WILDLIFE USE OF MANAGED FORESTS - A LANDSCAPE PERSPECTIVE

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TIMBER FISH & WILDLIFE

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INTRODUCTION

The managed forests of Washington State encompass approximately 17,305,000 acres (7,003,333 ha) of which about 63% are on State and private lands (Card et al. 1985). The Timber Fish and Wildlife (TFW) Agreement (1987) introduced both a framework for management practices on State and private forests, and a mechanism to evaluate and modify management practices to achieve stated resource goals. A critical question facing TFW resource managers is how to balance the TFW wildlife goal to "provide the greatest diversity of habitats (particularly riparian, wetlands and old growth), and to assure the greatest diversity of species within those habitats for the survival and reproduction of enough individuals to maintain the native wildlife of Washington forest lands" with the timber resource goal of "...continued growth and development of the State's forest products industry..." (Timber Fish and Wildlife 1987).

Franklin and Forman (1987) have proposed that the number, size, and arrangement of stands in a managed forest landscape could be modified to achieve different wildlife objectives. However, we must first be able to analyze and predict wildlife responses to varying landscape conditions. The response of wildlife species to local stand conditions has been hypothesized for certain species (see Thomas 1979, Brown 1985, Irwin et al. 1989), but these responses have so far only been evaluated in the field in unmanaged forests (Ruggiero et al. *in press*); no comprehensive research on wildlife communities in managed forests has been conducted in the Pacific Northwest. Even less is known of the response of wildlife populations and communities at the landscape level. We propose to develop a database of knowledge and methods to evaluate wildlife responses to changes in forest habitat conditions as a result of timber harvest at the watershed or landscape level. These are the tools that resource managers must have to accomplish the wildlife habitat objectives of the Timber Fish and Wildlife Agreement (1987).

Analysis of wildlife habitat relationships can be approached from a hierarchical perspective (e.g., Urban et al. 1987, Irwin et al. 1989). Irwin et al. (1989) identified three spatial levels in managed forests - landscape/watershed, stand, and gap - with three corresponding wildlife levels. At the stand level we are concerned with habitat features such as stand size, shape, and seral stage. When we view managed forests from a landscape perspective we are concerned with the spatial and temporal patterns among stands. At the landscape level we consider, for example, distances between stands, connectivity of stands, and conditions surrounding stands. The response of wildlife populations at the stand and landscape level will depend upon the particular life history characteristics of a species, the environment (habitat and other species present), and the species' population structure, which reflects the interaction of life history and the environment (Gilpin and Soule 1986).

Primary concerns in our proposed study of wildlife in managed forest landscapes are the responses of wildlife species to harvest regimes that affect the composition, size, and juxtaposition of habitat stands. The interaction of stand size and type, characteristics of adjacent stands, isolation of stands, and mobility of species will influence whether or not a species is present in a stand despite potentially high habitat suitability (e.g., Lehmkuhl and Ruggiero *in press*). For example, individuals of species with small home range requirements and limited dispersal capabilities might be restricted to single forest stands. If a stand is too small it might be unable to support a viable population (births < deaths) over time and the limited mobility of the species might preclude recolonization. Individuals of more dispersive species might intermittently inhabit the stand by immigrating from nearby "source" habitats, but be incapable of reproducing there (i.e., a "sink" habitat). This is the "source-sink" effect (Van Horne 1983, Pulliam 1988). Wide-ranging species can move between stands to exploit preferred resources, but the spatial distribution of stands can affect their use of habitat as well (e.g., Milne et al. 1989). In such a case, isolated stands of preferred habitat might not be used by these animals, whereas stands of less preferred habitat might be used if they are in close proximity to more suitable stands. Given the potentially varied and complex responses of wildlife to the distribution of stands in a managed forest landscape, we believe that it is necessary to examine wildlife habitat relationships at the stand level in addition to the landscape context of the stand. Our rationale for incorporating both stand- and landscape-level analyses is developed in the Technical Approach.

The May 1991 workshop with the Project research team, WSC members and outside consultants, and a later meeting of the WSC and the research team resulted in a number of recommendations to modify the objectives stated in the Request for Proposals (RFP). The objective of determining habitat relationships affecting long-term population viability was dropped with the realization that population viability analysis was beyond the scope of this rather broad exploratory project. Rather, data collection would focus on defining as yet unknown habitat relationships in managed forests at the stand and landscape levels. A second objective to produce a highly-structured, predictive computer model with widespread application to forest wildlife management was also dropped as unrealistic within the scope of the project. We agreed, however, that the research team would develop methods for analyzing landscape and stand-level impacts on wildlife in managed forests. Some of those methods will certainly include modelling efforts and the use of GIS, but may not be a highly structured and rigorously validated simulation model. The revised objectives of the project are to:

- describe the species composition and abundance levels of wildlife and plant communities occurring in forest stands of varying seral stages, size-classes, and landscape configurations in watershed managed primarily for timber production;

- develop methods for analyzing wildlife responses to landscape-level habitat conditions in managed watersheds.

TECHNICAL APPROACH

In this section we describe our general approach to the analysis of relationships between wildlife community composition and landscape characteristics. Our proposed approach is a result of suggestions developed by the May workshop participants and subsequent meetings with the WSC. Differences between our original proposal and the current one are noted in the text.

As discussed above, the landscape structure of a watershed may be described by a number of variables including stand size and shape (e.g., area/perimeter relationships, the distribution of shapes and sizes), and the isolation and connectivity of stands. Such analyses were not feasible on a large scale until the development of computer-based Geographical Information Systems (GIS) within the last few years. These methods have now become the primary means for organizing and analyzing spatial information (Burrough 1986). Although input of map information and field checking may be time consuming, the flexibility in data analysis afforded by GIS easily outweighs this investment. This is the approach we will use to analyze landscape structure and wildlife response to structural variation.

We plan to conduct separate analyses for a series of watersheds on both east and west sides of the Cascade Crest. For each region, we will initially select up to about 12 watershed landscapes (up from 7 in the first proposal) of about 5000 acres each that contain fourth- or fifth-order streams. Because random sampling would require a large sample to include the full range of forest fragmentation, or pattern, watersheds will be selected to represent a gradient of forest fragmentation as a result of timber harvest, as suggested in the workshop. The mapping, ground-truthing of map data, and spatial analysis of each watershed will begin early in the project period. Based on the map and ground-truthing data, 56 stands (63 in the first proposal) of varying size, age and context will be selected from all watersheds for wildlife sampling. This sampling approach will permit analyses of wildlife community composition at both the stand and watershed levels. Our sampling regime will be suitable for bats, forest-floor small mammals, breeding birds, raptors, reptiles, and amphibians. Landscape structure may be relatively more important for some species groups than others: different techniques or more intensive studies will target species for which standard sampling may not be adequate to elucidate habitat relationships. These species will be discussed in the Sampling Methodologies section.

Because of the logistical and financial constraints involved in sampling a large number of landscapes adequately, only a relatively small number of watersheds can be surveyed in each region over the project period. However, many of the basic processes that govern the presence and abundance of most animals in a landscape occur at the stand level. Stands are the building blocks of landscapes and, consequently, of models to understand landscapes. Stand-level surveys and analyses will be integrated into a landscape-level analysis to estimate the effects of timber harvesting alternatives on wildlife communities and populations.

The initial approach to data analysis will be to predict wildlife composition using descriptors of landscape structure as independent variables in a regression analysis. This model will be revised with data from the subsequent 2 years of sampling. More advanced analyses will then use a combination of statistical and spatial analytical techniques utilizing GIS and other systems. The result will be a comprehensive database of stand- and landscape-scale habitat relationships to validate relationships suggested by Brown (1985), and an analytical procedure for managers to use those data for forest wildlife management. While this is not the formal structured model envisioned in the RFP, the results will be a valid, flexible model and will provide useful tools for impact assessment.

- The approach outlined above would allow us to test a number of null hypotheses about wildlife in managed forest landscapes including:

- Stand size, seral stage, and juxtaposition have no effect on species richness or patterns of species abundance.

- No relationships exist between landscape pattern indices and vertebrate community composition.

- The abundance of a particular species in a stand is not related to the amount and distribution of that stand type within the landscape.

<u>Development of Study Design</u>

The following section on study design illustrates our revised approach to the project objectives. The final project study design will be finalized after further consultation with the WSC during early July.

Rationale for the Study Design

Milne et al. (1989) review some of the difficulties in predicting the occupation or use of habitat by animals. These problems include: (1) At some times the landscape may be "unsaturated" with organisms and thus many suitable areas may be vacant. This possibility reduces our ability to accurately describe the habitat requirements of wildlife species. (2) Humans may recognize different landscape variables to which other species may perceive no difference. (3) Models based on the analysis of correlations between animal abundance and landscape variables which lack explicit spatial information, make it difficult to translate correlational relationships to maps. (4) If populations are monitored infrequently, our ability to describe spatial variation in habitat use will be reduced. Thus the success of habitat modelling will be contingent on animal density, human perceptions, spatial information, and temporal variation in wildlife populations and habitat needs (Milne et al. 1989).

The study design must meet these challenges and still be logistically feasible. In evaluating the types of approaches that one might develop for wildlife-habitat modelling at the watershed level, we considered the following:

(1) *Wildlife-habitat relationships based on sampling conducted at the landscape level.* The variables in this analysis would describe the spatial composition of many (20-30) watersheds as the main sample units. Variables might include habitat diversity, diversity at any point in the landscape (i.e., contagion), and the shape of habitat patches (i.e., fractal dimension). These types of variables could be easily calculated from map data entered into a GIS. Wildlife sampling would be conducted throughout each watershed on a very broad scale (e.g., by running transects). Vertebrate sampling conducted at the scale of entire watersheds would, by necessity, result in data with relatively low predictive power, such as presence-absence data. The landscape variables could then be used, for example, as independent variables in a regression model to predict such wildlife community characteristics as species diversity or patterns of abundance among species.

Although this approach seems appealing, it has several critical problems. First, obtaining an adequate number of samples (i.e., watersheds) for statistical analysis is difficult due to the necessity of sampling terrestrial vertebrates throughout entire

FIGURE 1. PROJECT TIMELINE: PERSONNEL BY TASK. ■ = Analysis and Reporting; □ = Fieldwork

Years	1991 ¦ 1992 ¦ 1993 ¦ 1994 ¦ 1995
Biennia	B 1 ¦ Biennium 2 ¦ Biennium 3 ¦
Months	M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
TASK 1: PROJECT PLAN	
Develop Plan	■ ■ ■ ■ ■ ■
(West, Aubry, Hallett, O'Connell, Lehmkuhl, Raedeke, Martin, Manuwal, Everett, Franklin)	
WSC Meetings & Technical Review	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■
(Same as above)	
TASK 2 & 3: FIELD WORK & HABITAT ANALYSIS	
Watershed Selection & Mapping	□ □ □ □ □ □ □
(Same as above plus 2 GIS tecnicians)	
Study Site Selection & Establishment	□ □ □ □ □ □ □ □ □ □ □ □ □
(Same as above plus 6 Research Assistants)	
Amphibian, Reptile, & Small Mammal Sampling	□ ■ ■ ■ ■ ■ ■ □ ■ ■ ■ ■ □ ■ ■ ■ ■ ■ ■ □ ■ ■ ■ ■ □ ■ ■ ■ ■ ■ ■ □ ■ ■ ■ ■ □ ■ ■ ■ ■ ■
(Aubry, West, Hallett, O'Connell, 4 Research Assistants, 8 Hourly)	

FIGURE 1. (con't) PROJECT TIMELINE: PERSONNEL BY TASK. ■ = Analysis and Reporting; □ = Fieldwork

Years	1991 | 1992 | 1993 | 1994 | 1995
Biennia	B 1 | Biennium 2 | Biennium 3
Months	M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
Intensive Amphibian Study (Aubry, 1 Research Assistant, 1 hourly)	□□□□□□■■■ □□□□□□■■■
Carnivore Sampling (Aubry, West, Martin, O'Connell, 2 Hourly)	□■■ □■■ □■■
Bat Sampling and Intensive Study (West, Hallett, 1 Research Assistant, 1 Hourly)	□□□■■■■■■■■■□□□■■■■■■■■■□□□■■■■■■■■■□□□■■■■
Avian Sampling (Manuwal, Raphael, Hallett, O'Connell, 2 Research Assistants, 16-22 Hourly)	□□□■■■■■■■■■□□□■■■■■■■■■□□□■■■■■■
Stand Vegetation Sampling (West, Aubry, Hallett, O'Connell, Franklin, 1 Research Assistant, 8-12 Hourly)	□□□■■■■■■■■■□□□■■■■■■■■■□□□■■■■■■■■■□□□■■■■
TASK 4: IMPLEMENTING HABITAT OBJECTIVES (All project personnel except Hourly)	■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■

watersheds. Second, by sampling different sets of watersheds in each year to increase sample size, one loses the ability to examine or account for temporal variation in species abundance. Third, the extensive sampling across landscapes that is needed for this approach precludes collection of precise stand-level data that is virtually unknown for managed forest stands. Finally, we might find that many wildlife species do not respond to the landscape variables that we perceive or measure making model developmentunachievable. Initial work in the Pacific Northwest thus far indicates that the predictive power of landscape variables is weak (Lehmkuhl et al. *in press*).

(2) *Wildlife-habitat relationships based on sampling at the stand level.* In this approach, a moderate number of landscapes (about 12) per region that represent a gradient of landscape pattern would be selected for study. Terrestrial vertebrate groups would be sampled in a number of stands within each watershed, the number depending on the specific pattern and composition of the landscape. The selected stands would vary in size, seral stage, and landscape context (i.e., spatial relationship of a stand to others in the watershed). This approach would allow statistical analyses of wildlife-habitat relationships at both the stand and landscape scales. For example, one could attempt to predict components of wildlife community composition within stands using the variables of size, type, and context and then integrate these stand-level results into a landscape-level model (see Analysis and Modelling). We have selected this approach because it will provide a sufficient sample of stands for analysis, a high resolution of important stand-level habitat relationships, and incorporate most of the spatial variation of the watersheds. Temporal variation in habitat use will also be examined by sampling each of the stands and landscapes each year of the 3-year study.

Stratification of Study Sites and Sampling Design

The general design will be to survey vertebrate communities using techniques that provide estimates of species abundances in a discrete set of stands replicated in up to 12 landscapes (or more as budgetary and logistical constraints and landscape patterns will allow). This approach will provide a gradient of landscape pattern and stand configurations that will enable us to examine the influences of both landscape and underlying stand scales on wildlife. Study stands will be selected according to stand- and landscape-level criteria, including stand size and age categories identified *a priori*. Landscape context of the stands will be considered *ad hoc* during stand selection in a modification of the 3-category factorial design described in the first proposal.

Stand-level criteria.--There are two stand-level criteria that must be evaluated in order to reliably describe landscape-level habitat relationships in managed watersheds: stand size and forest type (seral stage). Stand shape strongly influences edge effects on wildlife populations (Harris 1984), but we will attempt to control for this effect by selecting stands that are more or less circular or block-shaped, i.e., all will have relatively low perimeter-to-area ratios. By sampling the full gradient of stand sizes, however, our study design allows us to examine edge effects, i.e., small stands will be nearly all edge habitat.

We propose to study three stand size-classes with modal categories of 2-5 acres, 20-40 acres, and 90-100+ acres (Figure 2). The smallest size-class is intended to represent the range of sizes of existing TFW Upland Management Areas (UMA's). The largest size-class represents common harvested units and regenerated stands in the target landscapes. The medium size-class is included to ensure that the full range of size– classes in managed landscapes is evaluated.

We propose to study three forest type-classes (seral stages): harvest-regeneration unit (no canopy; herbaceous layer only), immature forest (pre-canopy; herb and shrub layers only), and mature forest (closed-canopy). Each of these seral stages provides optimal habitat for a unique (but generally overlapping) array of wildlife species (Thomas 1979, Brown 1985). Consequently, the extent and distribution of each seral stage within each landscape will represent varying degrees of habitat fragmentation for those species associated with each seral stage. Because UMA's are designed to provide residual habitat for wildlife following timber harvest activity, we expect all of the small-size-class stands to be in the mature-tree seral stage. Bog and wetland UMA's will not be sampled.

Landscape-level criteria.-- A third implicit stand selection-criterion will consider the landscape context of potential study stands. Various parameters have been put forth as being important measures of landscape-level variation, such as dominance, contagion, and fractal dimension (O'Neill et al. 1988), and attempts have been made to study the effects of some of these variables on wildlife populations in forested habitats in Washington (Lehmkuhl et al. *in press*). For stand selection criteria, however, the most significant landscape-level effects on wildlife communities in managed forests will result from the kinds and amount of habitat adjacent to stands, and the degree of isolation of each habitat patch (stand) from similar habitat conditions. These factors comprise the landscape context. Our original proposal outlined a framework within which to assess the effects of landscape context on wildlife with a "context" index that classified stands into one of three context-classes. The index was based on three components: the percentage of stand perimeter adjacent to a given forest type (seral stage), multiplied by a weighting factor based on the degree to which that stand differs in seral stage, and the distance to the nearest stand of the same seral stage and size. An additional component to consider was the timeframe of isolation of each stand.

Our revised site selection methodology will not explicitly address context as a selection criteria in a 3-way factorial arrangement with stand area and age. Variation in landscape context will be accounted for implicitly, however, by selection of landscapes and their component stands along a gradient of forest fragmentation or landscape pattern. Stand context will be assessed for each candidate stand, and selection of stands will attempt the maximize the variation in stand context for each stand size and age combination.

The three criteria of stand size, forest type (seral stage), and stand context will provide the framework within which we will conduct replicated sampling of wildlife populations to analyze stand- and landscape-level wildlife habitat relationships.

Sampling Design.--We will sample eight replicates of the seven stand size and age combinations for a total of 56 stands sampled each year of the study. Each stand will be sampled every year of the study. Only 7 size and age combinations will be sampled because two of the possible nine combinations of the 3x3 size and age design are not expected to be common in the field. Stands in the smallest size-class will be few in number because our study landscapes will have been extensively logged in relatively large harvest units. Upland Management Areas will comprise most of the stands in the smallest size-class (class 1). Because UMA's are expected to be composed of mature forest, sampling small early successional stands will not be feasible.

As remnants of mature forest, UMA's may provide critical habitat for maintaining source populations of species with small home ranges, as survival refugia during periods of severe environmental conditions or resource shortages, or as islands of favorable habitat for wide—ranging species. Although we do not know the extent to which these small remnants occur in the landscapes we will be studying, we have included them in our study design because of their potential importance to wildlife populations in managed landscapes. We will include these areas in our sampling to the extent that suitable stands can be located. Furthermore, modified sampling strategies may need to be employed in these stands due to their small sizes or anomalous physiographic positions within the landscape.

We may want to select stands in landscapes at the high end of forest fragmentation because theory suggests that forest species will begin to decline in landscapes with 50-75+% of the habitat removed (Franklin and Forman 1987; McLennon 1986). We also may allocate some sample stands of a particular size and age configuration to landscapes at one or the other end of the fragmentation gradient. For example, we might expect medium-sized clearcuts to be little different from large clearcuts when located in near-completely cutover landscapes because there is little contextual diversity; but, we might expect medium-size stands to be much different in species composition than larger stands when located in landscapes with more forest and contextual diversity. We believe that some flexibility in locating sample stands will be necessary to address such issues.

Sampling Methodologies

In the following section we outline our general approach to field sampling. The final selection of study sites, vertebrate taxa, and survey techniques will be determined in conjunction with the WSC.

Watershed Mapping

Landscapes and the stands for field study will be selected by screening areas with the aid of geographic information systems (GIS). Initially, maps displaying forest types for the general study regions will be compiled from sources supplied by the land owners. Hopefully, maps will already be in a computer digital format compatible with our GIS. Otherwise, paper maps will be obtained from the landowner and digitized into the computer at our GIS labs. If neither of these options is available, we will have to map the regions from orthophotographs or remote sensing imagery in our GIS labs. East-side GIS work will be done at WSU, and west-side work will be done at the Olympia Forestry Sciences Lab.

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Size-class 1------------Age-class 3
  (2-5 acres)            (mature forest)


                   |------Age-class 1
                   |      (harvest-regeneration)
                   |
                   |
Size-class 2-----  |------Age-class 2
 (20-40 acres)     |      (immature, pre-canopy forest)
                   |
                   |
                   |------Age-class 3
                          (mature, closed-canopy forest)


                   |------Age-class 1
                   |      (harvest-regeneration)
                   |
                   |
Size-class 3-----  |------Age-class 2
 (90-100+ acres)   |      (immature, pre-canopy forest)
                   |
                   |
                   |------Age-class 3
                          (mature, closed-canopy forest)
```

Figure 2. Stand sampling design. The seven combinations of size and age classes will be replicated 8 times (7 x 8 = 56 stands total sampled) and distributed within about 12 landscapes selected along a gradient of forest fragmentation. The sampling design will be replicated east and west of the Cascade Range.

Selection of Study Sites

Potential landscapes for study will be selected by GIS analysis of the watersheds which have been mapped in each region. Comparison of stands will be done on several levels. At the stand level, landscapes will vary widely in the composition and size and age distributions of stands. We will want to sample the greatest variation in area, age, and context available. At the landscape level, landscape pattern will be assessed with indices that measure habitat diversity (dominance and diversity), diversity at any point in the landscape(contagion), and the shape of habitat patches (fractal dimension) (O'Neill et. al. 1988). Replicate landscapes also should be similar in total area, i.e., length and width (extent) (Turner 1990).

After potential landscapes are selected, stands conforming to the three criteria of size, forest type, and context will be selected for sampling in each landscape with the aid of GIS. Listing or displaying stands of different forest type and size are elementary operations with GIS. Measuring stand context will require the creation of an index to incorporate a measure of edgecomposition or diversity, and distance to the nearest stand of the same type. We can characterize each stand by size, type, and contextual attributes, then use graphical and tabular output to identify study stands.

Selection of Species

The general design will be to survey vertebrate communities using techniques that provide estimates of species abundances at both the stand and landscape level. Well-replicated sampling of vertebrate communities within upland managed forests has not been done in Washington. Species differ in their biology and ecological requirements and are therefore expected to vary in their response to landscape characteristics. Consequently, we think it is desirable to monitor a broad range of taxa to examine wildlife-habitat relationships within landscapes rather than limit samples to selected vertebrate taxa. At the same time, however, the methods will adequately sample many species of particular interest with regard to fragmentation. Once this study clarifies the associations, subsequent studies can be designed more parsimoniously.

We propose to sample a variety of taxa for which we have reliable methodologies, and have designed more intensive studies for two species groups - bats and pond-breeding amphibians - that may sensitive to the effects of fragmentation and that can be feasibly studied. Details of these directed studies follow the descriptions of methods for the community-level surveys below. For the community surveys, species abundance values associated with various stand and landscape conditions will be expressed as means with associated standard errors. We will attempt to keep the sampling effort at least roughly comparable to that of the Old-Growth Wildlife Habitat Program (OGWHP), because its sampling protocol was sufficient to allow statistical tests to be made for many species. It is also desirable to maintain as much commonality as possible with the TFW RMZ studies to make comparisons possible between managed upland forests, old-growth forests, riparian zone forests, and Riparian Management Zones.

Terrestrial Amphibian, Reptile, and Small Mammal Sampling.--During the OGWHP studies, techniques for sampling vertebrate communities were developed and refined for conditions in Pacific Northwest forests. Based on extensive experience with amphibian and small mammal surveys gained during these studies (Aubry et al. 1988, Aubry et al. *in press*, Aubry and Hall *in press*, Bury 1988, Bury and Corn 1987, 1988a,b, West *in press*) we propose to sample terrestrial amphibians, reptiles, and small mammals with pitfall traps. Data gathered with time-constrained searches (TCS) will augment the pitfall data for amphibians and reptiles. We propose these approaches for several reasons. Pitfall traps will effectively capture surface-active amphibians, some reptiles, and most of the smaller mammals, resulting in good estimates of relative abundance in forested habitats for both groups (Aubry and Hall *in press*, West *in press*). By capturing large numbers of individuals, this technique will also enable us to assess the demographic structure of populations through analyses of body size-classes for amphibians, and age-classes for small mammals.

Pitfall traps effectively sample small mammals that use tactile and olfactory cues for orientation more than visual cues. They therefore capture insectivores and non-jumping rodents well, but are less effective at capturing deermice, chipmunks, and jumping mice (Briese and Smith 1974, Williams and Braun 1983, Bury and Corn 1987). The latter species, however, are either ubiquitous or have specific habitat requirements unlikely to be met in upland areas.

In western Washington, TCS were shown to be less effective than pitfall trapping for providing information on the species richness and relative abundances of amphibian communities in forested habitats (Aubry et al. 1988). However, because animals are individually located, rather than being collectively trapped at a central location, TCS provide direct evidence of microhabitat selection. Of particular importance in these studies will be an assessment of the extent to which forest floor amphibians use downed woody debris (logs, and pieces of bark and wood) as hiding cover. Furthermore because reptiles are less prone to pitfall capture, particularly the snakes, we expect time-constrained sampling to be the primary data collection technique for reptiles.

Procedures.--We propose spring and fall trapping periods. Pitfall traps constructed after the plans of Corn and Bury (1990) and used in the OGWHP will be operated for two continuous weeks. Examination of capture curves during the OGWHP indicate that a two-week period will yield all but rare species. Thirty-six traps will be placed in a 6 x 6 grid with 15-m intervals between traps. As appropriate, animals will be prepared and deposited in the Burke Museum at the University of Washington and the Conner Museum at Washington State University.

Time-constrained searches consist of teams of people intensively searching a unit area for a specific length of time. We anticipate that teams of at least 2 people will search a series of fixed-radius plots in each stand for a specified number of search-hours. The plots will be systematically spaced throughout each stand. For each amphibian or reptile encountered, species, sex, age, weight, and length will be recorded. Basic field identification of species is essential and field personnel will be required to examine museum specimens and have field practice sessions prior to actual searches. To gather information on microhabitat use by reptiles and amphibians, we will record data on the position of each animal (i.e., on surface, under rock, under bark on snag, under bark on log, etc.), and describe the cover object or location where each animal is collected.

Breeding Bird Sampling.--We propose to use a modified point count method for surveying bird populations. Point counts are discussed by Verner (1985) and have been used in several recent studies (e.g., Verner and Ritter 1985, Hutto et al. 1986, Manuwal and Huff 1987, Manuwal *in press*, Huff et al. *in press*, Manuwal and Carey *in press*). The point count method is superior to other methods for sampling forest birds due to relatively poor visibility in forested habitats, and the rugged topography typical of Washington mountains. Other methods, particularly strip transects, are inefficient at determining either the species richness of stands, or at estimating the relative abundance of each species (Manuwal and Huff 1984, Verner 1985).

The modified point count method we propose to use involves estimating the distance to birds detected within 50 m, and then simply recording birds seen or heard in one of two concentric bands beyond 50 m: 51-75 m and >75 m. The increasing effects of observer bias and variation in bird detectability with distance in these habitats, prohibit the accurate estimation of detection distances beyond 50 m. The recording of detection distances within 50 m will enable us to draw detection curves for each species according to observer. With these data we will evaluate the variation in detectability both among and within species in various stand conditions, and the degree of observer bias (e.g., some individuals may be poorer at detecting species that call at very low or high frequencies than others). This will enable us to delete questionable detections from the data set, and thereby improve the power of our statistical analyses by reducing random variation.

Procedures.--In stand size-classes 2 and 3, twelve evenly spaced bird-count points (or stations) will be located within the stand. Each point will be 75—100 meters from the next point. In the small, size-class-1 sites, one to three stations will be established. Count duration and number of visits will remain the same as for the other larger sites. Each survey point will be marked with plastic flagging and numbered. Counts will begin within 15 minutes of dawn and be completed within 3 hours. Upon arriving at a survey point, the observer will remain stationary and quiet for a minimum of 1 minute to allow birds to settle down after initial disturbance by the observer. During the survey period, the observer will record on a field data form the birds heard or seen for a period of 8 minutes. During the survey, the observer will slowly scan the vegetation at all levels within the sampled zone. Birds not previously recorded will be tallied if they are detected between count points to obtain a complete species list for each stand; these data will not be used in calculating abundance indices. Observers will be systematically rotated among the stands being sampled to help correct for any between-observer bias in ability to detect birds among the stands. Furthermore, within-stand bias of bird detectability will be reduced by reversing the travel routes during successive visits to each stand. Detections of tree squirrels, which also give territorial calls that can be used as an index of abundance (Buchanan et al. 1990), will be recorded during the bird surveys.

Bird surveys will be conducted between mid-April and mid-June. Each stand will be surveyed 6 times during the spring. The surveys should be spaced throughout the breeding season to account for different breeding phenologies of bird species in this region. Surveys will be terminated when fledglings of several species begin to appear. Counts will be conducted when wind is less than 15 kph and when no significant rain or snow is falling, as these factors have been shown to significantly bias results. Every attempt will be made to avoid counting individual birds more than once.

Accurate monitoring of small forest birds will be successful only if the field personnel are competent. Competence in bird identification and in conducting sampling should be demonstrated before any data are collected. Periodic testing may be appropriate. Virtually all recognized techniques for counting birds are subject to observer bias, which results from differences in the attitude, field experience, and abilities of observers. In most forest habitats, birds are much more often heard than seen; for example, in our study of birds in the Douglas-fir forests of western Washington (Manuwal *in press*), we saw only 3-4 percent of the birds we heard. Field personnel therefore must be able to correctly identify birds by both calls and songs. Emlen and DeJong (1981) found that observers with slight hearing losses in the high-frequency ranges detected some species at only 25-90 percent of the distances at which observers with normal hearing detected them. Ramsey and Scott (1981) found that hearing thresholds of people over 40 years of age usually did not meet the minimum required to hear frequencies typical of the songs of many passerine birds. Other important observer attributes include alertness, field experience, knowledge of ornithology, and good physical condition. All field observers will have a 2-3 day training period in which all the above-mentioned characteristics will be evaluated.

Assumptions of our proposed technique are: (1) Birds are accurately identified, (2) sampling effort is adequate to detect species present, (3) sampling effort is adequate to obtain reliable indices of bird abundance, (4) differences among observers, years, and species' detectabilities (both within and among habitats) can be accounted for.

The following population parameters will be determined: bird species richness and indices of abundance for all species with adequate numbers of detections. All bird species detected within the survey area will be recorded and compared among study areas. The number of species (species richness) among all study areas will be used in the comparisons. A detection rate (mean number of birds detected per visit) will be calculated to facilitate comparison of bird abundance among stands. Detection rates reduce some of the distance estimation biases associated with the similar variable circular plot (VCP) technique described by Reynolds et al. (1980). Detection rates provide an abundance value for uncommon species for which densities can not be calculated using other approaches. Comparisons of species richness and detection rates can be accomplished using similarity indices, e.g, the Sorensen equation (Able and Noon 1976). We will evaluate the abundance pattern of the various species by using the coefficient of population similarity (Sp) (Odum 1950). Foraging guild structure will be evaluated by placing species into guild categories *a priori*. These categories were described by Sabo and Holmes (1983) and recently used by Manuwal and Huff (1987) and Manuwal (*in press*). They are: aerial predators, omnivore-scavengers, tree-seed eaters, bark insectivores, tree foliage insectivores, low understory herbivores/insectivores, aerial insectivores and nectar feeders/insectivores.

Raptorial Bird Sampling.--Raptorial birds are extremely difficult to survey because of their secretive habitats. Owls can be surveyed by the use of hooting or recorded call play--backs, whereas, diurnal hawks must be surveyed with different techniques. Nevertheless, an index of abundance can be calculated to compare raptor abundance/use at different sites. Our approach would involve the following methods: (1) record all raptors seen or heard during regular bird surveys; (2) after each regular survey, taped calls of the northern goshawk, Cooper's hawk, sharp-shinned hawk, American kestrel, and red-tailed hawk (for open habitats) would be played back from a speaker located in the study stand. Response (returned call or visual detection) would be noted; (3) a record of all raptor nest-sites would be kept. Nest-site characteristics, including stand and stand context would be recorded for each nest-site; (4) number of raptors observed on incidental trips would be recorded and used in a qualitative manner to assess use within each landscape. Owl presence will be documented by regular hooting or recorded call surveys at each site.

Bat Sampling.--Though often overlooked because of their nocturnal habits, bats collectively represent the second-most numerous species group of mammals in the Pacific Northwest, surpassed only by the rodents. There are 12 species known to inhabit the forests of Washington, but most aspects of their ecology are unstudied in this region. It has been shown recently that bats inhabiting forests west of the Cascade Crest in Oregon and Washington roost statistically more often in old than young forest (Thomas 1988, Thomas and West *in press*). The bats appear to be using areas with old trees for day-roosting, but leaving these sites to forage over water sources elsewhere, where the abundance of appropriately sized insects is higher than in the forest (Thomas 1988). Although the characteristics of natural roost sites have not been identified adequately for any bat species in Pacific Northwest forests, it is likely that as the average age of forests declines, so will their opportunities for roosting in natural habitat.

We propose to sample bats using the ultrasonic detectors developed for the OGWHP (Thomas and West 1989). These devices yield a frequency count of bat passes per unit time by automatically recording bat echolocation calls on cassette tape after they have been electronically transformed into frequencies audible to humans. Because echolocation calls in some cases differ by species, or by groups of closely related species, they can be identified. Mist netting or other forms of net capture are strongly biased with respect to species and are not reliable indicators of relative abundance. The detectors do not require capture, do not affect bat behavior, can distinguish feeding calls from travel echolocation calls, and are capable of accumulating large sample sizes for statistical analysis. We have sufficient numbers of detectors at the College of Forest Resources for this study.

Procedures.--We will sample bats on a site for 2 nights in June, July, and August. We will employ several bat detectors (5 or 6) simultaneously, such that each month's sample is completed over a 2-week period. Field sampling involves placement of the detectors in appropriate locations, changing batteries and cassettes, and keeping them running under generally adverse conditions. Data analysis is highly specialized. It involves the use of a period meter and a calibrated oscilloscope to provide time-frequency displays of the calls (Simmons et al. 1979, Fenton 1988). We will sum calls following the identification groups of Thomas (1988).

Carnivore Sampling.--Although carnivores are one of the highest profile groups, they are also one of the most difficult to study. Typically, their low density and large home ranges dictate research requiring extensive logistical support, often involving the use of airplane-based radio-telemetry equipment. This project does not have sufficient funds to deal intensively with any carnivore species. However, two techniques are available that may provide information on the presence of carnivores at relatively low cost: sooted aluminum track plate stations (Barrett 1983) and automatic camera stations (Joslin 1977, 1988). Both methods provide information on carnivores without constant attendance by field workers, and both have proved effective for sampling two key species: marten and fisher.

Track plate surveys can be done with stations constructed of plywood boxes (cubbies) hung on trees, which reduces the number of non-target species that take the bait and thereby render the station useless for providing data on mustelids. The box protects the sooted plate, and data can be collected for many days after placement. Based on recent work in California and eastern Washington (Martin pers. obs.), cubbies should be checked and maintained at least once per week, and 4-6 weeks of surveying should be adequate to detect the presence of marten or fisher in the vicinity.

Recent work by scientists at the Olympia PNW lab (Raphael and Jones pers. obs.) indicates that Joslin's inexpensive camera-station technique ($10-15 per station) can be successfully applied in Pacific Northwest forests, and will provide data on a number of carnivore species. Camera stations should also be checked at regular intervals of no more than one week to maximize the likelihood of detecting target species.

Both techniques will be investigated as potential means of detecting the presence of carnivores in our study landscapes, and will be implemented as time, logistical support, and funds allow.

Stand Vegetation Sampling.--We propose to measure structural and vegetational components of stands to (1) describe wildlife habitats at the stand level, (2) correlate habitat features at the stand-level with wildlife population parameters, and (3) identify stand components altered by harvest that affect wildlife species. These samples are necessary for the proposed study, but are also of critical importance in allowing the comparison of stand-level habitat characteristics between managed and unmanaged forests (OGWHP data sets). Such comparisons will give us insight into the cumulative effects of intensive forest management on wildlife.

Procedures.--Vegetation and site conditions will be described by measuring such standard variables as (1) percent cover by height-class and life form, (2) percent cover of forest floor by substrate type, (3) litter depth, (4) number, size, species, and dispersion of trees, (5) height of dominant canopy trees, (6) cover of down logs by decay-class, (7) number, size, and decay- class of snags, (8) cover by rock outcrop, (9) slope, and (10) aspect. Similar to the OGWHP, field sampling will be on different scales to allow correlation with data collected for different vertebrate groups. For example, for each bird survey point variables measuring ground cover characteristics will be measured in plots that are nested within larger plots for measuring variables for overstory cover, stand characteristics, and site characteristics. In a similar fashion, habitat variables to characterize pitfall trap locations will be measured in a smaller set of nested plots.

In addition to the above sampling to describe stand characteristics, we may measure selected variables important in the life history of certain vertebrate groups. For example, sampling of amphibians or reptiles might be coupled with habitat variables describing individual collection locations. These variables would enhance our understanding of species requirements and increase our ability to model their responses to the effects of forest management.

Intensive Study: Pond-breeding Salamanders.--Salamanders occurring in the Pacific Northwest can be classified into three groups according to their reproductive ecology:

stream-breeding salamanders, woodland salamanders, and pond-breeding salamanders. The streram-breeding Pacific giant salamander (*Dicamptodon tenebrosus*), Cope's giant salamander (*D. copei*), and Olympic salamander (*Rhyacotriton olympicus*) breed in cool, fast-moving headwater creeks. With the exception of metamorphosed Pacific giant salamanders, which occupy terrestrial habitats during the non-breeding season (Nussbaum 1969), individuals of these species remain near the creeks during their entire life cycles. In contrast, woodland salamanders, including the ensatina (*Ensatina eschscholtzii*), clouded salamander (*Aneides ferreus*), Oregon slender salamander (*Batrachoceps wrightii*), and all species in the genus *Plethodon* live in forested environments and lay their eggs in moist, protected terrestrial sites. These species are independent of streams or ponds for breeding and of the larval life stages that accompany such modes of reproduction. Like reptiles, the young of woodland salamanders hatch fully formed from the eggs (Nussbaum et al. 1983).

The third group, including the northwestern salamander (*Ambystoma gracile*), long-toed salamander (*A. macrodactylum*), tiger salamander (*A. tigrinum*), and roughskin newt (*Taricha granulosa*), are all pond-breeding species that migrate in the spring from overwintering habitats to breeding ponds, where they typically congregate in large numbers to mate and lay eggs (Nussbaum et al. 1983). The adults return to terrestrial habitats soon after the breeding season is over. Another migration away from the ponds occurs in the late summer and early fall when the metamorphosed larvae leave the ponds to seek overwintering habitats. The mode of reproduction that each species exhibits determinesthe extent to which it is likely to be directly influenced by landscape-scale environmental variation.

Although mark-recapture studies of salamanders in the Pacific Northwest have never been attempted, both stream-breeding and woodland salamanders probably spend their entire lives within single forest stands. Consequently, landscape-scale environmental influences on these species aremore likely to be indirect than direct, e.g., microclimatic changes occurring over long periods of time due to the harvesting of adjacent stands or increased risks of local extinctions due to the insularization of stands through forest fragmentation. We predict, however, that pond-breedingsalamanders will be directly affected by landscape fragmentation because their life cycles involveyearly movements among stands, not simply within them.

No research has been conducted on the landscape ecology of amphibians in the PacificNorthwest. Ponds are relatively scarce in forested habitats in this region (Lehmkuhl unpubl. data), so, pond-breeding salamanders in many areas must travel long distances through a variety of habitats to reach breeding ponds. The skin of all salamanders is permeable to water, restricting their activities to areas in both time and space to areas containing either standing water or moist environmental conditions. Dessication is therefore a constant threat to amphibian survival. Because timber harvesting negatively affects habitat suitability for aquatic amphibians, due in part to the drier conditions that result from removal of the canopy (Bury and Corn 1988b), migratory salamanders may be unable to cross young plantations on their way to breeding ponds. Consequently, both the sizes, arrangements, and environmental conditions of patches (stands), and the availability of suitable breeding ponds within forested landscapes will strongly influence the reproductive ecology of migratory salamanders.

Stand-level studies of pond-breeding salamanders in terrestrial habitats in Washington during the non-breeding season indicate that overwintering habitat may also be adversely affected by forest management. Pitfall trapping in October and November in the southern Washington Cascade Range revealed that both northwestern salamanders and roughskin newts are closely associated with old-growth forests during the overwintering period (Aubry and Hall in press). Because forest-floor conditions in old-growth stands are typically moist and buffered from climatic extremes (Spies and Franklin 1988), such conditions may provide critical overwintering habitat for pond-breeding salamanders.

We predict that fragmentation of forested landscapes will significantly affect the habitat relationships and population dynamics of migratory pond-breeding salamanders that occur there. As part of our studies of wildlife responses to landscape-scale environmental patterns in managed forests, we propose to select the pond-breeding migratory salamanders as one of ourprimary research targets.

Objectives.--Our primary objective is to investigate the movement patterns and reproductive ecology of pond-breeding salamanders in forested landscapes managed primarily for timber production. We predict that mortality of marked salamanders will increase and numbers of salamanders will decline as landscapes become more fragmented, with ponds becoming more isolated by unsuitable habitat and dispersal routes in forested stands become fewer. Also, we expect overwintering population sizes to decrease as stand sizes decreases and microclimate becomes dryer due to edge effects.

Methods.--We will use two methods to study populations of pond-breeding amphibians: (1) Permanently mark all pond-breeding salamanders captured in pitfall traps during the course of stand-scale vertebrate community studies in both east- and west-side study areas. (2) Establish drift fences, with pitfall traps on both sides, around entire breeding ponds to capture and identify all individuals either entering or leaving the breeding ponds and determine their movement patterns.

Using standard techniques (Ferner 1979), we will individually mark all pond-breeding salamanders we capture in pitfall traps during the stand-scale vertebrate community studies described elsewhere. In this region, pitfall traps will generally not kill pond-breeding salamanders. We conducted similar pitfall trapping studies in 45 forested stands in southern Washington as part of the Forest Service's Old-Growth Vertebrate Community Studies (Aubry and Hall in press), and although traps were checked only about once per week, virtually all amphibians were captured alive.

The technique of completely enclosing breeding ponds with drift fences and pitfall traps to capture all individuals either entering or leaving the ponds was developed by Gill (1978) for studies of red-spotted newts (*Notophthalmus viridescens*) in the Shenandoah Mountains of Virginia. He estimates that in any given season, he captured about 90 percent of all salamanders present. However, in multi-year studies the probability of capturing all individuals at least once is nearly 100 percent.

Strips of aluminum sheeting will be buried in the ground to completely encircle potential breeding ponds. Baffles made of 15-cm strips of aluminum window screening will be folded over the top of each drift fence to deter salamanders from climbing over. Pitfall traps will be spaced 15 m apart and constructed and buried in accordance with descriptions of pitfall trapping techniques used in the vertebrate community sampling. Traps will be checked twice per week to ensure that all salamanders are captured alive. Unmarked individuals captured at the breeding ponds during the fall sampling will also be marked. Thus, we will be able to determine migratory movements occurring both into and out of the breeding ponds.

Intensive Study: Bats.--Our information base for bats in Washington is very limited. Little is known about the current ranges and population sizes of bat species in this region. It is also difficult to assess trends in population size because little information exists regarding historic population sizes. The status of only 3% of bats worldwide is well known (Stebbings 1980). Documented declines are primarily due to disturbance of bats in maternity colonies and hibernacula, and loss of habitat (Mohr 1948; Edgerton et al. 1966; Cockrum 1969; Tuttle 1979). As Pacific Northwest bat species are closely associated with old-growth Douglas-fir forests (Thomas and West, in press), the recent, rapid decline in extent of old-growth forests on the west coast has undoubtedly had detrimental effects on bat populations.

To evaluate the effects of forest management upon bat populations of the Pacific Northwest, we need improved estimates of current geographic distributions, population sizes, and habitat-use patterns. Distributional records for many species are incomplete and information on population sizes for most species virtually non-existent. Some progress is now being made in understanding habitat-use patterns, as in the general survey portion of this project, but this work has only begun. Critical habitat elements, especially the characteristics of naturally-occurring roost sites and size and variation of foraging ranges, must be described (Christy and West, in review).

As part of the OGWHP, vegetative parameters were regressed against levels of activity to determine stand-level habitat characteristics of importance to forest-dwelling bats (Thomas and West, in press). The density of damaged or diseased trees, snag size and decay class, elevation, and chronological stand age were all weakly associated with higher activity levels. However, these regression variables did not explain the old-growth associations, leaving 83% of the total among sample variation unexplained. The relationship between the measured vegetation characteristics and activity levels was too weak to draw definite conclusions. Thomas and West (in press) postulate that the weakness of the association stems from our current lack of knowledge concerning natural roost site characteristics and failure to measure the appropriate variables. This information gap severely constrains our ability to provide suitable habitat for the bats of the Pacific Northwest.

Natural roost sites in Pacific Northwest forests are difficult to locate and their characteristics are not well known. In other parts of the country and the world, small bats roost preferentially in the oldest available trees (Lunney et al. 1988b; Barclay, Faure and Farr 1988; Gardner et al. 1991). Features of old living trees, such as thick bark with cracks and crevices, offer many potential roosting sites for individual bats. Hollow trees also provide ideal sites for the large maternity colonies which *Myotis* bats commonly form in the spring. Old-growth forest is also important habitat for the large species of bats, especially the hoary and the silver-haired bats. In Oregon, Perkins and Cross (1988) found that these species were captured with much greater frequency in old-growth than in young or mature forests. Although few roost sites have been found in the Pacific Northwest, the silver-haired bat and hoary bat commonly roost in forested areas in other parts of their ranges. It is therefore likely that these bats are roosting in the old-growth forests of the Pacific Northwest. Big brown bats are highly associated with man-made structures. In natural situations, however, the habitat selection of big brown bats appears to be similar to that of silver-haired bats, and capture frequency of big brown bats has been found to increase with snag density in southern Oregon (Cross and others 1976).

The size of foraging ranges or familiar areas are poorly known for temperate insectivorous bats. The information which is available indicates that bats are capable of traveling relatively long distances between foraging and roosting sites. Pacific Northwest bats generally feed over water and then fly into the forest to roost (Cross 1988), thus forming a link between upland forests and riparian zones. Few groups of animals, other than some birds, have such a movement pattern. Little brown *Myotis* have been observed foraging 2-5 km from day roosts (Thomas and West, in press), big brown *Myotis* are known to travel up to 4.1 km to foraging habitat (Brigham and Fenton, 1986). Using radiotelemetry Gardner et al. (1991a) found that adult female Indiana *Myotis* (*Myotis sodalis*) will travel up to 2.5 km from roosts to foraging areas, and that Indiana *Myotis* have fairly large home ranges (Gardner et al. 1991b). These roughly circular ranges vary from 33 ha for juvenile males to 213 ha for post-lactating females. However, Tuttle (1976) found that growth rates of juvenile gray *Myotis* (*Myotis grisescens*), which feed almost exclusively on aquatic insects, are inversely proportional to the distance of the maternity colony from water. Lunney et al. (1988a) also found that most activity in small, insectivorous bats in Australia (*Eptesicus vulturnus*, *Nyctophilus gouldi* and *Nyctophilus geoffreyi*) was confined to within 1 km of the site of original capture, indicating small foraging ranges. This conflicting information indicates that bats may be capable of traveling long distances to forage but this travel may be energetically costly and may lead to reduced fitness.

Until the essential characteristics of movement patterns and roost sites are known, it will be very difficult to manage forests for the persistence of native bat populations. Recent advances in the miniaturization of radiotelemetry components has now made radio tracking of bats feasible, and holds promise for gaining information on movements and roost characteristics. We propose to focus additional effort on these two knowledge gaps.

Objectives.--The general survey for bats using ultrasonic detectors described above will provide relative use information for stands and landscapes managed primarily for timber production. Additionally we wish to investigate the movement patterns and roost characteristics of bats. Bats use different parts of the landscape for roosting and foraging. It is important, therefore, not only to understand roost characteristics but also the juxtaposition of these habitat elements.

We predict that as more landscape area is harvested bat abundance (indexed by use) will decline. This should occur because the abundance of acceptable roosts will decline and the distance between roosts and foraging areas will increase. With a knowledge of roost characteristics and distances traveled during foraging, we ultimately expect that suitable roosts can be provided in managed forests within appropriate commuting distances to foraging areas.

Methods.--Tuttle traps (Tuttle 1974) will be the primary method for capture. Species identification, weight, reproductive status, forearm length, and sex of each bat will be recorded. Captured bats will either be punch marked or banded and fitted with radio transmitters and released.

Until recently, radiotransmitters have been too heavy to use on *Myotis* bats. It has been shown that increases of greater than 5% of body mass of bats decrease maneuverability and foraging ability (Aldridge and Brigham, 1988). However, Gardner et al. (1991) found that roost selection behavior did not seem to be altered by increases in body weight of up to 15% in the Indiana bat. The transmitters which will be used in this study weigh from .65-.7 g. This will constitute an increase of 16-17% in body weight when attached to a bat of 4 grams. As 4 grams will be the smallest bat encountered in the study, the transmitters should not severely affect roost selection.

The transmitters will be placed on female *Myotis* (post-parturition) which will be tracked to their day roosts. Male *Myotis* often roost singly or in small groups (Barbour and Davis, 1969; Dalquest and Walton, 1970) In contrast to male *Myotis*, females form maternity colonies to allow their offspring to roost in clusters, reducing the energetic costs of thermoregulation and thereby increasing the developmental rate of the young (Barbour and Davis, 1969; Tuttle, 1975). After feeding, mother bats will return to these colonies to roost during the day. Successful radio tracking of single female bats should, therefore, lead to the discovery of colonial roost sites housing many bats, possibly of several species. It is likely that the availability of suitable maternity roosts is far more limiting to bat abundance than the availability of individual roosting sites. The characterization of maternity sites should, therefore, take precedence over the characterization of individual roost sites.

Holohil model BD2B transmitters using the frequency range of 150-152 kHz will be used for radiotelemetry (Holohil Systems, Ltd.) as well as Telonics TR-2 receivers. Both Yagi and dipole receiving antennas will be used.

Transmitters will be placed on the middle of the back of selected bats, between the scapulae, with the antenna trailing down the back. Transmitters will be attached with some form of glue (cyanoacrylate, epoxy, rubber silastic or surgical cement). A layer of glue will be applied, then a mat of hair will be placed over the glue and another layer of glue will be applied. The transmitter will be placed on top of the final layer of glue. This has been deemed the most effective method of attaching transmitters to bats, which often groom transmitters off of one another (Wilkinson and Bradbury, 1988).

At each roost site, several general characteristics will be recorded: tree species; tree age; tree size; bark thickness; status (alive or dead); height, aspect and number of roost entrances; general type of roost site (i.e. bark flake, hollow snag, split trunk) and distance of roost tree from water. Tree age will be estimated by coring with an increment borer. Tree size will be estimated through measurements of diameter at breast height (DBH) and height. The DBH will be measured with diameter tape and heights will be measured with a clinometer. Bark thickness will be estimated by coring the tree with an increment borer and measuring the amount of bark in the resulting core. Roost sites will also be photographed and mapped.

Colony sizes will be estimated through visual counts as the bats leave the roosts. Bats generally emerge at twilight and are visible as silhouettes against the sky. A team of observers watching the various roost entrances can get a reasonable estimate of colony size as the bats emerge (Thomas and LaVal, 1988).

Distances flown by the bats will be estimated through several measures. The distances from the site of capture to the roost, from the roost to the site of a shed transmitter and from the roost to the site of recapture will be recorded. Attempts will also be made to locate radiotagged bats at night when they are feeding to characterize the general areas in which they commonly forage.

Analysis and Modelling

In this section we outline our general approach to data analysis (Task 3). Final analytical methods will be developed after consultation with the WSC. For a project of this magnitude, it is imperative that data analysis be initiated concurrently with field sampling (Fig. 1). Field data will be entered daily for screening and analysis.

Landscape Analysis

Analysis of wildlife habitat from a landscape perspective will be conducted at several levels. From the viewpoint of a given species, the characteristics of stands (patches) will be important to measure. The distribution and variation of stand sizes may indicate the probability of finding an animal in a landscape. Stand shape may be important if the species is sensitive to edge effects: long thin stands will have much edge and little interior "core" habitat. Edge composition and edge length will indicate the amount of edge habitat for edge sensitive species and indicate the complexity of habitat boundaries. Finally, measuring the juxtaposition and isolation of stands will be important to understand the isolation of subpopulations of animals in particular stands and the probability of dispersal among stands.

Measures of landscape pattern (O'Neill et. al. 1988, Turner et. al. 1989) are a larger level of measurement that considers all stands in the landscape regardless of habitat type. We will calculate dominance and diversity indices to examine the types and amount of habitats among landscapes. Fractal indices will be used to measure the complexity of stand shapes, such that regularly shaped stands (e.g., harvest-regeneration areas) have low fractal dimension and irregular or complex stand shapes yield a high fractal dimension. An index of contagion or point diversity will indicate the diversity of habitats at any given location and the complexity of the landscape. Total edge and probabilities of having any given habitats adjacent to each other will indicate the kinds of edges and boundaries the animal will encounter while moving through the landscape. Our primary tools for landscape analysis will be various GIS and statistical analysis programs available at the Olympia Forest Service Lab and WSU.

Both stand- and landscape-level questions require that we analyze the spatial structure of managed watersheds prior to the selection of sampling areas. This analysis will provide information on the degree of variation in spatial structure among watersheds (e.g., percentage of different forest types, distribution of stand sizes, etc.). We will then be able to select a set of watersheds representing a range of conditions. This screening will commence in summer 1991, as we identify suitable watersheds and obtain mapping data.

Wildlife Data Analysis

Species have different habitat relationships and function at different scales within a landscape (Milne et al. 1989). Consequently, this project will utilize several complementary approaches to data analysis to examine both community- and species-level responses.

Community-Level Responses.--Initial exploratory data analysis will examine relationships between wildlife community composition and habitat by considering abundance data for all species of a taxonomic group across all stands sampled. At the end of the first year's sampling we will have two sets of data: (1) variables characterizing habitat in each of the stands (i.e., area, type, and context) and (2) for each taxonomic group, species abundances in each stand. As a preliminary step, we will first look at correlations among species across all stands by using principal components analysis or related techniques such as detrended correspondence analysis (Gauch 1982, Jongman et al. 1987, Aubry et al. in press). If two or more species are highly correlated in their use of stands they can be treated together in subsequent analyses. Next we will examine the relationship between the species and habitat variables using canonical correlation analysis (Gauch 1982, Jongman et al. 1987). This approach is valuable because it simultaneously considers the interrelationships within a data set (e.g., correlations in abundance among species) and between data sets (i.e., species abundances and stand characteristics). These early analyses will not account for temporal variation in habitat utilization, but will indicate the influence of particular stand characteristics on community composition.

We are also interested in predicting the composition of wildlife communities as a function of habitat condition. Regression analysis will be conducted to determine if stand characteristics (independent variables) can be used to predict such community attributes as species diversity (dependent variable) in the stands. We may anticipate, for example, that there will be a pronounced effect of stand size on species diversity. Moreover, regression analysis allows determination of the importance of other stand variables after a significant component like size is incorporated in the model.

One of the difficulties in developing models of wildlife-habitat relationships is the variability in animal species' abundances over time. Temporal variation can be examined in a similar fashion using analysis of covariance (Timm 1975). Additional variables representing the time of sample can be included in the model (possibly with interaction terms) to determine differences due to fluctuations in density or to density-dependent changes in habitat utilization that may be expected to occur.

Species-Level Responses.--For particular species, multiple regression can be used to predict abundance of species or guild as a function of stand characteristics (discussed above). Another approach that we will employ will be to examine differences in the characteristics of stands that are utilized by a species versus those that are not. There are two approaches to this analysis. First, multivariate analysis of variance will be used to determine if significant differences exist in the habitat characteristics of stands that are utilized by a species versus those that are not used (Milne et al. 1989). When significant differences are found, discriminant function analysis will be used to determine the habitat characteristics that differ between used and not-used stands (Timm 1975). A second approach was suggested by Milne et al. (1989) for examining spatial constraints on the location of individual animals by comparing the observed distribution of organisms with an expected distribution. They used a spatially neutral model of deer wintering habitat to examine the effects of landscape fragmentation on the aggregation of deer habitat. Several GIS's were employed to construct a database and develop landscape variables to discriminate between suitable and unsuitable habitat. The comparison of observed versus expected distribution indicated that deer do not utilize isolated, but otherwise suitable, habitat. This type of analysis holds great promise in developing predictive tools for managers.

Finally, the habitat utilizations of many species are altered with increased density. Rosenzweig and Abramsky (1985) provide a graphical approach for examining such density-dependent habitat selection when temporal replication of abundance estimates is possible. Application of this method provides an additional means of evaluating the temporal variation in habitat use.

MANAGEMENT APPLICATIONS OF RESEARCH RESULTS

Habitat Relationships

We will identify those species that use forest stages which characteristically result from intensive timber management, primarily successional stages following even-age timber harvest through rotation-age stands (60-80 years). This information will be compared with results of wildlife studies in unmanaged-forest, done by our project personnel, to provide a better picture of how the cumulative effects of timber harvest influence the richness and abundance of forest wildlife communities at a broad scale.

At an operational level, vegetation and microhabitat studies within individual stands will indicate important stand structural characteristics that forest managers should strive to create or retain during timber harvest. The implications of varying the size of harvest units, or leaving corridors in the landscape likewise can be examined.

Information Transfer

Our research will be applicable to the management of forests at two primary levels. First, we will develop and examine tools for analyzing how stand and landscape components affect wildlife community composition. This work will indicate the types of variables and data analysis required for incorporating landscape characteristics into harvest planning to benefit wildlife. This information will be made available through peer-reviewed professional journals. Additionally, workshops will be developed through the Continuing Education Program at UW and the Cooperative Extension Program at WSU.

Second, we will make recommendations for harvest planning based on our findings. This information will be of interest to a much broader audience and particularly to individuals making on-the- ground decisions. An extension research bulletin that highlights the major results of our research and its implications for management of upland areas could be written for managers. Publication of applied articles based on this research through the Western

Journal of Applied Forestry would also be appropriate. Applicable interim results will be presented via WSU Cooperative Extension Newsletters to forest owners. Presentation of both interim and final results at regional meetings such as the Washington State Forestry Conference and annual meetings of Washington and Inland Empire Association of Foresters, Washington Forest Protection Association, and Washington Farm Forestry will provide for the transfer of information.

Finally, throughout the project we will keep the WSC informed through annual or more frequent meetings of interim findings that may be useful in developing guidelines for upland management.

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