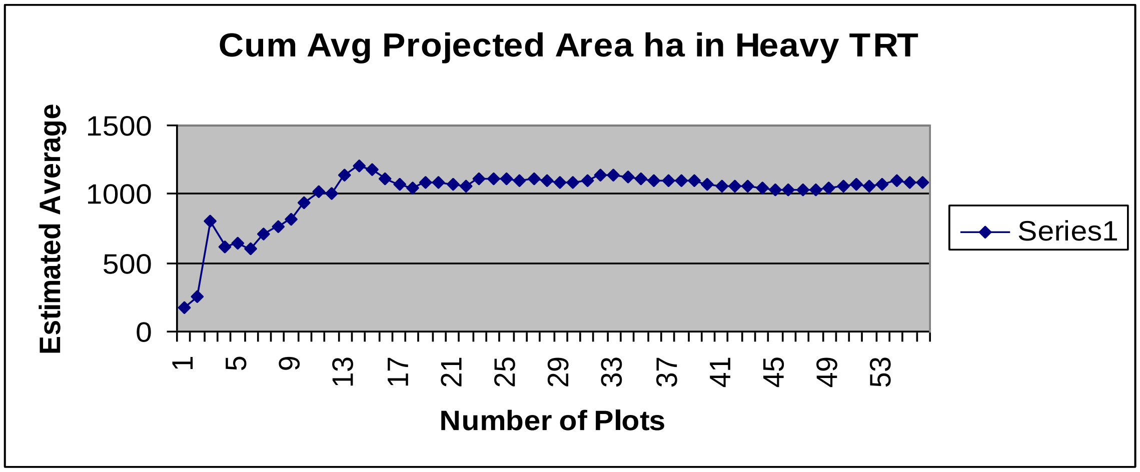

Figure 2.20 Graph showing the stabilization of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

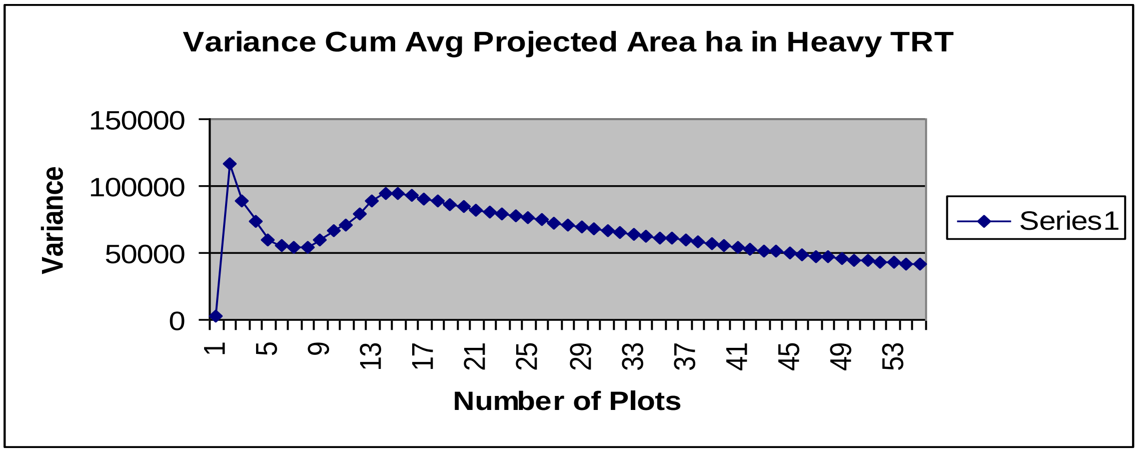

Figure 2.21 Graph showing the stabilization of the variance of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

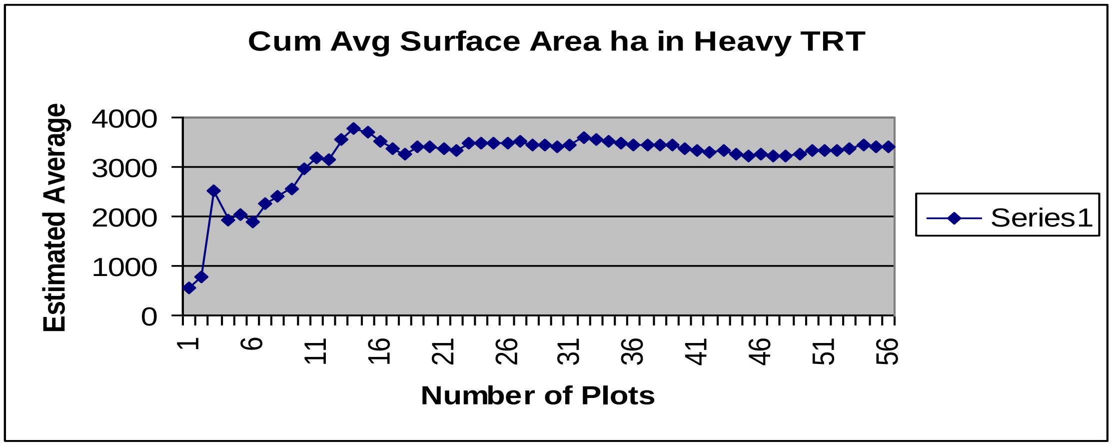

Figure 2.22 Graph showing the stabilization of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

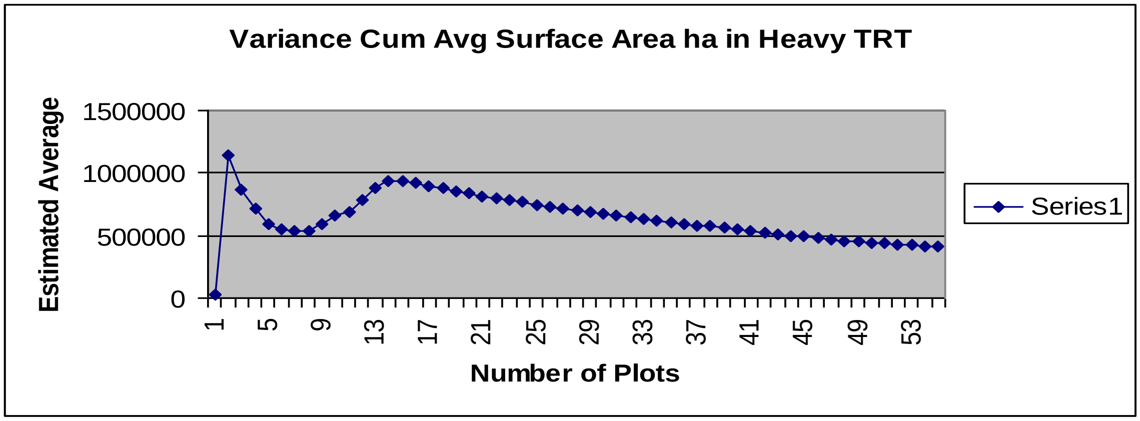

Figure 2.23 Graph showing the stabilization of the variance of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Heavy Treatment TACs as number of plots increase

<u>Control</u>

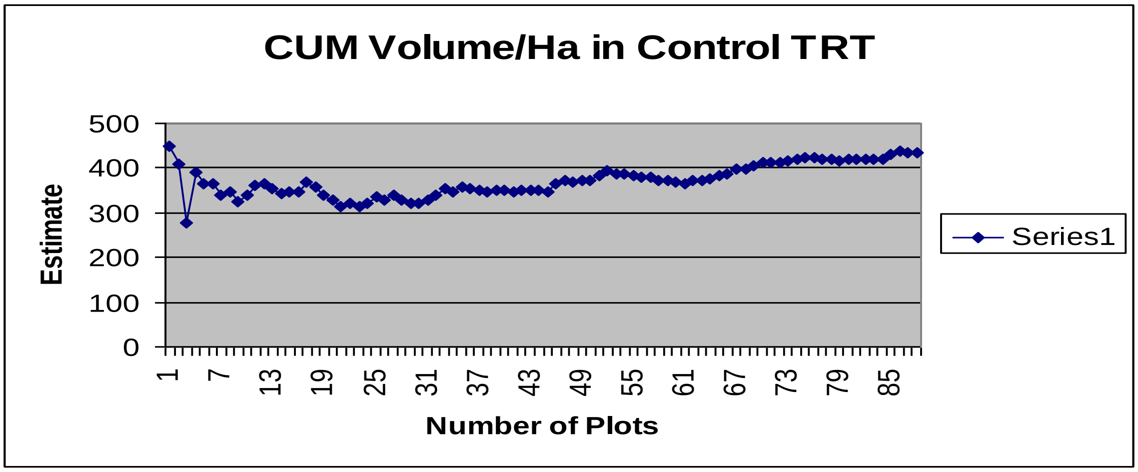

Figure 2.24 Graph showing the stabilization of the estimated mean of the Volume Area per ha for Coarse Woody Debris in Control TACs as number of plots increase

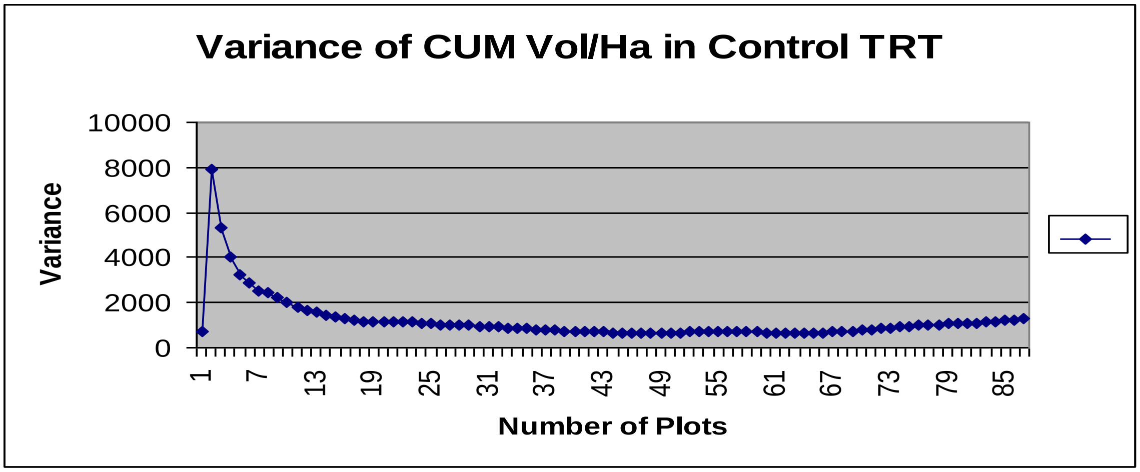

Figure 2.25 Graph showing the stabilization of the variance of estimated mean of Volume Area per ha for Coarse Woody Debris in Control TACs as number of plots increase

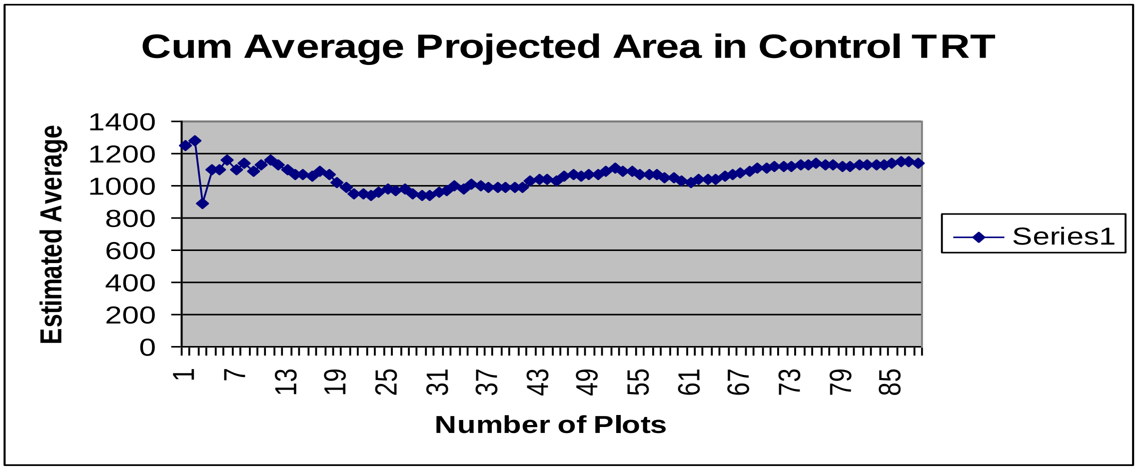

Figure 2.26 Graph showing the stabilization of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Control TACs as number of plots increase

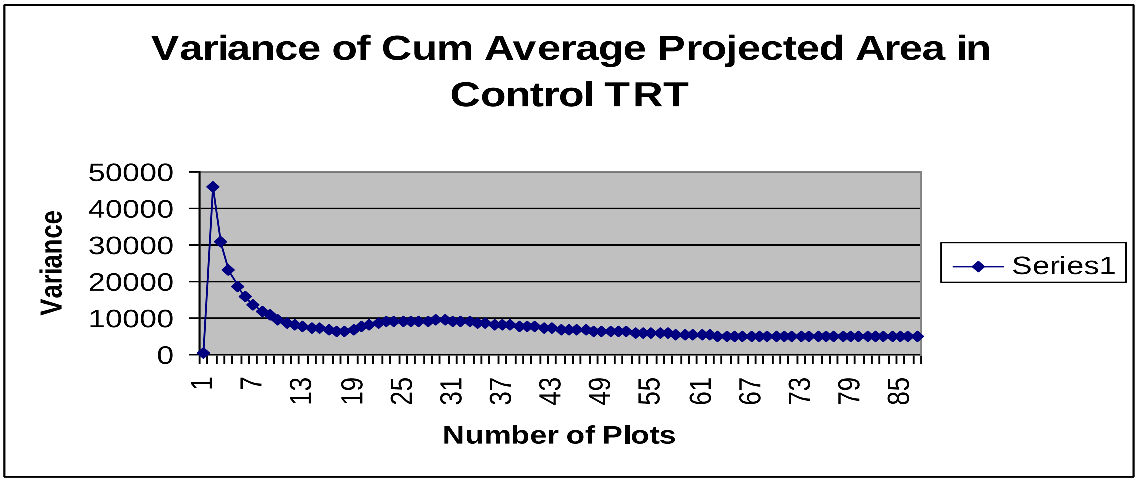

Figure 2.27 Graph showing the stabilization of the variance of the estimated mean of the Projected Area per ha for Coarse Woody Debris in Heavy TACs as number of plots increase

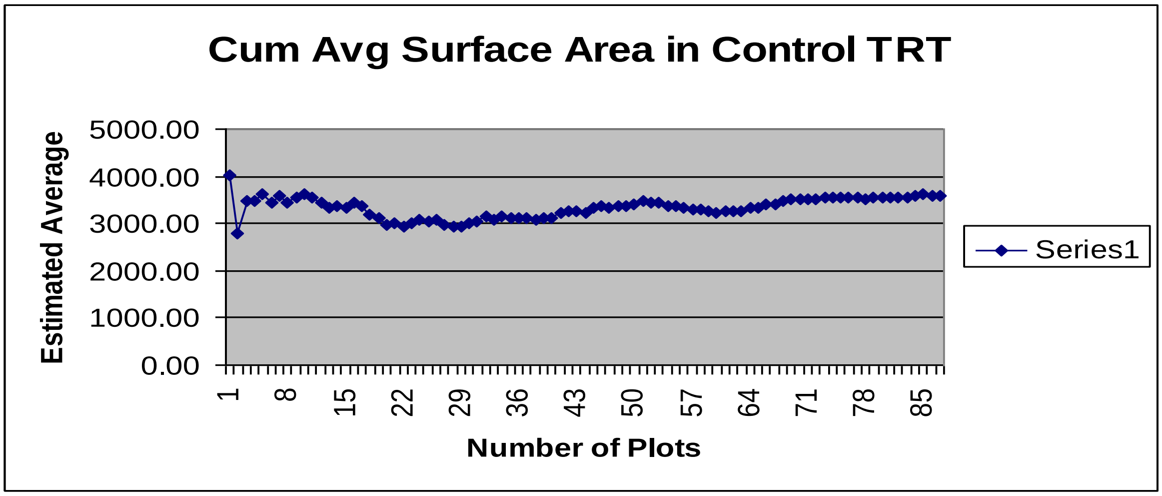

Figure 2.28 Graph showing the stabilization of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Control TACs as number of plots increase

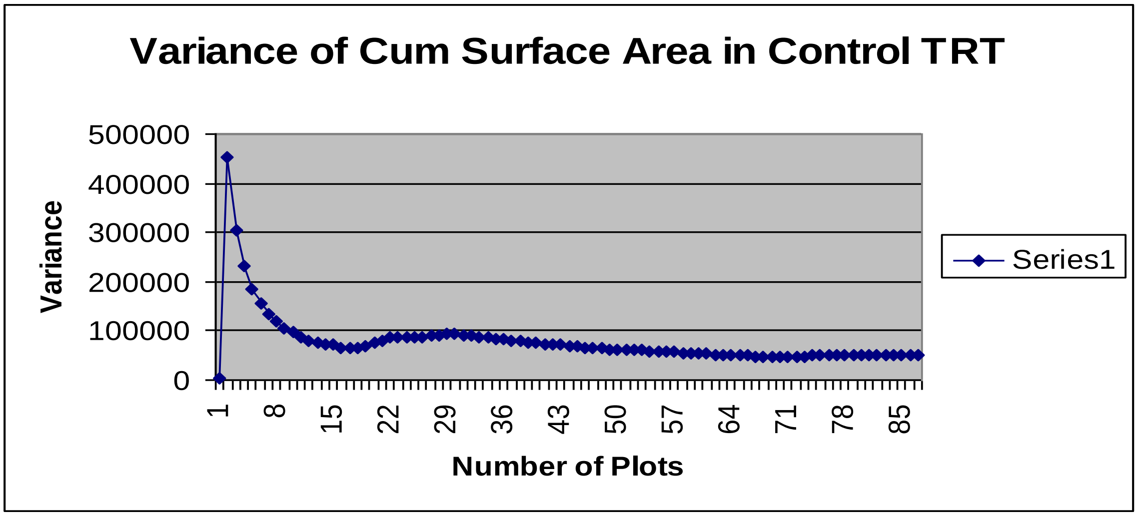

Figure 2.29 Graph showing the stabilization of the variance of the estimated mean of the Surface Area per ha for Coarse Woody Debris in Control TACs as number of plots increase

Appendix 3. Small mammal population estimation using Program MARK (written by Tom Manning).

This is a detailed summary of how we analyzed the 2007-08 small mammal trapping data from the Young Stand Study (http://andrewsforest.oregonstate.edu/research/related/ccem/yst/ystd.html).

Introduction

The data in question consist of mark-and-recapture data for a variety of rodent and insectivore species from 16 treatment areas (TACs) organized into 4 replicate blocks of 4 thinning treatments on the Willamette National Forest. We used Program MARK to produce estimates of population size for as many species as practical and meaningful. The aim was to produce a single estimate for each species in each TAC in each year separately, with no attempt to join the data for the two sample years in any way.

Parameters estimated

In the process of producing the estimates of population size, MARK also produces estimates of the probabilities of survival and capture, and another probability statistic, *p*(ent), which is analogous to recruitment, or the probability of an animal entering the trappable population. In this case, the estimates of survival are meaningless, since they are computed only for the particular week in which each TAC was sampled. Likewise, estimates of capture probability and entry probability are not meaningful for this analysis, beyond their utility in producing the estimates of population size.

Also, it is not possible to derive a true estimate of survival between the 2 sampling years using MARK, since the probability of survival from 2007 to 2008 is confounded with the probability of recapture in 2008. In order to derive an estimate of survival for that time interval, we would need at least one more sample later than 2008.

Sampling Design and Analytical Structure

Among the species examined, differences in behavior played a role in how We structured these analyses. Some of the species of interest (flying squirrels, deer mice) are nocturnal, and very unlikely to be encountered during the afternoon trap checks. For flying squirrels, 99.4% of captures were processed during morning trap checks; the corresponding figure for deer mice is 95.5%. Chipmunks are largely diurnal, and were encountered almost as frequently during afternoon trap checks (41%) as during mornings. Therefore, we analyzed the nocturnal species using only morning trap check data, and chipmunks using capture data from both morning and afternoon trap checks.

In addition to these behavioral differences, we needed to consider irregularities in the sampling scheme. The general sampling scheme was 7 consecutive trap occasions in each TAC per year. These consisted of 4 morning trap checks and the 3 intervening afternoons; that is, traps were set on Day 1, animals were marked and released mornings and afternoons of Days 2-4 and on the morning of Day 5, after which the traps were closed and removed from the sampling area. Unfortunately, this scheme was not applied universally: during the first week of work in 2007, some deviation from this scheme occurred while we struggled to contrive a workable design. Specifically, in 2007, TACs 9 and 10 were sampled only in the mornings (thus, 4 occasions), TAC 11 was sampled on 4 mornings and 1 afternoon, and TAC 12 was sampled on 3 mornings and 2 afternoons (Table 3.1). Thereafter, all TACs were sampled in the way described at the beginning of this paragraph. In the table, blank cells indicate trap occasions for which there are no data.

One more consideration is that MARK allows the user to specify different intervals between sample occasions, and we took advantage of this to more accurately reflect the differences in trap effort between morning and afternoon trap checks. We specified that 7 hours elapsed between AM and PM checks, and then 17 hours elapsed before the next morning trap check.

The analytical structure resulting from these considerations of species behavior, sampling irregularities, and intervals between trap checks is shown in Table 3.2. Program MARK has the flexibility to deal with all these contingencies.

Note that for flying squirrels, all data were analyzed in the same way, with 4 occasions and 24-hr intervals between occasions. This was possible despite the sampling irregularities in 2007 because: 1. only morning trap data were used so that problems with "missed" afternoon checks were avoided; and 2. problems with the single missed morning check (TAC 12) were avoided because no flying squirrels were caught in TAC 12 that year. Using only morning data assumes that the only two afternoon captures of fliers were ignored, but both of these animals were initially captured in morning checks and thus those individuals are represented in the data.

Similarly for deer mice, nearly all data were analyzed with 4 occasions and 24-hr intervals. The only exception is that we had only 3 occasions (mornings) for TAC 12 in 2007. We handled this by modeling TAC 12 separately, specifying only 3 occasions. Again, attempting to include afternoon data for the few mice caught during daylight resulted in poor model fit and lack of numerical convergence, so we estimated populations of mice using only morning data.

The situation for chipmunks is more complicated because we used as much data as was available, regardless of the irregularities. Thus, we ran MARK with 7 occasions and intervals of 7 and 17 hours for all of 2008 and for 12 of 16 TACs in 2007. We modeled 2007 TACs 9 & 10 (together, but separately from the other TACs, with 4 mornings and interval = 24 hrs), TAC 11 with 5 occasions (intervals 24, 24, 7, and 17 hrs), and TAC 12 with 5 occasions (7, 17, 7, 17 hrs). Estimates of population size and associated standard errors for each of these models were tabulated together for subsequent comparison.

In all, we modeled ten sets of data for the 2 years and 3 species. The different datasets are listed in Table 3.3 below, along with occasions and intervals used, and which model structure was judged to be the best fit.

Modeling Procedure

Choice of Estimation Procedure

We used the POPAN formulation of the Jolly-Seber model within MARK to derive estimates of population parameters. This is a model that assumes no population closure, allows for accounting of trap mortalities, and estimates population size (N).

Goodness-of-Fit Testing

The downside of using POPAN is that it does not incorporate tests for goodness-of-fit. In order to get some test of model fit, and to compute a correction ($\hat{c}$) for lack of fit, we first fit models to each dataset using the Cormack-Jolly-Seber (CJS) routines in MARK. In each case, we started with a fully time-dependent model, in which survival and capture probabilities are allowed to vary with trap occasion. We then bootstrapped 100 simulations of the full model, and computed the ratio of the mean deviance from the simulations to the deviance from my actual data, to get an estimate of $\hat{c}$, which gave a test of goodness-of-fit as well as a correction factor. We considered values of $\hat{c}$ lower than 0.5 and higher than 2.0 to be evidence of fit that was poor enough to require close examination of the data before proceeding with analysis. In one case, $\hat{c}$ was outside the allowable range ($\hat{c} = 2.10$ for 2007 chipmunks in TAC 12 only). For this one case, we examined tests of dispersion (obtained using Program RELEASE, also included in MARK), and determined that there was no systematic bias in the data, and that the over-dispersion indicated by my high $\hat{c}$ value was likely the result of noise. In all other cases, $\hat{c}$ was between 0.7 and 1.87, values considered acceptable for analysis.

Reduction and Comparison of Models

Once we had determined that the CJS full model was an adequate fit for each of my datasets, we fit reduced models in order to determine the best model (that is, best fitting yet most parsimonious) to use in POPAN estimations. The full model design allowed parameters for survival and capture probabilities to vary with block, treatment, and trap occasion. We first removed variation in time from the model by eliminating all parameters that represented trap occasions or interactions that included trap occasions. The second reduction removed blocks as a factor by eliminating parameters for blocks and block X treatment interactions, resulting in a "treatments only" model. Once these two reduced models were included in the set of possible models, we adjusted the Akaike statistics by applying the $\hat{c}$ adjustment computed earlier using bootstrap simulations. Then we compared models based on Akaike weights. Below is a case-by-case justification for which model was chosen:

2007 Flying squirrels: "Treatments only" model had 93% support, so we used that.
2008 Flying squirrels: "Treatments only" model had 89% support, so we used that.

2007 Deer mice, all but TAC 12: "Blocks only" had 79% support, but there appeared to be substantial interaction with Treatment, so we used the "Blocks & Trts" model.
2007 Deer mice, TAC 12 only: There was only 1 block and 1 treatment represented, so by default we used the full model.
2008 Deer mice: "Blocks only" model had 99.5% support, so we used that.

2007 Chipmunks, TACs 1-8 & 13-16: Strong block x treatment interaction suggested, so we used "Blocks & Trts" model.
2007 Chipmunks, TACs 9 & 10: Full model had 99.5% support, so we used that.
2007 Chipmunks, TAC 11: There was only 1 block and 1 treatment represented, so by default we used the full model.
2007 Chipmunks, TAC 12: There was only 1 block and 1 treatment represented, so by default we used the full model.
2008 Chipmunks: "Treatments only" model had 90% support, so we used that.

Producing estimates of N from POPAN

To get the actual estimates of N from MARK, we called up the POPAN routines from within MARK, and ran them with custom-made design matrices, which we constructed in Excel and imported into MARK. This is a very cumbersome process, but it allowed us to model parameters representing our 4 YSS blocks, the 4 YSS treatments, and the various numbers of trap occasions that resulted from the irregular sampling design in the first week of 2007. Part of the set-up for the POPAN procedure involves specifying link functions for each parameter. Following the recommendations in the on-line MARK manual, we used logit link functions for all the survival and capture parameters, group-specific logit link functions for the different groups' *p*(ent) parameters, and log link functions for the 16 N parameters. Parameter estimates and their associated SE's were saved to text files, then tabulated in Excel spreadsheets and charts.

Comparing estimates using ANOVA in SAS

We tried two general approaches to comparing these estimates of N using ANOVA.

Ad-hoc Approach

This was simply running repeated-measures ANOVA (SAS Procedure MIXED) to compare all treatments against each other. The repeated measures were the two most recent years (2007 and 2008) of sampling. Block was included as a random effect, and we examined differences in year, treatment, and interactions of year and treatment. Estimates of N were log transformed for chipmunks and mice, and because there were a few zero values in the data for fliers, we transformed all flier data as log(Y+1). All 3 species showed marked treatment effects (all $p < 0.012$), and there was a significant year effect for chipmunks ($p = 0.0107$). There were no significant year X treatment interactions, and we interpreted that as meaning that the same patterns held across years even though there were more captures in 2008.

Means comparisons show that:
- Flying squirrels were more abundant in the controls than in the heavy thin treatments;
- Deer mice were more abundant in each thinned treatment than they were in controls;
- Townsend's chipmunks were more abundant in heavy and light thin treatments than they were in controls.

Orthogonal Approach

We devised a set of orthogonal comparisons that seemed to make sense in terms of the study design. These were:

Controls vs all thinning treatments	(Does thinning make a difference?)
Heavy Thin vs Light and Gap Thin	(Does intensity of thinning make a difference?)
Light Thin vs Gap Thin	(Does thinning with gaps differ from homogeneous thinning?)

Using the same SAS ANOVA program we used in the ad-hoc approach, we made each of these comparisons for each of the three species. We found no significant treatment effects using this approach, but there is at least one test of interest that did not run, for reasons we do not understand. That was for deer mice, Controls vs all Thinned Treatments.

Attempts to analyze Shrew and Vole Abundances

After chipmunks, deer mice, and flying squirrels, the most frequently captured species in these stands in 2007-08 were shrews (mostly *Sorex trowbridgii*, but also a few dozen *S. pacificus/sonomae*) and voles (mostly *Clethrionomys californicus* and a smaller number of *Microtus oregoni*). Analysis of these species presents problems that do not apply to the rodents analyzed above: none of these species was captured in every TAC in each year; the majority of captures were mortalities (>80% for shrews and about 50% for voles); and shrews are not easily marked.

Voles

We tried to use the same approach used with the 3 abundant species for analyzing *Clethrionomys*, with no satisfying results. Capture data were too sparse to use 7-occasion data (that is, morning and afternoon trap checks). The estimates of population size that resulted from 4-occasion data (morning checks only) were identical in almost every case to the numbers of animals actually captured in each TAC, and SE's were all zero. We did not try analyzing *Microtus* this way, because there were even fewer captures of this species than for *Clethrionomys*.

Shrews

Not finding a catch-per-unit-effort estimator for unmarked animals in the MARK package, we tried the regression method first developed by Leslie and Davis (1939, Journal of Animal Ecology 8:94-113) and detailed by Krebs (1999, Ecological Methodology). This method depends on a decrease in captures with increasing trap effort. Unfortunately, our data do not reflect such a pattern, so in the majority of cases estimation of N was not possible. And this method is not robust to trap occasions with no captures. Our shrew captures could be described as sporadic. In the best case for *S. trowbridgii* (TAC 9, 2007), an estimate of 100 animals was computed by using the Leslie regression, but the 95% CI was 21 to 179 (actual captures were 40). And as we say, most cases were not estimable.

The Leslie regression estimator is designed for use with removal data. Not all of our shrews were removals; about 20% were live captures which were released. As far as we know, very few shrews were recaptured (one time that we know of). We dealt with this mix of live and dead captures by using only capture data for dead shrews. Therefore, counted only captures of dead voles, but adjusted my trap effort by deducting 0.5 trap-“night” (1 trap for one check) for each trap closed when checked: these closed traps included empty/sprung traps and traps holding animals (any species, including live shrews). Our reasoning was that these traps were unavailable to animals for half the “night”, on average. We also adjusted for inoperable traps by deducting an entire trap-“night” for each stuck trap. All trap effort data were adjusted for different time intervals between trap occasions (morning vs afternoon, and the few occasions in 2007 which had 24-hr intervals). Finally, all of the computations included data for Sherman and pitfall traps only, since voles and shrews are not captured in Tomahawk traps.

In general, we are better off not trying to estimate population size statistically for species with sparse data (voles) or unmarked animals (shrews). In most cases, it isn’t possible, or gives no different results than the number of animals captured.

Closed Models

As a point of comparison with the open models, we also tried using the closed population models of Otis et al (1978) which comprise the set of techniques embodied in Program CAPTURE. These models, and a few more, are incorporated in the closed model portion of Program MARK.

We modeled flying squirrel abundance for each year using the closed model approach, using the same 4 occasions and a “treatments only” model. The results were surprisingly comparable to the open model estimates produced by the POPAN module. Point estimates of N for 12 of the 16 TACs in 2007, and 9 of 16 for 2008, were identical to the POPAN estimates. Where estimates from the two approaches differed, POPAN estimates were on average about 30-35% higher. For those cases where both models produced realistic SE’s, there was no pattern as to which approach yielded tighter SE’s, and half of the 95% CI’s were tighter for the closed model, and half for POPAN. But, when the closed model had the greater CI width, that width was generally twice as much as in the cases where POPAN had wider CIs. Thus, POPAN estimates of population size were frequently (9 of 32 times) higher (by about 30-35%) than closed model estimates, and were also frequently more precise.

We ran ANOVAs using the estimates from the closed models for 2007-08 GLSA, and identical SAS procedures, and got essentially the same results, but a very slightly higher p-value for the single significant result (Controls > Heavy Thins, $p = 0.008$ under POPAN open model, and $p = 0.009$ under the closed model).

Table 3.1: Sampling scheme for Young Stand Study mammal work, 2007-08.

	2007							2008						
	Day 1		Day 2		Day 3		Day 4	Day 1		Day 2		Day 3		Day 4
TAC	am	pm	am	pm	am	pm	am	am	pm	am	pm	am	pm	am
1	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	√	√	√	√	√	√	√	√	√	√	√	√	√	√
5	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	√	√	√	√	√	√	√	√	√	√	√	√	√	√
7	√	√	√	√	√	√	√	√	√	√	√	√	√	√
8	√	√	√	√	√	√	√	√	√	√	√	√	√	√
9	√		√		√		√	√	√	√	√	√	√	√
10	√		√		√		√	√	√	√	√	√	√	√
11	√		√		√	√	√	√	√	√	√	√	√	√
12			√	√	√	√	√	√	√	√	√	√	√	√
13	√	√	√	√	√	√	√	√	√	√	√	√	√	√
14	√	√	√	√	√	√	√	√	√	√	√	√	√	√
15	√	√	√	√	√	√	√	√	√	√	√	√	√	√
16	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 3.2. Occasions and intervals used in MARK for analysis of different taxa and TACs.

	Flying Squirrels				Deer Mice				Townsend's Chipmunk			
	Year 2007		Year 2008		Year 2007		Year 2008		Year 2007		Year 2008	
TAC	Occasions	Intervals	Occasions	Intervals	Occasions	Intervals	Occasions	Intervals	Occasions	Intervals	Occasions	Intervals
1	4	24 hrs	4	24 hrs	4	24 hrs	4	24 hrs	7	7,17,7,17,7,17	7	7,17,7,17,7,17
2	"	"	"	"	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"	"	"	"	"	"
4	"	"	"	"	"	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"	"	"	"	"	"
6	"	"	"	"	"	"	"	"	"	"	"	"
7	"	"	"	"	"	"	"	"	"	"	"	"
8	"	"	"	"	"	"	"	"	"	"	"	"
9	"	"	"	"	"	"	"	"	4	24 hrs	"	"
10	"	"	"	"	"	"	"	"	4	24 hrs	"	"
11	"	"	"	"	"	"	"	"	5	24,24,7,17	"	"
12	"	"	"	"	3	"	"	"	5	7,17,7,17	"	"
13	"	"	"	"	"	"	"	"	"	"	"	"
14	"	"	"	"	"	"	"	"	"	"	"	"
15	"	"	"	"	"	"	"	"	"	"	"	"
16	"	"	"	"	"	"	"	"	"	"	"	"

Table 3.3. Datasets and Models used to Compute Estimates of Population Size for 3 species on Young Stand Study, 2007-2008

Species	Year	TACs	Occasions	Intervals	Model with Best Fit	QAICc Wt	ĉ
GLSA	2007	all	4	24 hrs	Treatments only	93%	1.57
GLSA	2008	all	4	24 hrs	Treatments only	89%	1.87
PEMA	2007	all but 12	4	24 hrs	Blocks and Treatments	99.8%	1.05
PEMA	2007	12 only	3	24 hrs	Full model *	N/A	1.55
PEMA	2008	all	4	24 hrs	Blocks only	99.5%	1.4
TATO	2007	9 & 10	4	24 hrs	Full model	99.5%	0.7
TATO	2007	1-8 & 12-16	7	7,17,7,17,7,17	Blocks and Treatments	61%	1.34
TATO	2008	all	7	7,17,7,17,7,17	Treatments only	90%	1.27
TATO	2007	11	5	24,24,7,17	Full model *	N/A	1.75
TATO	2007	12	5	7,17,7,17	Full model *	N/A	2.1

Notes
* Full model run by default because data don't include more than one treatment or block

Appendix 4 – Correlations between dead wood and mammal captures. Bolded r values are significant at P<0.05.

			Rotten (decay classes 3-5)			**Sound (decay classes 1-2)**			**Totals by Debris Type**		
Species	**Capture year**	**CWD year**	**Vol/ha**	**Area/ha**	**Surf/ha**	**Vol/ha**	**Area/ha**	**Surf/ha**	**Vol/ha**	**Area/ha**	**Surf/ha**
Red-backed vole	1991	1992	-0.006	0.098	0.098	-0.006	-0.087	-0.087	-0.007	0.051	0.051
	1992	1992	-0.238	-0.110	-0.110	-0.291	-0.395	-0.395	-0.293	-0.212	-0.212
	1998	1996	0.117	0.353	0.353	-0.049	0.088	0.088	0.113	0.425	0.425
	1999	1996	0.083	0.314	0.314	-0.321	-0.404	-0.404	0.026	0.096	0.096
	2007	2006	**0.669**	**0.709**	**0.709**	-0.225	-0.276	-0.276	0.436	0.312	0.312
Flying squirrel	1991	1992	0.019	-0.229	-0.229	0.062	-0.008	-0.008	0.036	-0.186	-0.186
	1992	1992	-0.015	-0.240	-0.240	0.040	-0.050	-0.050	0.002	-0.208	-0.208
	1998	1996	-0.476	-0.295	-0.295	-0.204	-0.053	-0.053	-0.533	-0.343	-0.343
	1999	1996	0.282	0.271	0.271	-0.369	-0.245	-0.245	0.225	0.144	0.144
	2007	2006	0.307	0.463	0.463	-0.316	-0.187	-0.187	0.080	0.199	0.199
Creeping vole	1998	1996	-0.038	-0.105	-0.105	-0.157	-0.091	-0.091	-0.068	-0.164	-0.164
	1999	1996	0.168	-0.161	-0.161	0.096	0.130	0.130	0.192	-0.094	-0.094
	2007	2006	-0.203	-0.250	-0.250	-0.022	-0.012	-0.012	-0.184	-0.195	-0.195
Deer mouse	1991	1992	0.054	-0.054	-0.054	**0.512**	0.381	0.381	0.221	0.076	0.076
	1992	1992	-0.049	-0.242	-0.242	**0.512**	0.317	0.317	0.138	-0.095	-0.095
	1998	1996	-0.104	-0.306	-0.306	0.381	0.408	0.408	-0.037	-0.085	-0.085
	1999	1996	-0.083	-0.231	-0.231	0.134	0.180	0.180	-0.061	-0.140	-0.140
	2007	2006	-0.227	-0.340	-0.340	0.435	0.314	0.314	0.055	-0.008	-0.008
Trowbridge’s shrew	1991	1992	-0.373	-0.141	-0.141	-0.387	**-0.508**	**-0.508**	-0.435	-0.271	-0.271
	1992	1992	-0.286	-0.475	-0.475	-0.019	-0.008	-0.008	-0.237	-0.383	-0.383
	1998	1996	-0.344	-0.316	-0.316	0.086	0.266	0.266	-0.341	-0.179	-0.179
	1999	1996	0.153	0.039	0.039	-0.090	-0.236	-0.236	0.142	-0.097	-0.097
	2007	2006	0.322	0.436	0.436	0.008	0.292	0.292	0.276	**0.552**	**0.552**
Townsend’s chipmunk	1991	1992	-0.169	-0.402	-0.402	0.025	-0.082	-0.082	-0.128	-0.347	-0.347
	1992	1992	-0.397	**-0.599**	**-0.599**	-0.172	-0.275	-0.275	-0.380	**-0.565**	**-0.565**

1998	1996	0.361	0.234	0.234	0.335	0.366	0.366	0.438	0.461	0.461
1999	1996	0.145	0.064	0.064	0.369	0.303	0.303	0.219	0.245	0.245
2007	2006	-0.269	-0.365	-0.365	0.290	0.347	0.347	-0.062	-0.001	-0.001