RESEARCH AND MONITORING PLAN FOR NORTHERN GOSHAWKS *(Accipter gentilis atricapillus) IN THE WESTERN GREAT LAKES REGION*

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By

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EXECUTIVE SUMMARY

Conservation of northern goshawks (*Accipiter gentilis atricapillus*) in the western Great Lakes region (the northern forested portions of Michigan, Minnesota, and Wisconsin and the southern forested portions of Ontario) is hampered by a lack of population data and information about goshawk-habitat relations. In this report, we provide a brief summary of existing information on goshawks in the WGLR, and conclude that existing data are few and have limited applicability to regional conservation and monitoring of the breeding goshawk population. Furthermore, we identify important considerations in establishing monitoring protocols for goshawks, and suggest approaches to address limitations associated with existing data.

As a basis for developing a regional goshawk monitoring and research plan, we convened a meeting of regional stakeholders in January 1998. At that meeting, state and federal natural resource conservation agencies and non-governmental organizations with an interest in goshawk conservation indicated that regional information priorities included 1) identifying goshawk breeding habitat, 2) understanding the influence of forest management on goshawk habitat, 3) delineating the spatial distribution of goshawk habitat, 4) understanding temporal changes in goshawk habitat, 5) monitoring regional population trends, 6) identifying causes of mortality, and 7) identifying goshawk wintering habitat. Furthermore, stakeholders identified the regional breeding population of goshawks and the habitats that population uses throughout the year as regional priorities. To address these information priorities, we propose a two-phase monitoring and research plan.

Phase I would include 1) identifying a representative sample of WGLR breeding goshawks, 2) using this sample to identify year-round range and habitat use and preference, 3) using this sample to monitor goshawk population trends through time, through either a survey or demographic approach, or some combination of those two approaches, and 4) evaluating regional and extra-regional data on goshawk-habitat relations to develop preliminary models that hypothesize linkages between habitat and demographic performance. Phase II would include relating regional habitat information to population performance by modifying existing models or developing new models.

Monitoring effort might then shift emphasis to habitat, with periodic population surveys to verify continued occupancy of suitable habitat by goshawks.

Finally, we propose that a task force use this plan as a framework for agreeing on and implementing a strategy for goshawk monitoring and research in the WGLR. This task force should include representatives of stakeholders concerned with goshawk conservation in the region, be relatively small (< 10 members), have authority to commit necessary resources to a regional strategy, have a timeline within which to establish a strategy, and allocate resources through a peer-review process for regional data collection and analysis and model development and validation.

1.0 ACKNOWLEDGEMENTS

2.0 INTRODUCTION

Because the northern goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) often nests (Siders and Kennedy 1996; Squires and Ruggiero 1996) and hunts (Bright-Smith and Mannan 1994; Beier and Drennan 1997) in mature forests, potential conflicts between timber harvest and maintenance of viable goshawk populations concerns various publics (Kennedy 1997). Due to these concerns, the U. S. Fish and Wildlife Service (FWS) recently conducted a status review of goshawk populations west of the 100th meridian to determine if listing this population as threatened under the Endangered Species Act (ESA) was warranted (Clark 1997).

Although only the western U.S. population was formally reviewed for listing, there is concern about the status of this subspecies throughout its range. This concern has resulted in the listing of the goshawk as a Species of Concern (or Sensitive Species) by several governmental agencies in the western Great Lakes region (WGLR—northern forested portions of Michigan, Minnesota, and Wisconsin, and the southern forest portions of Ontario); Michigan's Department of Natural Resources (Weise 1998), the U. S. Forest Service's Eastern Region (Lewis 1998), and the FWS (Lewis 1998). In addition, conflicts over the potential impact of forest management practices on goshawk nesting habitat are escalating in the WGLR (e.g., Saint Paul Pioneer Press 1998*a,b*) and a recent paper published by Erdman et al. (1998) claims that the breeding population of goshawks is declining in northeastern Wisconsin.

To facilitate science-based management decisions concerning the goshawk and thus avoid potential conflicts in the WGLR, FWS: 1) initiated an extensive review of existing goshawk information for the WGLR; and 2) convened a workshop on its status at the 1997 Midwest Regional Raptor Management and Peregrine Symposium (West 1998). The purpose of this workshop was to initiate a coordinated discussion on the following regional topics: 1) current population status and biology of the goshawk; 2) status of past and ongoing monitoring and research activities that relate to goshawk biology and management; 3) information gaps and future data collection needs for the goshawk; 4) management issues that potentially impact goshawks; and 5) a course of action to address

future conservation of this species (Lewis 1998). At this workshop, participants agreed that a regional research and monitoring plan for the goshawk needed to be developed.

The data review discussed above was initiated because most of the information on goshawks in the WGLR is unpublished and thus, difficult to access by management agencies and concerned publics. In addition, the majority of information on goshawk biology has been collected in the western U.S. and the applicability of these datasets to management of WGLR goshawks is not clear because of the differences between the western and WGLR landscapes. This data review has been completed and results of this project are presented in Dick and Plumpton (1998). Based on their report and other published goshawk papers, we briefly summarize the types of information currently available for management decisions in the WGLR in the section *Summary of Current Information on Goshawks in the WGLR* (section 2.2)

It was clear from the Milwaukee meeting that the regional data were insufficient to facilitate science-based conservation plans for this species (West 1998) [and this has been corroborated by Dick and Plumpton (1998)]. There was a clear consensus at that meeting that more data were needed on regional goshawk populations but that future goshawk research and monitoring needs to be conducted in an organized manner to ensure that resulting data are useful for addressing management concerns. Research efforts should be directed at filling in existing data gaps, not repeating what has already been accomplished. We developed a research and monitoring plan for future goshawk investigations in the Great Lakes Region to; 1) provide an evaluation of available datasets relative to population monitoring, 2) identify future goshawk research needs in this region, and 3) recommend approaches to use to obtain this information. The focus of the research plan described herein will be to recommend the most effective approach to obtaining the information necessary to monitor goshawk populations and potential impacts to these populations in the WGLR.

2.1 SUMMARY OF APPROACH USED TO DEVELOP PLAN

An important first step in developing a research and monitoring program is to assess existing knowledge and research in the light of their utility in monitoring populations. As previously mentioned,

existing information on goshawks in the WGLR was recently summarized by Dick and Plumpton (1998). We briefly summarize their pertinent results in this report and evaluate the utility of these data for monitoring goshawk populations in the WGLR (see *Summary of Current Information on Goshawks in the WGLR* [Section 2.2]).

2.1.1 Determining Goals, Objectives and Information Priorities

After existing information is reviewed, there are a number of questions that need to be addressed relative to developing a research and monitoring plan for goshawks in the WGLR:

1) What is the objective of monitoring and what data are sufficient to meet this objective?

2) What is the appropriate population to monitor, both temporally (e.g., breeding population) and spatially (geographic area of interest)?

3) Is it possible to reliably estimate the size of this population?

4) If not, is there an index to population size that can be derived? If so, what is the relationship between the index and population size?

5) What characteristics of population trajectory are of interest?

6) What influences on population size are important and how do they need to be considered?

7) What human activities might be influencing goshawk populations and which ones are of particular importance to management?

To help address these questions we (with the help of The Raptor Center at the University of Minnesota) organized and facilitated a meeting of representatives of regional organizations concerned and actively involved with goshawk conservation in the WGLR (hereafter referred to as *stakeholders*). This stakeholders meeting occurred on 21 January 1998, at The Raptor Center on the St. Paul Campus of the University of Minnesota. State and federal natural resources management agencies (U.S. Fish and Wildlife Service – Region 3, U.S. Forest Service – Midwest Region, Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Michigan Department of Natural Resources), non-governmental organizations (Minnesota Audubon Council), the forest products industry (NCASI), and falconry associations (Minnesota Falconer's Association) were invited to participate in this meeting. Meeting participants (see Appendix A for a list of invited

stakeholders) were asked to represent their agency/organization with no more than two individuals (however some organizations decided to send more or fewer people), to keep meeting attendance to a manageable level, and stimulate discussion in a small group setting. Because the purpose of this meeting was to solicit stakeholder input (and to limit the number of people attending the meeting), we chose not to bring the research community into the process during this meeting (although some researchers voluntarily attended or were invited by a stakeholder organization). Rather, we hope to engage the research community as peer-reviewers of this report and any publications that result from this report.

During this meeting we tried to address the aforementioned questions and develop a consensus among stakeholders about the priority information needs for goshawks in the WGLR. To accomplish this goal, the meeting was organized as a round-table discussion combined with *defacto* decision analysis techniques. Our approach mimicked an abbreviated decision conference (Goodwin and Wright 1991) and is the type of approach recommended by Grumbine (1997) for implementing ecosystem management.

During the first half of the meeting we discussed: 1) Dick and Plumpton's (1998) data review (presented by T. Dick); and 2) current and future biopolitical issues related to goshawks in the WGLR. This second topic focused on a discussion of the; 1) current regulatory status of the goshawk, 2) current biopolitical climate relevant to goshawks in the WGLR, and 3) biopolitical concerns about goshawks. During the second half of the meeting, we discussed the aforementioned questions and the types of information that were needed to make science-based conservation decisions on goshawks in the WGLR. Recognizing that resources were not available to collect all possible information relevant to goshawk conservation, we prioritized these categories to determine the most pressing information needs as perceived by these stakeholders.

To determine these priorities, we initiated this discussion by having each attendee evaluate the relative importance of each information category. To do this they each completed a survey form that contained an initial list of the information categories and four rating categories; 1) very important (VI), 2) moderately important (MI), 3) not important (NI), and 4) no opinion (NO). We then

proceeded with a discussion of these topics. Based on this discussion, we modified the survey form to include additional information categories (this second ballot is depicted in Table 1; the topics not included in Ballot 1 are indicated in Table 2) and asked the attendees to conduct this rating a second time. The purpose of this second "ballot" was to determine if there was more of a consensus on these issues after the group discussion. Because of time constraints, we could not complete the second ballot at the meeting, which would have been the preferred method. Instead, we mailed the second ballot to the attendees with a copy of the draft meeting notes. The ballots were mailed to all meeting attendees at the end of February 1998 and were returned to us no later then 10 March, six weeks after the stakeholders meeting.

We analyzed the ballots to determine: 1) the rankings of the information topics; and 2) whether or not the topic rankings were different before and after the group discussion. The rankings of the topics in each ballot were determined by calculating a weighted score (W_T) for each topic. We assigned a score of two to each VI vote, a score of one to each MI vote and scores of 0 to each NI and NO votes. W_T was calculated for each topic within each ballot as:

$$W_T = \frac{2 \sum VI + \sum MI}{N}$$

where VI = a vote of Very Important, MI = a vote of Moderately Important and N = the total number of ballots. For each ballot, we then ranked the W_Ts in ascending order (lowest ranking topics were rated higher than topics with higher ranks) and analyzed the distribution of these rankings using a Wilcoxon signed-rank test (Sokal and Rohlf 1981), which is analogous to a non-parametric, paired t-test. This analysis was used to determine if the ranking distributions changed after the group discussions.

2.1.2 Evaluation of Sampling and Methodological Approaches

After the goals and objectives of the monitoring plan and information needs were prioritized, we identified and evaluated approaches that could be used to obtain the necessary information

identified by the stakeholders to make science-based management decisions. We based this on; 1) an evaluation of the existing information on goshawks both in the WGLR (Dick and Plumpton 1998) and throughout its range, 2) survey methodologies and monitoring programs of rare species, and 3) our experience in designing raptor research and monitoring programs.

2.2 SUMMARY OF CURRENT INFORMATION ON GOSHAWKS IN THE WGLR

The WGLR is at the southern extent of the current breeding range of goshawks (Squires and Reynolds 1997). Because it is a peripheral population, it is predicted to be rarer (i.e., lower density), and have more variation in demographic parameters than populations from the center of the subspecies range (Caughley et al. 1988, Lawton 1993). Because density influences sampling approaches and precision of parameter estimation (see Section 2.8 - *Experimental and Sampling Design Considerations* for more details on sampling concepts), and because goshawk breeding densities may be low, monitoring trends in goshawk abundance in the WGLR may be difficult. In addition, the nature of interaction between this peripheral population and population units located nearer cores of the species' distribution (i.e., meta-population dynamics) is unknown, and size of peripheral populations may fluctuate more widely than size of core populations. High fluctuation in size of peripheral populations (high parameter variation) also influences sampling approach and the ability to monitor population trends.

In the WGLR, the population status of goshawks is largely unknown (Dick and Plumpton 1998). Kennedy (1997) recently reviewed the published demographic data available on goshawks and all of the demographic information contained in her review was collected in the western and northeastern U.S. Existing information on goshawk population ecology in the WGLR is limited to long-term monitoring of reproductive success of known nest sites in a few study areas (see *Demographic Approach – Reproductive Success Only* section (Section 3.2.1) for a detailed discussion of the limitations of this approach). Most of these data have not been published nor are they summarized in a form that is readily accessible for regional management decisions (but see Erdman et al. 1998). Erdman et al. (1998) modeled breeding population trends of northeastern Wisconsin goshawks from 1971-1992 but the model has not been documented so it is not possible to assess the

validity of their results. In addition, their model includes an estimate of annual adult survival (0.80), which is based on their mark-resighting data. However, they do not document the methods used to conduct this survival analysis. With 12 years of mark-resighting data on 45 adults, Kennedy (1997) estimated the 95% confidence interval of annual adult survival to be 0.60-0.96. She concluded that precise estimates of survival required large numbers of marked birds (> 100), high resighting rates and at least five years of data. Erdman et al. (1998) present the only published estimate of adult survival on breeding goshawks in the WGLR. This estimate is based on reoccupancy estimates of known breeding areas where breeding area occupants are unmarked adults and sample sizes are well below the criteria outlined by Kennedy and DeStefano. Further it's not clear from Erdman et al. (1998) what methods were used to determine reoccupancy and to what extent breeding dispersal occurs in their sample (Section 3.1.2.2). Therefore, it's our opinion that the accuracy of this survival estimate is uncertain and the estimate is likely to be imprecise due to small sample sizes. No other trend analyses have been conducted for WGLR goshawks.

Many records of goshawk prey items are available for the WGLR (primarily from prey remains collected opportunistically at nests) but an intensive, quantitative diet study is lacking (Dick and Plumpton 1998). These anecdotal reports, which are summarized in Dick and Plumpton (1998), indicate that goshawks in the WGLR eat a wide variety of prey species. Erdman et al. (1998) listed the two main prey species in northeastern Wisconsin as snowshoe hare (*Lepus americanus*) and ruffed grouse (*Bonasa umbellus*) but did not report the results of diet analyses that support these statements. Thus, the degree to which goshawks in the WGLR likely forage on prey species whose populations maybe cyclic, and the numerical and functional response of goshawks to cyclic prey, is unknown.

There is essentially no information on movements during the breeding season for WGLR goshawks, as there is for other populations of goshawks (Squires and Reynolds 1997). The residency status of goshawks in the WGLR is unknown because few birds have been radio-tracked after the breeding season [but see Dolittle (1997) for two winter home range estimates for northern Wisconsin birds and currently goshawks are being followed year-round in northern Minnesota (Boal et al. unpubl. data)]. Little is known about the ecology of goshawks outside of the breeding season throughout

its range. Factors affecting survival and physical condition outside of the WGLR may have impacts on regional population dynamics. Migration data and limited tracking of breeding birds throughout the winter suggest the goshawk is a partial migrant throughout its range (Squires and Ruggerio 1995, Squires and Reynolds 1997, K. Titus unpubl. data, S. Dewey and P. L. Kennedy unpubl. data, E. McClaren unpubl. data). The degree to which fall/winter invasions of goshawks from populations that breed farther north in the boreal forest of Canada and Alaska influence population dynamics of WGLR goshawks is unknown (Dick and Plumpton 1998).

Siders and Kennedy (1994) reviewed nesting habitat studies conducted on sympatric *Accipiter* species and no information was available from the WGLR at that time. A recent summary of the western habitat data by Daw et al. (1998) indicates an important pattern is emerging from these studies: goshawks, regardless of region or forest type, tend to select stands with relatively large trees and relatively high canopy closure (>50-60%) for nesting. The applicability of this pattern to goshawks nesting in the WGLR is unclear because few habitat studies have been conducted. Data recently published by Rosenfield et al. (1998) on goshawk nest trees and nest sites in Wisconsin generally support the Daw et al. conclusion. The average % canopy closure and mean dbh at Wisconsin nest sites were 81.6% and 29.4 cm. Within the WGLR, habitat data are not available for foraging areas or home ranges at any time of the year but a study has been initiated to collect this type of information in north central Minnesota during the 1998 and 1999 breeding seasons. The limited habitat use data collected to date in the WGLR are difficult to interpret in a management context because they have not been coupled with habitat preference analyses as they have in other regions (Squires and Ruggerio 1996, Daw et al. 1998).

2.3 GOALS, OBJECTIVES AND INFORMATION PRIORITIES

It is clear from the Dick and Plumpton (1998) review that more data are needed on regional goshawk populations to enhance science-based management decisions. So how did the stakeholders prioritize the types of information needed for this region? The results of the ballot analysis are presented in Table 2. All stakeholders attending the Stakeholders Meeting completed the first ballot,

but only 10 of the 19 participants (53% return rate) completed and returned the second ballot. However, the ranking distributions of the two ballots were not significantly different ($T_S = 59$; $p > 0.1$; $\alpha = 0.05$) indicating that the group discussions did not significantly alter the 10 attendees' prioritization of information topics. As these distributions were not different, we calculated an average rank for each topic (calculated as the average rank of ballots 1 and 2) and used these average ranks to determine information priorities of the stakeholders represented at the meeting. For topics on Ballot 2 that were not included in the first ballot because they were added during the meeting, we used the rank on Ballot 2.

Seven topics had an average rank ≤ 4 and these were identified as the top information priorities of the stakeholders that attended the Stakeholders Meeting. These seven topics were used in designing this regional research and monitoring plan. These topics, in order of importance (with average ranks in brackets – note that some topics have tied ranks indicating equal importance and that topics are not mutually exclusive) are; 1) identification of goshawk breeding habitat [1.5], 2) influence of forest management on goshawk habitat [1.5], 3) spatial distribution of goshawk habitat [2], 4) temporal changes in goshawk habitat [2], 5) regional population trends [2.5], 6) identify causes of mortality [3], and 7) identify goshawk wintering habitat [3.5]. Based on these priorities and a general lack of information specific to WGLR goshawks, the objective of this plan will be to evaluate and recommend approaches to use in the WGLR to:

1) Assess changes in population trend and/or demographic performance of goshawks breeding in the WGLR.

2) Determine goshawk-habitat relationships for nesting and wintering habitat within the WGLR.

3) Assess changes in the amount and distribution of nesting and wintering habitat for goshawks within the WGLR with a focus on the role forest management plays in affecting changes.

2.4 DEFINE POPULATION OF INTEREST

At the meeting (and reflected in the ballots – Table 2) the population of interest was identified as the regional breeding population in its year-round habitat with a particular emphasis on breeding and wintering habitat. As understood by stakeholders and defined in this report, the WGLR includes the northern forested portions of Michigan, Minnesota, Wisconsin and the southern forested portions of Ontario. The regional boundaries to this population of interest are primarily political. There is no evidence that this geographic area is a distinct biological population (Dick and Plumpton 1998). Furthermore, within this region there are political units that could influence the design and implementation of a research and monitoring plan (e.g., land ownership boundaries). But a major premise of this plan is that the primary political boundaries are regional boundaries.

The birds that migrate through the region are of lower priority unless it is demonstrated that these birds are recruited into the breeding population. To date, none of the birds banded during migration within the region have subsequently been observed as breeding birds within the region (Dick and Plumpton 1998). However, there has been very little effort to determine if these migrants do enter the breeding population. If future studies indicate these birds are a source of regional recruitment to the breeding population, this prioritization should be reevaluated.

2.5 LARGE-SCALE RAPTOR MONITORING PLANS

Over the past several years, there has been a growing interest in efforts to monitor raptor populations beyond the scale of single study areas (at regional, national and/or global scales). Interest in status and raptor population trends has resulted in recent efforts to bring together various individuals and organizations to review the current state of knowledge and develop a strategy to monitor raptor populations in North America. In August of 1996, an international workshop was convened in Boise, ID, to begin discussing these issues, and to develop a comprehensive North American program for monitoring the population status of diurnal raptors. The results of this workshop are summarized in Fuller (1997) and the report is available on the World Wide Web at http://www.im.nbs.gov or ftp://ftp.im.nbs.gov. The regional monitoring plan we present for goshawks in this report is based on this

North American monitoring plan so we summarize below the information in Fuller (1997) that is pertinent to this plan.

The goal of raptor monitoring was defined in the North American monitoring plan as a program that monitors the status and trends in continental and regional populations of Nearctic diurnal raptors in Canada, Mexico, and the U.S. Implicit in this goal are some specific objectives:

1) To ensure, <u>at a minimum</u>, the ability to detect a 50% reduction in population size over a 25-yr period (average rate of decline of 2%/yr) with $\alpha = 0.10$ and $\beta = 0.20$; with the expectation that power to detect trends for the majority of species would be much greater.

2) To identify the best combination of monitoring techniques for each species.

3) To recommend improvements in data collection efforts, analysis methods, and regional coverage for each species and monitoring technique.

Setting objectives for power in a monitoring program is important because our ability to detect trends is dependent upon the sampling approach employed (Thompson et al. 1998). The aforementioned power goals have been recommended as minimally appropriate for large-scale raptor monitoring programs. However, selection of these values can be modified to meet the needs of the specific program (e.g., goshawks in WGLR), and these values should be included as part of the monitoring program design. For example, in the Mexican Spotted Owl Recovery Program the power goals are: after 10 years of monitoring, power of 90% to detect a 20% decline at alpha = 0.05 [which equates to an average annual decline of 2.2% (Block et al. 1995:76-77)].

There are also a number of statistical issues that must be addressed in developing a large-scale raptor monitoring program. First, the goal of monitoring is to understand the long-term trajectory of a population, including trends (an interval-specific measure of rate of change), cycles, and responses to perturbations. To accomplish this requires unbiased and precise estimates of attributes of populations such as population size or change in population size or other demographic parameters. Several issues emerge relative to designing monitoring programs that can produce these estimates:

1) The populations that will be monitored (both biological and statistical) must be defined. In the case of most raptors, identifying the population is closely related to geographic scale. Most raptor studies have been conducted on the scale of local study areas (10's and 100's of km^2), and techniques for monitoring raptors at this scale are reasonably well established. At regional (1,000's and 10,000's of km^2, e.g., WGLR) and continental (100,000's and 1,000,000's of km^2) scales, techniques for monitoring raptor populations are not nearly as well established.

2) If the population can be clearly defined, is it possible to estimate its size directly? If not, is it possible to derive an index to population size, or a population estimate adjusted for biases?

3) If an index to population size can be derived, is it possible to validate the index?

Once these issues are adequately addressed, there are a number of other statistical issues related to trend analysis that also must be considered in the design of a raptor monitoring plan:

1) Over what time interval is the population to be monitored?

2) What is an appropriate time interval between successive estimates (sample size)?

3) What is the acceptable level of precision for individual estimates?

4) What is an acceptable level of power to detect biologically meaningful trends?

For a detailed discussion of design considerations for monitoring programs for vertebrate populations see Thompson et al. (1998).

2.6 ASSUMPTIONS OF THE DESIGN OF THIS PLAN

This plan is based on the following assumptions.

1. Goshawks occur throughout this region and investing in searching for them will result in reasonable sample sizes

2. This breeding population is not irruptive or cyclic. See Section 3.1.3.2.1 for details on this point and implications for monitoring if this assumption is violated.

3. The population dynamics are dictated primarily by fecundity and mortality. Immigration

and emigration do not have a significant effect on regional population dynamics.

4. Habitat relationships can be accurately described if resources are committed to measuring these relationships.

5. There is a strong relationship between habitat and demography. If that relationship exists and can be demonstrated, it would be desirable to monitor habitat with periodic demographic validation checks.

These assumptions need to be evaluated and if they are violated determine what the effects are on population monitoring.

2.7 OVERVIEW OF RESEARCH AND MONITORING APPROACH

We propose an approach for designing and implementing a long-term research and monitoring plan for the goshawk in the WGLR that includes two phases:

PHASE I

1. Initiate standardized population surveys to collect information relevant to evaluating regional population trends and/or demographic performance.

2. Determine regional breeding and wintering habitat, habitat use patterns and habitat preferences.

3. Develop regional databases that can be used to evaluate temporal and spatial changes in breeding and wintering habitat.

4. Evaluate the utility of non-regional data (e.g., via meta-analysis) to develop preliminary models of goshawk habitat relationships and population dynamics.

PHASE II

1. Develop a model that predicts critical goshawk habitat, which is defined as an area that provides resources for goshawk population persistence in the WGLR (see *Phase I – Identify Goshawk Habitat Relationships* (Section 4.0) for more details on the definition of goshawk critical habitat).

2. Refine and test the predictive model to examine relationships between habitat data and

population size or other relevant demographic parameters.

3. If habitat models can predict goshawk population performance, switch emphasis from population-based monitoring to habitat-based monitoring. Periodic population –based monitoring (perhaps every 5-10 years) will probably need to be conducted to calibrate habitat models. If habitat models do not adequately predict population performance, continue population-based monitoring and re-evaluate habitat relationship information.

This approach is summarized in Figs. 1 and 2 and is based in part on ideas presented in recent monitoring plans developed for the marbled murrelet (*Brachyramphus marmoratus*) (Madsen et al. 1997) and northern spotted owl (*Strix occidentalis caurina*) (Lint et al. 1997) in the Pacific Northwest and in a recent paper by Roloff and Haufler (1997) on linking habitat models with population viability analyses. The emphasis of this plan is to use the demographic and habitat data collected in Phase I to develop habitat-based models that use habitat features to predict goshawk occurrence and demographic performance in Phase II. If reliable habitat models can be developed to predict population status and trend at a landscape scale, monitoring can switch from population-based monitoring to habitat-based monitoring approach. The relative costs of these approaches are not clear but we are recommending this approach because we assume that habitat monitoring will be less costly than population-based monitoring. The habitat-based monitoring would emphasize monitoring the habitat features that predict goshawk performance and/or status with less of an emphasis on monitoring population parameters. However, assessing presence/absence of breeding goshawks in suitable habitat (as identified by the habitat models) would need to continue in Phase II to ensure that this habitat remains occupied. **<u>WE EMPHASIZE</u>** that the switch from Phase I to Phase II can only occur **<u>IF</u>** the habitat models are demonstrated to reliably predict goshawk population performance in the WGLR. Models that are not validated are essentially equivalent to untested hypotheses, so population-based monitoring would have to continue until validated models are developed.

2.8 EXPERIMENTAL AND SAMPLING DESIGN CONSIDERATIONS

Prior to discussing experimental and sampling design considerations of the WGLR research

and monitoring plan, it is first necessary to define terminology relative to biological populations and estimating population parameters. Biological populations are groups of animals of the same species, bounded in space and time, for which it is appropriate to discuss attributes such as population size, growth rate, recruitment, mortality, etc. We defined the population of goshawks of interest in the WGLR in the previous section (Section 2.4) on *Define Population of Interest*. From a conservation perspective, it is often desirable to have information about attributes of biological populations, for example, population size and growth rate. If it is possible to enumerate every individual in a population (i.e., perform a census), then these attributes can be known exactly, and conservation decisions can be made based on the true attributes of populations. For most biological populations of conservation concern, however, it is not practical to completely enumerate all individuals in a population, and thus some sort of sampling approach is necessary to estimate population attributes. This alternative approach is based on sampling, and is generally referred to as a sample survey, or survey. Surveys result in estimates of population attributes. Because they are not a complete enumeration of a population, these estimates have some degree of error (precision) associated with them. There are at least two important consequences of using sample surveys. First, it is not possible to know the true value of the population parameter of interest (the estimate is a random variable), and second, it is only appropriate to make inferences about the entire population if the sampling strategy was representative of the entire population.

To date, there have been no attempts to estimate population size (or other population attributes) of northern goshawks across the WGLR (Dick and Plumpton 1998). No regional sampling strategy has been established, and it is statistically inappropriate to make inferences to a regional population based on local studies. Kennedy (1997, 1998) discusses an example of inappropriate inference on goshawk population trends.

Samples must also correspond appropriately to the temporal and spatial scales over which inference is to be made. For example, to make inferences about how goshawks use landscapes, the appropriate spatial scale to sample is that of the landscape. Extending study results at one spatial scale to another spatial scale can have unpredictable results (Hall et al. 1997, DeStefano 1998, Smallwood

1998). It is also important that the resolution of data matches the scale of the question being addressed. For example, a satellite image of vegetation cover types will not delineate potential breeding areas unless some information on forest structure is included as a data layer in a GIS that is also using the satellite imagery data. Managers and researchers need to recognize that their perceptions of wildlife-habitat relationships are scale-dependent, reflecting the different scales at which animals operate and at which managers and researchers operate.

Because it is not possible to completely enumerate the WGLR goshawk population, a certain amount of error (sampling error and, potentially, measurement error) will be associated with any estimate of any population attribute (e.g., population size). To assess the magnitude of this error, and to compare attributes between or among populations, or through time, it is necessary to replicate samples through space or time, or both. Further, replication needs to be appropriate for the scale of inference (see above), and in general, precision of an estimate increases as replication increases.

In the WGLR, most existing data on goshawks has been collected at a spatial scale below that of the region (e.g., northeastern Wisconsin; Erdman et al. 1998), and it is not appropriate to make inferences about regional (or even statewide) populations from these studies, because they were not designed with sampling that would represent these larger spatial scales. Two exceptions are the studies by Rosenfield et al. (1998) and Postupalsky (1997) who are conducting their studies at a larger spatial scale (statewide – Wisconsin and Michigan, respectively). However, it is not clear if even these two statewide studies contain representative samples of breeding areas because, similar to the local studies, their sampling did not include randomly selected study areas. It is currently not known whether the samples in any of these studies are representative of the WGLR goshawk population.

In terms of temporal scale, authors need to be specific about when their studies were undertaken and to what time period(s) the results of these studies apply. It is common to ignore temporal variation or sample from narrow time periods in which the resulting relationships apply only minimally to other situations (Morrison et al. 1992, Hall et al. 1997).

Finally, given that it is of interest to monitor the size of a population (in this case, the breeding population of goshawks in the WGLR), and that a sampling protocol is employed at the

appropriate scale and with sampling that represents the regional population, how likely is it that a

population decline of conservation significance can be detected? The answer to this question is

clearly important to monitoring population trends, yet this probability, called statistical power, has

rarely been calculated for any monitoring program. An awareness of statistical power is particularly

important in conservation planning for rare species because the consequences of incorrect decisions

can be severe: the extinction of a species or extirpation of a population. A number of recent papers

have pointed out the importance of considering power in ecological studies (Taylor and Gerrodette

1993, Journal of Wildlife Management 1995, Steidl et al. 1997, Gerrard et al. 1998). Consideration of

statistical power is an integral part of proper experimental and sampling design, which means it is a

critical component in the development of a WGLR goshawk research and monitoring program.

Our purpose here has been to provide an overview of relevant concepts for monitoring

biological populations. Furthermore, it is not our purpose to provide a detailed experimental design

for this plan but rather to provide an overview of issues that need to be considered. For a more in-

depth consideration of aspects related to monitoring biological populations in general, and raptor

populations in specific, we refer the reader to Thompson et al. (1998) and Fuller and Mosher (1989),

respectively. In addition, for a summary of raptor population trends in North American forests see

Fuller (1996).

3.0. PHASE I – MONITORING POPULATION TRENDS AND/OR POPULATION PERFORMANCE

There are two general approaches that can be used to monitor population trends: the survey

method and the demographic method (Taylor and Gerrodette 1993). Using a survey method would

entail attempting to estimate population size (or some index of population size) directly over several

years and determine whether or not the estimates indicated a trend over time. Because it is not feasible

to census the entire population of most bird species (including raptors), population monitoring is

almost always based upon surveys of a sample of the population (thus the name Survey Method). The

demographic method would involve monitoring trends in survival and fecundity and then using these

data to calculate λ or r. The finite population growth rate (λ) can be calculated based on following reproduction and survival of individual cohorts (age classes), or λ can be estimated through simulation based on annual variation in cohort survivorship and reproduction. $\lambda = 1$ indicates a stationary population (i.e., a population that is neither increasing or decreasing in size), $\lambda > 1$ represents an increasing population, and $\lambda < 1$ is indicative of a declining population (Gotelli 1998).

Given a fixed amount of effort, which approach has the greatest probability of detecting a decline in population size? Taylor and Gerrodette (1993) evaluated this question using power analyses of the extensive datasets available for the northern spotted owl. They concluded that the survey approach has higher statistical power when animal densities are higher and that the demographic approach has higher power at lower densities. The monitoring plan for the northern spotted owl relies on the demographic approach (using mark-recapture of breeding birds) because there is an extensive historical dataset of this type and it is believed that this approach will provide information that is more suitable for predictive habitat modeling (Lint et al. 1997). However, the survey method is recommended for the marbled murrelet monitoring program because nests of this species are very difficult to locate and thus, following the fates of individual birds using mark-recapture or radio-telemetry is almost impossible (Madsen et al. 1997). The survey method is also being used to monitor population trends of Mexican spotted owl (*Strix occidentalis lucida*) (Ganey et al. 1998). In the following section we evaluate these two approaches for monitoring goshawk population trends in the WGLR. It may also be desirable to consider some combination of these approaches.

3.1 SURVEY APPROACH

The first decision in designing a goshawk survey would be to identify the appropriate population-level response variable(s) that would be monitored for population trend analyses. Generally, surveys of goshawks and many other raptors focus on monitoring the breeding population and are designed to monitor changes in distribution, breeding densities, or some index of population size (e.g., number of migrants counted/hour, monitor the status of a sample of nests over time). We discuss the pros and cons of each of these response variables below.

3.1.1 Monitoring Changes in Distribution

Range size and abundance are correlated variables (Mehlman 1994). Within particular taxa and geographical regions, species with large ranges tend to have greater local abundances at sites where they occur than do species that are more restricted geographically (Lawton 1993, Gaston 1994*b*). Examples include plants, birds, mammals, fish and a variety of invertebrates (Lawton 1993). Hengeveld (1989) showed that declines in European populations of fir trees were accompanied by range fragmentation. However, population declines are not always accompanied by range fragmentation. The highly endangered Kirtland's warbler (*Dendroica kirtlandii*), for example, exhibited a range contraction when its populations collapsed by 60% between 1960 and 1971. This species withdrew to the historical center of its range; leaving peripheral areas virtually empty (Wilcove and Terborgh 1984). For goshawks, Kennedy (1997) found; (1) no evidence for goshawk range contractions in western North America, and (2) its breeding range appears to be expanding (perhaps due to reoccupancy of former range) in the eastern U.S. A recent analysis of breeding distribution in Wisconsin by Rosenfield et al. (1998) supports her conclusions. No analyses of range fragmentation have been conducted for this species.

The limited data on range-size/population abundance correlations do indicate that population declines will be associated with range fragmentations and/or contractions. Using Breeding Bird Survey data on North American passerines, Gaston and Curnutt (1998) recently tested the prediction that when the local abundance of a species is reduced its regional distribution should contract. This prediction was supported for the majority of species analyzed, but all combinations of increasing, decreasing, and stable local abundances and distributional occurrence were observed. Their results combined with the fact that distributional change is not a variable that is typically monitored suggest that research would be needed to determine if trends in WGLR goshawk distribution are correlated with trends in local abundance. If this correlation exists, distributional trends would be potentially useful as a very coarse-grained index of population trends and the simplest approach to monitoring distributional changes would be to monitor temporal changes in goshawk range sizes within the WGLR. This would be analogous to monitoring range contractions/expansions within the WGLR and

would require identifying the current range boundaries of the goshawk within the region and then monitoring the presence/absence of the species at these boundaries at regular intervals (e.g., 3-5 yr). The presence/absence of this species at range boundaries could be evaluated using broadcast surveys along roads located at the range boundaries or perhaps via helicopter surveys of forested habitat before leaf-out at the boundaries.

Once presence/absence data are collected, extent of occurrence (distance/area between the outer-most limits to a species occurrence) can be estimated. There are a variety of techniques for estimating extent of occurrence and a detailed discussion of these methods is beyond the scope of this work. We refer the readers to Gaston (1994a,b) for a detailed discussion of this topic.

The limitations to monitoring extent of occurrence as a response variable are that it does not allow one to estimate distributional changes that result from range fragmentation and that regional trends in distribution may not reflect population trends at specific sites. Estimating changes in range fragmentation would require an estimate of the area of occupancy of the species throughout the WGLR. This is the area over which the species is actually found. Area of occupancy will be smaller than extent of occurrence because species do not occupy all areas (or habitats) within the geographic limits to their occurrence (no species is continually distributed in space).

One potential approach to monitoring area of occupancy for goshawks involves call broadcasts (Geissler and Fuller 1987, Iverson and Fuller 1991). This approach employs repeatedly broadcasting calls from the same locations, and using the pattern of responses to estimate the probability of detecting an animal given that one is present. Probability of detection—area occupied techniques have been used successfully on red-shouldered hawks *(Buteo lineatus)* (McLeod and Andersen 1998), and are particularly promising for monitoring species in landscapes where proportion of area occupied is high, and birds have a high probability of responding to a call. To date, little work with this technique has been conducted with goshawks. However, if goshawks respond readily to call broadcasts (see discussion of "kip" call, below), probability of detection – area occupied techniques may be useful in monitoring goshawk populations. Before this technique could be applied widely, however, it would need to be validated in areas where goshawk density and occurrence have been

estimated independently. In addition, it may be possible to use a modification of this approach to map the occurrence of goshawks throughout a landscape through time.

3.1.2 Monitoring Occupancy of a Sample of Nests Over Time

Monitoring the occupancy of a sample of nests or breeding areas over time is a common approach used to monitor raptor population status [e.g., peregrine falcons (*Falco peregrinus*) – Tordoff and Redig (1997), Millsap et al. (1998); bald eagles (*Haliaeetus leucocephalus*) (Hatfield et al. 1996)] and has been attempted to be used to assess goshawk status in northeastern Wisconsin (Erdman et al. 1998). Nests are the focus of many monitoring programs because nesting habitat is essential for bird populations and because raptors can reliably be observed near nests. In addition, unlike passerines, many raptors may have high site fidelity to a nest location so the nest becomes a reliable location to resight breeding birds. Finally, it is one of the least expensive monitoring methods available for raptors. However, monitoring a sample of nests over time as an index of population trends has limitations.

3.1.2.1. Concern 1 - Is the sample of nests representative?

Regional breeding population trends can only be inferred from a representative sample of nests. As discussed earlier, a representative sample is one in which the nests represent the larger population to which inference is to be made and are not located using biased search patterns. As Siders and Kennedy (1996) and Daw et al. (1998) point out, many goshawk nests incorporated in published and unpublished samples were discovered opportunistically or by use of *a priori* assumptions of habitat structure (e.g., drainage bottoms with large trees, high canopy closure and other old-growth characteristics). These nests may not constitute a representative sample because they were not located as part of a rigorous sampling protocol where the landscape was randomly sampled for goshawk nests using standardized search protocols.

The simplest solution to this problem is to search for nests using stratified random sampling. This technique involves dividing the study area into smaller, non-overlapping areas (strata) based on features such as habitat or predicted bird density (Fuller and Mosher 1989). For example, the forest

communities (non-forested communities do not need to be surveyed because all goshawk nest sites are in trees) of the WGLR could be stratified into ecological provinces, vegetation types [e.g., boreal-hardwood conifer forest, Great Lakes pine forest (Tester 1995)] or ecoregions (Bailey 1995). Survey locations could then be randomly located within each stratum and searched for nests. Strata could also be delineated based on landownership and other political boundaries as influencing variables.

3.1.2.1.1. Preferred Methods for Locating Nests

Standardized search protocols must be used to survey locations for nests to standardize search effort. The probability of locating a nest must be the same across survey locations. If some survey locations are searched more thoroughly than other locations, data cannot be summarized across locations. A good example of standardized protocols was the quadrat sampling conducted by Rosenfield et al. (1998). To locate nests they conducted tree-by-tree foot surveys of 4 quadrats that were chosen without past or present knowledge of forest seral stages or use of these sites by goshawks. Another example of comparable search techniques was summarized by Kennedy (1997) when she compared occupancy rates among 3 western study areas (comparable data were not available from the WGLR). As she noted, inter-study comparisons of occupancy rates need to be conducted cautiously because occupancy rate is probably positively correlated with the amount of effort expended to determine breeding area status. Level of effort was comparable among the three studies in her evaluation where all breeding areas were checked a minimum of 2-3 times each year and most breeding areas were visited numerous times each season. In two of the study areas, an area with a radius 0.7-1.0 km (the post-fledging area as defined by Kennedy et al. 1994) surrounding the previously active nest was intensively surveyed using broadcast vocalizations (broadcast surveys are described in more detail below) and visual searches of all individual trees. The third study area used the same searching methods but the investigator's search area was larger, a 1.6 km-radius surrounding the previously active nest.

As noted by the aforementioned examples, several methods can be used to search plots for goshawk nests (individually and in combination) and all of these methods can be standardized; broadcast surveys, foot surveys, and aerial surveys. A good general description of these types of

surveys can be found in Fuller and Mosher (1989). Details of these methods relative to locating goshawk nests in the WGLR are described below. These methods are discussed again in the *Breeding Density* section (Section 3.1.3) in terms of their utility for estimating goshawk breeding density.

3.1.2.1.1.1. Broadcast Surveys

Kennedy and Stahlecker (1993) demonstrated experimentally that broadcasting conspecific calls increases the detectability of goshawks as compared with foot surveys, particularly if the broadcasting occurs within 100-200 m of the nest. This technique combined with exhaustive foot surveys within the vicinity of the response increases the probability of locating nests. Both Kennedy and Stahlecker (1993) and Joy et al. (1994) describe similar protocols for establishing foot transects to survey forested plots with broadcast surveys. Broadcast surveys could also be conducted on roads using procedures described by McLeod and Andersen (1998) for red-shouldered hawks.

Recently, Watson *et al.* (1999) used a slight modification of Kennedy and Stahlecker's (1993) experimental design to test the effectiveness of broadcasting adult alarm and juvenile food-begging calls versus silent walk-ins at goshawk nests in dense, coniferous forests of Western and Eastern Washington. Using a broadcast output of 85dB, Watson *et al.* (1999) reported the probability of detecting goshawks in these occupied stands was 20% (at 400m), 25% (at 250m), and 42% (at 100m), with goshawks being detected at least once in eight broadcast trials 94% of the time. They concluded that broadcast surveys increased detection rates at successful nest sites significantly more than silent walk-ins and that surveys were more effective during the nestling period than during the post-fledgling period. These experiments confirmed that broadcast surveys were an effective survey method for goshawks inhabiting forests of the Pacific Northwest.

All goshawk broadcast surveys currently use the goshawk's adult alarm call or the juvenile food begging call. Another vocalization that has the potential to increase goshawk detectability substantially is the male's contact call (*kek*), which he produces when he enters the nest stand with prey (Squires and Reynolds 1997). Females and juveniles are very responsive to this call. It is easily overlooked in the field because males only vocalize once or twice before the female begins her Recognition Wail and food transfer occurs (Squires and Reynolds 1997). However, because the

female and juveniles are so responsive to this call, we think it should be tested using methods

described by McLeod and Andersen (1998) to determine if the male's food delivery call increases

goshawk detectability as compared with the alarm call. This test is currently being done on Vancouver

Island with a population of Queen Charlotte goshawks (*A. g. laingii*) (E. McLaren and P. L. Kennedy,

unpubl. data).

3.1.2.1.1.2. Foot Surveys

For locating goshawk nests over large areas, foot surveys are the least efficient method

because of low detectability of the species (Kennedy and Stahlecker 1993). However, foot surveys

could be used in conjunction with broadcast surveys if searching were to occur during incubation

(early to mid-April through early to mid-May in the WGLR). Broadcast surveys for raptors may not

be efficient during incubation because females are less responsive and less likely to leave the nest

when incubating eggs than when tending nestlings (Fuller and Mosher 1981, Rosenfield et al. 1988).

Foot surveys can also be used to evaluate the accuracy of other survey techniques (see more

discussion of this point in the *Aerial Surveys* section - Section 3.1.2.1.1.3).

3.1.2.1.1.3. Aerial Surveys

Aerial surveys to locate nests have been used successfully for a variety of raptor species that

nest in non-forested, and to a lesser extent, forested habitats (Fuller and Mosher 1989, Cook and

Anderson 1990). As pointed out by Fuller and Mosher (1989), aerial surveys reach remote areas

quickly and cover large areas efficiently. The total cost of some surveys can be reduced and the work

completed in less time when aerial searches are used rather than ground searches.

Aerial surveys have not been used extensively to locate goshawk nests (but see McGowan

1975, Looman et al. 1985) because the majority of goshawk studies have been conducted in

coniferous habitat where nests are difficult to detect from above the canopy. However, a large

percentage of the potential goshawk habitat in the WGLR is deciduous forest and mixed deciduous--

coniferous forest (Mladenoff et al. 1997, Niemi et al. 1998) so goshawk nests could potentially be

located in these habitat types if surveys are conducted before leaf-out. This approach has been used

successfully to locate red-shouldered hawk nests in the Midwest (Cook and Anderson 1990, Belleman 1998). Aerial surveys would also be suitable for goshawks, because similar to red-shouldered hawks, incubation is well advanced before leaf-out. Thus, aerial surveys have the potential to maximize detection and minimize nest abandonment (decreases after courtship).

Aerial surveys for goshawks would require flying near treetop at slow speeds. The preferred crafts capable of this type of flying would be machines that can safely fly at low altitude and slow speeds such as helicopters, gyroplanes, or powered parafoils. Gyroplanes and parafoils would be much less expensive than helicopters but their utility for nest searches has not been tested. If aerial surveys were to be implemented in the WGLR goshawk monitoring program, the accuracy of these surveys and the probability of detecting nesting goshawks from the air (Ayers and Anderson 1999) should be evaluated. This could be done by ground-truthing the nest structures located from the air and conducting foot searches of some of the aerial survey areas to determine what percentage of nests were not detected from the air and determine what factors associated with nests affect detectability (Ayers and Anderson 1999)

3.1.2.2. Concern 2 – Movement Among Breeding Areas

Monitoring a sample of nests over time as an index to monitoring population trends assumes unoccupied breeding areas can be accurately identified. This is based on the assumption, which is usually untested, that breeding dispersal in goshawks is minimal. Breeding dispersal occurs when adults move among breeding areas (defined in Section 3.1.2.3) between years. If breeding dispersal occurs in a population, the disappearance of breeding adults on a breeding area is difficult to interpret.

The occurrence and/or extent of breeding dispersal in the WGLR is unknown but breeding dispersal in goshawks does occur regularly in other portions of their range. In a California population, 26.9% of the banded breeding birds monitored over a 9-year period changed breeding areas at least once during that period (Detrich and Woodbridge 1994). Detrich and Woodbridge did not detect any difference in the degree of dispersal between the sexes. However, in a 6-year study in northern Arizona using resighting of banded birds, breeding area fidelity of males (91.7% avg.) was higher then for females (78.6% avg.) (Reynolds and Joy 1998).

Breeding dispersal has also been recorded in Alaska (K. Titus, pers. comm.), Utah (S. Dewey and P. L. Kennedy, unpubl. data) and Vancouver Island, British Columbia (E. McClaren and P. L. Kennedy, unpubl. data) by searching for birds during courtship and incubation the year or two after they were tagged with radio transmitters. In all of these studies radio-tagged dispersers were located in breeding areas that had not been previously located within the study area.

Currently, battery-powered radio transmitters for female goshawks can last 2-3 years and male transmitters can last 1½ to 2 years. Therefore, this technology could be used to efficiently determine the degree of breeding dispersal within the WGLR by using spring aerial surveys to locate a sample of radio-tagged birds. The only limitation to this approach is that long-distance dispersal (dispersal outside of the study area boundaries) would not be detected; satellite transmitters (Britten et al. *in press*) could be used to document long-distance dispersal.

3.1.2.3. Concern 3 – Alternative nest sites are frequently overlooked

Goshawks are known to maintain 1-8 alternative nests within a breeding area (Squires and Reynolds 1997). A single nest may be used in sequential years, but often an alternative is selected. In California, mean distance between alternative nests was 273 m and ranged from 30 – 2,066 m (Woodbridge and Detrich 1994). In Arizona, mean inter-alternative nest distance was 489 m and the range was 21-3,410 m. Approximately 89% of alternative nests in Arizona were within 900 m and 95% were within 1,400 m of one another (Reynolds and Joy 1998).

Clearly, the potential for misclassifying an occupied breeding area as unoccupied is great if nest site searches are restricted to the immediate vicinity (50-100 m) of the most recently used nest. If alternative nest sites are known, these should then be checked for activity. If these are not occupied then the following approach is recommended; conduct foot searches within 800 m of the most recently used nest within a breeding area (Kennedy et al. 1994, Reynolds and Joy 1998), to reduce the probability of misclassification, if an active nest is not located during these foot searches, areas within 1.5 km (minimally) of nests should be searched using broadcast survey techniques (Reynolds and Joy 1994). Even if these more rigorous approaches are used to locate alternative nests, population size estimates based on simple counts of nests will still produce negatively biased estimates (Gould and

Fuller 1995). These negatively biased results occur because population size based on simple counts of occupied nests assumes, erroneously, that resighting probabilities = 1 and bird detectabilities remain constant over time. This problem can be alleviated by using Jolly-Seber models to estimate breeding density (see section on *Capture-recapture data and Jolly-Seber models* - Section 3.1.3.1).

3.1.2.4. Concern 4 – Assumes nest site attributes are static

Monitoring nest site occupancy over time as an index of population trend is based on the assumption that the sample of nest sites that is monitored is representative of the population of interest. If the characteristics of these nest sites change disproportionate to other nest sites, these nests are no longer a representative sample (e.g., because their location is known, some nests may be buffered from human-induced landscape modifications, and remain occupied). However, nest site attributes are not static features because they can never be entirely buffered from human-induced modification and because features of natural habitats are dynamic. For example, the largest single block of presettlement forest in the WGLR is located in the Boundary Waters Canoe Area Wilderness (BWCAW) in Minnesota. The spatial pattern, age structure, and species composition of the unlogged portions of this forest have been altered significantly from presettlement conditions because of lower fire frequency since 1910 (Clark 1990, Frelich 1995). The current forest contains twice as much spruce (*Picea* spp.), fir (*Abies* spp.), and birch (*Betula* spp.) as was recorded in presettlement times but less then one-third as much red (*Pinus resinosa*) and white pine (*P. strobus*) (Frelich 1995). The effect of this change on goshawk populations is unknown but clearly goshawk habitat has changed in the BWCAW even in the absence of timber harvest. These kinds of changes are not restricted to reserves such as the BWCAW but likely have influenced all goshawk landscapes (J. Gallagher pers. comm).

In addition to human-induced landscape changes, goshawk habitat in the WGLR will be modified by natural disturbances such as fire, flood, wind, snow, and ice. These natural disturbances and the disturbances caused by human presence (e.g., harvesting, grazing, urbanization) result in a dynamic landscape where the amount and distribution of goshawk habitat will change temporally and spatially within the WGLR. Because of the non-static nature of the WGLR landscape, we predict

goshawk breeding areas will be spatially dynamic and these dynamics need to be incorporated into a monitoring plan for WGLR goshawks, particularly if goshawk monitoring is conducted for greater than 10 years. In this case, monitoring a fixed sample of nests over time would need to be augmented by surveys of new areas at regular intervals.

3.1.3. Monitoring Changes in Breeding Density

The abundance of any terrestrial organism is more appropriately presented as "crude" density, the number of individuals per unit of area. Because the goshawk presumably occupies a variety of habitats throughout the WGLR (Rosenfield et al. 1998), ecological density, the number of individuals per area of usable habitat, would be a more meaningful measure of abundance (Ward et al. 1995). However, ecological density cannot be estimated until after the range of habitats used by the goshawk in the WGLR is identified, so the following discussion is related to how to estimate crude density (hereafter referred to as density) as a response variable in a WGLR research and monitoring plan. The pros and cons of each of these approaches are discussed below.

3.1.3.1. Capture-recapture Data and Jolly-Seber Models

As indicated in previous sections, simple tallies of nests to create an index to population size or to estimate breeding density in a study area is fraught with problems and produces biased estimates of population size (Gould and Fuller 1995). A solution to this problem would be to estimate population size using Jolly-Seber models. The Jolly-Seber model is a capture-recapture model allowing for an open population in which additions and/or deletions occur. The model can be used to estimate population density within a study area of defined boundaries. It can produce unbiased estimates of density for each sampling period (e.g., year). This method has been described extensively in the literature and the application of this approach to raptors is described by Gould and Fuller (1995).

Recapture is a general term referring to either the actual capture of an individually marked bird, the resighting of individuals, or both (Gould and Fuller 1995). For goshawks in the WGLR, capture-recapture data would be obtained by resighting banded birds on nesting breeding areas during

nest checks. All unbanded birds on breeding areas would need to be trapped and banded and sampling effort would need to be constant among years. Changing the sampling effort over time introduces biases into population size estimates. If the intensity with which sampling occurs or the amount of area sampled increases over time, then increases in counts do not necessarily reflect population size increases (Franklin et al. 1990, Gould and Fuller 1995). In the WGLR, study areas must be defined that are sampled equally every year (i.e., constant-size area sampled with equal intensity) before a proper trend analysis of population size can be conducted (Gould and Fuller 1995). If new areas are searched to account for landscape changes described in the previous section, it is important to document the amount of area sampled and the intensity with which it is sampled to determine if the density estimates are correlated with area sampled (Gould and Fuller 1995). A limitation of this technique for goshawks in the WGLR is that it would require a study area with defined boundaries that contained a minimum sample size of 25 regularly active nest sites. If the density estimates for Wisconsin [1 breeding pair per 3807 ha (Rosenfield et al. 1996)] are representative of regional densities, the Jolly-Seber method would require a study area of 95,175 ha (see Quadrat Sampling Section (section 3.1.3.2) for more details). How many study areas are necessary is a function of the desired statistical power of the program. The study area locations will be based on the decisions made on how to stratify the region and the locations need to represent this stratification.

Earlier versions of Jolly-Seber models produced biased estimates of population size if individuals temporarily emigrate from the population. Under such circumstances, the Jolly-Seber model assumes the individuals remained in the population undetected, thus lowering the resighting probability estimate and inflating the population estimate (Gould and Fuller 1995). However, recent modifications of the Jolly-Seber models allow for emigration (Pradel et al. 1997).

3.1.3.2. Quadrat sampling

The simplest way to estimate density is to count individuals within an area and divide the count by the size of the study area. Rosenfield et al. (1996) used this approach to estimate density of pairs of goshawks (breeding density) in four quadrats of approximately 3,800 ha in size in northern Wisconsin. They did tree-by-tree searches of each quadrat and the result of these searches was an

estimate of breeding density of 1 pair of goshawks per 3807 ha (1 pair per quadrat). This procedure

could be repeated throughout the region with quadrats of similar size (or perhaps larger) randomly

located within the ecoregions of the WGLR.

3.1. 3. 2. 1. Power Analyses of Quadrat Sampling in WGLR

Because quadrat sampling has been initiated in the region, we investigated the statistical

power of this approach for detecting trends in regional breeding populations. We used program

MONITOR (Gibbs and Melvin 1993, Gibbs 1995) to investigate the potential influence of the number

of plots, the time period over which plots were monitored, and breeding density (equivalent to varying

plot size) on the statistical power of quadrat-based population monitoring of goshawks in the WGLR.

We estimated spatial variation in breeding density based on density estimates for two study areas in

Oregon (DeStefano et al. 1994) and one study area in California (Woodbridge and Detrich 1994),

using a normal distribution with the mean breeding density for the three study areas and the standard

error of the mean density. This distribution was adjusted to coincide with estimated breeding

densities in the WGLR (Rosenfield et al. 1996). We estimated sampling variation based on repeated

counts of breeding goshawks in subsequent years on Oregon study areas (DeStefano et al. 1994),

again adjusted for expected breeding densities in the WGLR (Rosenfield et al. 1996). We simulated

monitoring 5, 15, and 25 plots for 5, 20, and 25 years, based on the breeding density and twice the

breeding density estimated by Rosenfield et al. (1996) in Wisconsin. We assumed no variation among

plots in numerical trends, an exponential (constant rate) of increase/decrease, used count (integer) data

that were log-transformed after adding 1 [log(x+1)], constant sampling variance among plots, and all

power estimates were derived based on 500 simulations.

Results of power analyses are presented in Fig. 3. Using expected breeding densities for

WGLR goshawks (Rosenfield et al. 1996) indicated that regardless of the number of plots (within the

range we simulated), statistical power was low when monitoring occurred for 5 years. Power curves

for all numbers of plots were similar when monitoring occurred for both 20 and 25 years, with a slight

increase in power for increasing numbers of plots. Increasing breeding density (or, equivalently,

doubling the plot size) resulted in non-monotypically increasing power curves, which we adjusted by

extrapolation. At twice the estimated breeding density, statistical power was appreciably higher under the 5-year monitoring scenario (compared with statistical power under the condition of unaltered breeding density), and comparable with statistical power using estimated breeding density from Wisconsin under the 20- and 25-year monitoring scenarios. Power increased slightly as a function of the number of plots monitored.

Statistical power to detect a 50% decline over a 25-year period exceeded 0.80 in all scenarios except monitoring for 5 years at breeding densities estimated for Wisconsin. These simulations suggest that it may be possible to monitor WGLR goshawk populations with a well-designed, quadrat-based sampling strategy. Other scenarios could be investigated, including monitoring individual plots less frequently than every year. A potential compromise between number of plots and the frequency with which each plot is monitored is lattice-sampling, where some plots are visited annually and the rest are visited every t years with t > 1. Such a design is useful when the trend is small and when high within-site autocorrelation exists in successive years (Bart and Robson 1995). Currently data do not exist to evaluate the relationship between density estimates and plot size. If nesting density reported by Rosenfield et al. (1996) is representative of the region, then their plot size is a minimum. We note also, that plot size should be evaluated prior to initiating a quadrat-based sampling strategy in the WGLR.

These power analyses were conducted under a number of simplifying assumptions. For example, we assumed that the goshawk population in the WGLR was neither cyclic nor irruptive. Because the goshawk population in the WGLR is a peripheral population and this population may exhibit cyclic or irruptive features, any monitoring program designed to monitor population trends must be able to differentiate a declining population (Figs. 4B and 4D) from either a stationary cyclic (Fig. 4A) or stationary but fluctuating population (Fig. 4C). These complex dynamics reduce power and add complexity to data interpretation. With these considerations in mind, it is still evident that any monitoring program for goshawks in the WGLR must be long-term. If goshawk populations are cyclic, it would be necessary to complete a minimum of two cycles before trends are apparent, which may substantially increase the time interval necessary to monitor populations. Bart and Robson

(1995) conducted a power analysis to determine the power of roadside surveys to detect trends in raptor abundance. Their analyses suggested that a minimum of 8 years would be required for 80% probability of detecting trends in raptor populations unless such trends were > 3% annually and > 10 birds are recorded per 100 stations.

3.1.3.3. Area Occupied Technique

As indicated in the section on *Monitoring Changes in Distribution* (Section 3.1.1), probability of detection—area occupied techniques may be useful in monitoring goshawk populations, particularly if goshawks exhibit a high probability of responding to a call broadcast. Currently, the relationship between estimates of area occupied and breeding density have not been clearly established (see discussion in McLeod and Andersen 1998), and before this technique could be used to monitor breeding density, such a relationship would have to be evaluated. Bart and Robson (1995) describe a double-sampling procedure that could be used to calibrate this technique. Density would need to be estimated on quadrats using tree-by-tree or aerial searches. These estimates would be compared to the estimates obtained from the area occupied technique. For example, if the mean number of birds per survey route was 2, and the actual density of birds per 100 km^2 from quadrat sampling in the same area was 3, then the results for other broadcast survey routes would be multiplied by 1.5 to obtain an estimate of density per 100 km^2 (Bart and Robson 1995).

3.1.4. Monitor the Number of Migrants

One of the limitations of all of the aforementioned survey techniques is they can only be used to monitor trends in the breeding population. This is not a serious problem for the WGLR goshawk monitoring program because the population of interest is the regional breeding population (see section on *Define Population of Interest* - Section 2.4). However, long-term monitoring of migrant goshawks has been conducted in the region (Dick and Plumpton 1998) so it seems appropriate to discuss the utility of these programs for monitoring trends in WGLR goshawk populations.

Counts of migrants at migration stations (e.g., number of birds seen/hr) are commonly used to index trends in raptor populations throughout the world. The utility of migration counts for

monitoring population trends has been much debated [see Fuller (1998) for a detailed discussion of the strengths and weaknesses of migration counts as an index to population size]. To track population change, a constant proportion of the index to the true population size must be maintained, or the proportion must be estimated. These validation studies have not been conducted on the goshawk so the trends in the current migration count data are difficult to interpret.

Also, trends in migration counts could reflect distributional changes and changes in residency patterns rather than changes in population size. For example, recent analyses of Christmas Bird Count data suggest that sharp-shinned hawks (*A. striatus*) are increasing in these counts. Several authors have suggested that more sharp-shinned hawks are over-wintering in northern North America because bird feeders provide a stable over-winter food source. This could be the reason that counts of sharp-shinned hawks at northern migration stations have been lower in recent years (Davis 1992, Vivrette et al. 1996). Because goshawk migrations are characterized by irruptive invasions, migration counts of this species are more likely to reflect residency patterns than changes in abundance (Bednarz et al. 1990, Titus and Fuller 1990).

We do not recommend using migration counts as a population monitoring tool for goshawks in the WGLR until validation studies are conducted and these indices are demonstrated to calibrate with some estimate of population size. However, migration counts could be continued and used as an addendum to demographic studies to determine if the counts reflect demographic changes in the regional goshawk breeding population (Kennedy 1998).

3.2 DEMOGRAPHIC APPROACH

An alternative to monitoring temporal trends in population abundance would be to monitor temporal changes in vital rates (e.g., reproductive success, survival, recruitment). One advantage of this approach is it would provide some explanation for observed population trends. This may be more suitable than the survey approach for monitoring trends in WGLR goshawks because it has higher statistical power when animal densities are low. Preliminary density estimates for goshawks in

Wisconsin (Rosenfield et al. 1996) suggest that densities in this region are much lower than in other portions of the species' range.

Similar to the survey approach, there are a variety of response variables (vital rates) that could be monitored using this approach. It may be possible to monitor single vital rates [e.g., reproduction, survival (1-mortality-emmigration) or recruitment (birth + immigration)], or to monitor both reproductive success and survival or recruitment and survival and use these data to estimate λ or *r*. We discuss the pros and cons of these approaches below.

3.2.1. Monitor Reproductive Success Only

A common approach to monitoring trends in demographics of raptors and other birds is to monitor trends in reproductive success only. This approach is regularly used because it is one of the least labor-intensive methods of collecting demographic data--it requires only visits to known nests. Kennedy (1997) analyzed temporal trends in reproductive success for two western populations of goshawks and found that it varied widely, but that there was no evidence of a negative or positive trend. Visual inspection of reproductive success data presented in Erdman et al. (1998 – Fig. 4) corroborates Kennedy's findings for a Wisconsin population of goshawks.

Monitoring reproductive success by itself is not a good index of population trends because reproductive success is not correlated with population abundance. A meta-analysis of the northern spotted owl datasets indicated that, compared to survival, reproductive success had little relationship to abundance (Burnham et al. 1996, Raphael et al. 1996). Similarly, 7 years of monitoring broad-winged hawk (*Buteo platypterus*) breeding density and reproduction revealed neither statistically significant nor apparent relationships between reproductive success or productivity and breeding density in north central Minnesota (D.E. Andersen unpubl. data). Trends in reproductive success in avian populations may be correlated more with dispersal rates and breeding area turnover than with abundance. Reproduction may be low during periods of high survival (i.e., low breeding area turnover) and vice versa. Whatever relationships exist, however, there is little or no evidence for a relationship between breeding density and reproductive success in most raptors.

One potential reason that reproductive success is not well correlated with abundance is that it varies with the characteristics of the bird occupying a breeding area and the habitat characteristics of the breeding area. For example, breeding performance of birds has been documented to vary with age of the breeding area occupant (Sydeman et al. 1991, Newton and Rothery 1997, Wiebe and Martin 1998). For the sparrowhawk (*A. nisus*), a smaller-bodied, European relative of the goshawk, reproductive value increased until 4 years of age and then declined (Newton and Rothery 1997). Mean annual reproduction of 4- and 5-year-old females was twice that of first year breeders. Thus, new recruits can increase abundance but may have lower reproductive success on average than older birds, which could influence the lack of correlation between reproductive success and abundance discussed above.

Habitat features of the breeding area also influences reproductive success (Newton 1991). Although "high quality" is often synonymous with food supply in breeding areas, there may be other habitat features that facilitate high productivity. For example, habitat structure within a breeding area that reduces the risk of predation or exposure or facilitates access to prey may influence breeding performance of breeding area occupants (Reynolds et al. 1992, Beier and Drennan 1997, Dewey 1999). In contrast, "poor quality" habitat may contribute to poor reproductive success. As mentioned earlier (Section 3.1.2.2) breeding dispersal is commonly encountered in goshawk populations. The cause of these movements is unknown. However, in Tengmalm's owls (*Aegolius funereus*), high breeding area turnover rates seem to be induced by food stress (Löfgren et al. 1986). If goshawks move to new breeding areas for the same reason, this may indicate variable food supplies or other habitat features that influence breeding area occupancy (e.g., variable predation rates). The interacting effect of bird and breeding area attributes results in; 1) high annual variation in fecundity, and 2) few breeding pairs producing most of the young in populations of most long-lived avian species (Newton 1989).

3.2.2. Monitoring Reproduction and Survival

To adequately monitor population trends using the demographic approach would require monitoring both survival and reproduction (or recruitment). Recent analyses of vital rates of the

northern spotted owl indicate that adult survival is the key demographic parameter influencing

population declines (Burnham et al. 1996). Similar to the analyses done on the northern spotted owl,

information on these vital rates could then be used to calculate λ or r for the WGLR goshawk

population. This requires age-specific survival and reproduction data. Methods used to estimate these

parameters from data on reproductive output and age-class survival data are detailed in Franklin et al.

(1996).

Estimating age-specific reproductive output requires monitoring reproductive success of

individually marked or radio-tagged birds. There are two ways to estimate survival of northern

goshawks in the WGLR: 1) a Jolly-Seber analysis of mark-resighting data of banded, breeding adults;

or 2) survivorship function estimates (e.g., Kaplan-Meier procedures) based on radio-tagged birds.

The pros and cons of these two approaches are briefly described below.

3.2.2.1. Estimating survival from mark-resighting data

Mark-resighting data and Jolly-Seber models were described in Section 3.1.3.1 *Capture-recapture data and Jolly-Seber models.* This procedure can also be used to estimate survival rates. If

population size were to be estimated using Jolly-Seber models, the same dataset could be used to

estimate survival. However, DeStefano et al. (1994) and Kennedy (1997) tried to estimate adult

survival of goshawks and they found that precise survival estimates could only be estimated with

capture-recapture techniques if the estimates were based on large numbers of marked birds (>100),

high resighting rates, and at least 5 years of data. Both studies concluded that this would require large

study areas (the entire WGLR?) and large field crews--similar to the approach used to estimate

survival for the northern spotted owl (Forsman et al. 1996).

To calculate λ or r requires age-specific fecundity and survival data. Thus, estimates of

juvenile survival would be required. However, this approach is unlikely to result in precise estimates

of juvenile survival because the probability of resighting a juvenile as a recruit is very small. For

example, only 12% of the 1,169 nestling northern spotted owls banded in four study areas were re-

observed and juvenile survival estimates based on these data may have been biased (Raphael et al.

1996). On the Kaibab Plateau in Arizona, 6 of 256 goshawk nestlings banded from 1991-1996 were resighted in subsequent years – too few to estimate survival rates for juveniles (Reynolds and Joy 1998). Thus, λ could not be estimated for this population, which has one of the highest breeding densities of goshawks throughout its range.

3.2.2.2. Estimating survival with radio-telemetry

Estimates of survival can be derived from radio-telemetry data and are preferable to estimates based on capture-recapture data when permanent emigration occurs, radios do not influence survival, and sufficient numbers of radios are available for precise estimates. Survival can be estimated from telemetry data using the Kaplan-Meier procedure (Kaplan and Meier 1958), which accounts for animals lost due to radio failure, or emigration from the study area through censoring, and also allows for staggered entry of individuals as they are born or added to the study (Pollock et al. 1989). Five important assumptions underlie the Kaplan-Meier estimator; 1) individuals have been randomly sampled, 2) survival of the marked animals is independent of other individuals, 3) attached radios do not influence survival, 4) censoring is random and unrelated to an individual's fate, and 5) newly marked individuals have the same survival probability as previously marked individuals.

Kaplan-Meier estimates of survival have been derived for nestling and fledgling goshawks in New Mexico (Kennedy 1997) and Utah (Dewey 1999) and for adult goshawks in Alaska (Iverson et al. 1996). However, none of these are estimates of annual survival, which are necessary for estimating λ. Precise estimates of adult and juvenile survival could be derived for WGLR goshawks using this procedure but it would require large sample sizes. Iverson et al. (1996) radio-tagged 39 adult goshawks and did not have enough data to estimate annual survival rates for this sample of adults. Power analyses have not been conducted for this technique but we predict that > 50 individuals within each age class would be required to produce reasonable annual survival estimates for WGLR goshawks.

4.0. PHASE I - IDENTIFY GOSHAWK HABITAT RELATIONSHIPS

Before we can discuss habitat-monitoring approaches we need to define the habitat-related

terms we will be using. As pointed out by Hall et al. (1997) one of the major problems with wildlife-habitat studies is that habitat concepts and terminology are poorly defined, which hampers design and interpretation of results from habitat studies. The terminology we will use in this paper (and described below) is based on that recommended by Hall et al. (1997).

- ❑ **Goshawk habitat** – the resources and conditions present in an area that produces occupancy by goshawks.

- ❑ **Goshawk habitat type** – type of vegetation association in an area occupied by goshawks.

- ❑ **Goshawk habitat use** – the way in which a goshawk uses a collection of physical and biological components (i.e., resources) in a habitat.

- ❑ **Goshawk habitat availability** – the accessibility and procurability of physical and biological components of goshawk habitat.

- ❑ **Goshawk habitat abundance** – the quantity of the resources in goshawk habitat.

- ❑ **Goshawk habitat selection** – this is a hierarchical **process** involving a presumed series of innate and learned behavioral decisions made by goshawks about what habitat it would use at different scales of the environment.

- ❑ **Goshawk habitat preference –** this is the consequence of the goshawk's habitat selection process, resulting in disproportional use of some resources over others.

- ❑ **Goshawk habitat quality –** the ability of the environment to provide conditions appropriate for individual goshawk and goshawk population persistence.

- ❑ **Goshawk critical habitat –** equivalent to high quality habitat, which is an area that provides resources for goshawk population persistence in the WGLR.

- ❑ **Landscape –** a mosaic of habitat patches across which goshawks move, settle, reproduce and die. The landscape containing a goshawk population can, in principle, be mapped as a mosaic of suitable and unsuitable patches. Each map is specific to the goshawk habitat requirements and must be done at a scale appropriate to the goshawk (Meffe and Carroll 1994).

Identification of goshawk breeding and wintering habitat in the WGLR were information

priorities to the stakeholders (Table 2). Habitat studies in the WGLR are necessary because regional goshawk habitat cannot be managed if goshawk habitat relationships are poorly understood. Because WGLR landscapes are different from western landscapes, the stakeholders did not think the existing habitat information on goshawks (collected primarily in western forests) was applicable to the WGLR. In addition, existing habitat information does not clearly delineate the degree of association between goshawks and mature forests, which is the focus of the goshawk biopolitical controversy. In the recent status evaluation of the goshawk, the FWS concluded, "The information presented in the [listing] petition relies largely on the contention that the northern goshawk is dependent on large, unbroken tracts of "old-growth" and mature forest. However, FWS has found no evidence to support this claim. FWS found that while the goshawk typically does use mature forest or larger trees for nesting habitat, it appears to be a forest generalist in terms of the types and ages of forests it will use to meet its life history requirement. Goshawks can use small patches of mature habitat to meet their nesting requirements within a mosaic of habitats of different age classes" (Clark 1998). These findings suggest that more habitat studies are needed that are designed to determine the range of habitats used by the goshawk.

Because the concern over goshawk population viability is focused on the vegetative association of this species (i.e., mature forests), we recommend the habitat portion of Phase I focus on collecting information that will; 1) define regional breeding and wintering habitat types at several spatial scales (defined in Section 4.1.1), 2) measure the abundance of these types at similar spatial scales, 3) identify habitat type preferences at these spatial scales, 4) evaluate temporal and spatial changes in preferred goshawk habitat as a result of changing land use patterns, and 5) provide information on the responses of goshawks to silvicultural treatments. In addition, existing habitat data available for other regions and countries need to be evaluated to determine if general habitat trends are apparent and guide habitat data collection efforts in the WGLR. The results of such a meta-analysis could then be used to develop preliminary habitat models for the WGLR goshawks.

4.1. IDENTIFY GOSHAWK HABITAT TYPES IN THE WGLR

Basing a monitoring program on habitat monitoring (which will begin in Phase II) is a relatively new idea and the specific methods for developing models linking habitat and demographic performance are not well established in the conservation arena. Thus, in comparison with our detailed discussion of demographic monitoring approaches, our discussion of habitat monitoring is a conceptual overview of things to consider in developing this plan. It is not a detailed evaluation of habitat techniques, methods, and experimental design.

Habitat use studies in the WGLR should focus on answering the following questions; 1) what is the structure and composition of breeding and wintering habitat at a variety of spatial scales? 2) what proportion of the total landscape is goshawk habitat? 3) what is the distribution of sizes of habitat patches? 4) what is the distribution of distances (connectivity) between habitat patches? and 5) what is the relationship between forest structure and prey availability? The purpose of addressing Questions 3 and 4 is to evaluate the degree of habitat fragmentation that occurs in goshawk habitat and to identify minimum (and maximum?) patch sizes used by goshawks in the WGLR.

4.1.1. Spatial Scale of Habitat Data

As noted in the section on *Experimental and Sampling Design Considerations* (Section 2.8), samples must correspond appropriately to the spatial scale over which inference is to be made. All existing WGLR habitat data have been collected at the nest-tree and nest-site scales (Dick and Plumpton 1998). Information is also needed on goshawk habitat use at the scale of the nest stand, home range (year round) and on landscapes that support home ranges (DeStefano 1998, Smallwood 1998). A study of goshawk breeding season home range habitat use is currently being conducted in Minnesota (C. Boal et al., unpubl. data and Mortensen and Mortensen, unpubl. data). However, the inference of this study will be restricted to the sample of nests included in the study because none of the goshawk nests in Minnesota have been located using unbiased sampling techniques.

4.1.2. Obtaining a Regionally Representative Sample

Within the WGLR, nest tree and nest site habitat has been described for Wisconsin nests

(Rosenfield et al. 1998). The Wisconsin dataset is the only dataset in the WGLR that is not restricted to a local study area and a portion of their habitat data was collected at nests located through quadrat sampling. Rosenfield et al. (1998) tried to determine if habitat data varied between nest sites located using potentially biased and unbiased survey methods (see Section 3.1.2.1 for more details) . Although they report no statistically significant differences with an experimentwise $\alpha = 0.002$ (to correct for problems of multiple pairwise comparisons), comparisons of individual habitat variables suggest that nest sites located in a potentially biased manner have larger trees ($P = 0.03$) and less ground cover ($P = 0.03$) then sites located using unbiased methods**.**

Similar to the demographic studies, breeding habitat studies need to be based on nest sites located using unbiased sampling methods (see *Experimental and Sampling Design Considerations Section* - Section 2.8 - for a discussion of inference problems associated with nonrandom sampling methods). Methods that could be used to locate a representative sample of nests are discussed in detail in the section titled *Concern 1 - Is the sample of nests representative?*(Section 3.1.2.1).

4.1.3. What Habitat Variables Should Be Measured?

Most wildlife habitat studies (including those of goshawk habitat) are not designed in a hypothesis-testing framework. Rationales for the choice of response variables are rarely given and the study design could best be described as a "measure anything we can think of" design [notable exceptions for goshawks are the habitat use analyses done by Siders and Kennedy (1996) in New Mexico and a recent study on goshawk habitat in Oregon by Daw et al. (1998)]. The utility of such studies to management is often limited because their results only describe patterns observed at a single site. The applicability of these patterns to other sites is unknown but could potentially be evaluated with a meta-analysis of existing habitat data. This would have to include non-regional data because of the paucity of regional data (Dick and Plumpton 1998). To avoid this problem we recommend that WGLR habitat use studies choose response variables that are appropriate for answering the aforementioned questions (see Section 4.1 - *Identify goshawk habitat types in the WGLR*). Examples of appropriate variables for addressing these questions at the nest-stand scale include; habitat type of

the nest stand, average dbh of the stand, average stand size, average % canopy closure and average stand age. These variables could be measured at all known nest sites in the WGLR, and at sites located in the future via unbiased search methods.

At the home range and landscape scales, appropriate response variables would include metrics that determine the distribution of forest and non-forested patch sizes and inter-patch distances in year-round home ranges and the landscapes in which these home ranges are embedded. In addition, land-use patterns of goshawk home ranges and associated landscapes should be evaluated to determine if goshawks are associated with certain types of land-use patterns. To determine habitat use patterns within home ranges at these two larger spatial scales will require; 1) estimates of year-round home ranges based on radio-telemetry data, and 2) suitable Geographic Information System (GIS) coverage of the regional study areas. If this coverage is not available, development of such coverages would be an integral part of these habitat studies.

4.1.4 PREY

Prey abundance is an important habitat attribute. We know from food supplementation experiments in New Mexico (Ward and Kennedy 1996) and Utah (Dewey 1999) that goshawks are food-limited and have a demographic response to super-abundant food in some years. However, in some years they do not have a demographic response to super-abundant food suggesting that food is not always limiting, perhaps only periodically during ecological "crunches." Although not tested in the WGLR the results of the Ward and Kennedy (1996) and Dewey (1999) studies most likely apply to this region. If goshawk populations are cyclic in the WGLR, this population may only be food-limited when prey species populations are in the low phase of their population cycles.

Dewey's (1999) and Ward and Kennedy's (1996) results validate the current management approach for goshawks that emphasizes managing the landscape to maintain habitat for prey items typically taken by goshawks (Reynolds et al. 1992). These management guidelines are based on the assumption that goshawk populations are regulated by food availability. Availability of goshawk prey may be strongly influenced by forest management practices. More than any other activity these

practices will likely determine the long-term persistence of the species. Carey et al. (1992) and Carey (1995) showed that scuirid populations were more abundant and remained at relatively constant levels in old growth forests in comparison to managed second growth stands. Similarly, Schwab and Sinclair (1994) reported that avian populations were more abundant and diverse in mature forests than younger forests. Recently, Burke and Nol (1998) also reported that arthropod abundance (food resources for many forest-dwelling insectivores) was significantly reduced along edges and in small woodlots, further suggesting that food supplies may be reduced by forest fragmentation (Robinson 1998). Understanding how prey species are influenced by changes in forest structure and pattern resulting from forest management practices is critical to the development of sound species conservation plans for forest-dwelling birds. So as part of this plan, we recommend that efforts be directed to; 1) determine goshawk prey use in the WGLR, and 2) to examine how prey species respond to changes in forest structure and landscape pattern, both in terms of abundance and availability.

4.2. IDENTIFY GOSHAWK HABITAT PREFERENCES IN THE WGLR

Obtaining habitat use data is a critical first step in describing the range of habitats used by the goshawk in the WGLR. However, these types of studies cannot be used to determine if the goshawk is opportunistic in its choice of habitats or actually is selecting certain habitats for its activities. To answer these questions, habitat preference analyses are necessary. However, preference analyses cannot be used to identify critical goshawk habitat--that requires an understanding of the demographic performance of goshawk habitats (*see Phase II*).

The thrust of preference analyses is to compare the habitat use data with habitat abundance. These preference analyses should be conducted at the nest tree, nest site, nest stand, home range and landscape scales. Habitat abundance at the nest tree, nest site and nest stand scales can be obtained by measuring the appropriate response variables at random points. Measuring habitat abundance at the home range and landscape scales will require suitable GIS coverage of the region. The specific methods used to conduct these analyses will depend upon the response variables and the type of GIS

coverage. There are no published multi-scale habitat studies on goshawks in other regions to use for comparison. But several excellent examples exist of multi-scale, habitat preference analyses for other raptor species (Marzluff et al. 1997a, 1997b) which can be used as templates for designing multi-scale goshawk habitat preference studies in the WGLR.

4.3. EVALUATE TEMPORAL AND SPATIAL CHANGES IN PREFERRED GOSHAWK HABITAT

Once goshawk habitat preferences have been identified for the region, the location of all goshawk preferred habitat in the WGLR would need to be mapped. This map will provide the foundation for evaluating the temporal and spatial changes that may occur to preferred goshawk habitat. Initial efforts to produce a goshawk habitat map will focus on using certain habitat variables to define goshawk habitat on a regional scale. The habitat variables predicted to be most valuable in developing the landscape-scale map are; landcover class, cover type, year of stand origin, total tree crown closure and cover, forest canopy structure, tree overstory size class, and if available, dominant tree species. Potential variables to map for trends in habitat at the home range and nest stand scale would be those variables associated with tree resources such as; densities of standing live trees by size class, snag densities, and densities of downed wood and logs.

Changes in habitat at the landscape scale due to timber harvest could be accounted for annually using change detection or agency and industry harvest records. Changes in habitat at the home range scale would have to be based on annual changes in forest inventory plot data or GIS datasets. The trend in goshawk habitat could be estimated periodically (perhaps every five years) after the baseline map is developed. Monitoring over time will allow estimates of change in amount and distribution of goshawk habitat. It will also provide a method for evaluating the effectiveness of any regional management plans developed for the species.

4.4. RESPONSES OF GOSHAWKS TO SILVICULTURAL TREATMENTS

Although correlative studies are valuable in identifying patterns, they do not imply cause and effect (Krebs 1994). For example, trends in population or preferred habitat do not imply causes of

population change; experimental data are needed for such an evaluation. The WGLR is in a unique position to show some leadership in this arena and not develop a dependence on the correlative approach as has been done in other regions. We strongly support the suggestion of Ganey and Dick (1995), DeStefano (1998) and Kennedy (1998) that on-site experiments be initiated to measure the response of goshawks and other forest-dwelling raptors, and their prey to regional silvicultural treatments. These quasi-experiments [where the application of the treatment (e.g., timber harvest) is not under the control of the investigator] are being implemented continuously in the WGLR (J. Gallagher, pers. comm.) in the form of timber harvest near goshawk nests--most sale areas are identified years before the sale allowing for the collection of adequate pre-treatment data. Monitoring pre- and post-treatment movements of even a few pairs of birds, and pre- and post-treatment changes in prey abundance would provide us with fascinating qualitative insights into goshawk responses to harvest and could be the basis for designing additional experiments.

Although controlled experiments in forest management are exceedingly difficult and costly to design and conduct, experiments using forest management activities as treatments could provide a great opportunity to learn about the response of goshawks to current silvicultural practices in the WGLR. Quasi-experiments have been successfully conducted on passerine communities (Bierregaard and Lovejoy 1989, Schmiegelow et al. 1997) and goshawks have been successfully used as experimental units in field experiments (Kenward et al. 1993, Ward and Kennedy 1996, Dewey 1999). Experiments that are costly in the short run can be highly worthwhile for the long term if they substantially reduce the odds of using incorrect policies and if the results can be applied to many locations (Walters and Green 1997). In addition, experimental silvicultural prescriptions could be developed and applied near nest sites, guided by knowledge of goshawk habitat preferences. McKelvey and Witherspoon (1992) provide an example of a conceptual approach that integrates silviculture with knowledge of stand structures used by spotted owls.

5.0 PHASE I – DEVELOPMENT OF PRELIMINARY HABITAT MODELS

There is currently not enough regional data to develop and parameterize a regional habitat model to predict suitable goshawk habitat. However, there exists considerable habitat information on goshawks from other regions and countries that could be used to develop preliminary habitat models for WGLR goshawks and these models could be tested and modified once regional habitat data are available. Although we continue to suggest caution when considering data from other regions, we shouldn't dismiss all information provided by other studies until we identify regional, ecological dissimilarities. Certainly, habitat relationships for ponderosa pine (*Pinus ponderosa*) forests in the intermountain region likely will not be the same as habitat relationships in deciduous forests of northern Minnesota. However, some repeatable behaviors and patterns of habitat use probably occur across the holarctic distribution of this species including the WGLR. For example, recent literature reviews of goshawk nest site and nest area (12-ha) habitat characteristics in North America suggest that abundant large trees and high canopy closure are two consistent habitat features (Siders and Kennedy 1994; Squires and Reynolds 1997; McGrath 1998, Daw et al. 1998). The most efficient way to identify consistent patterns in data collected in multiple studies is to conduct meta-analyses of the existing habitat literature (Kennedy 1997, 1998). This analysis could be used to identify the habitat predictor variables and conceptualize linkages between habitat and population dynamics. We want to emphasize that these preliminary models will be used to generate hypotheses and would need validation, which occurs in Phase II.

After meta-analyses identify important, range-wide habitat patterns, these variables, combined with silvicultural information for the WGLR, could be used to develop management guidelines for WGLR goshawks similar to the southwestern guidelines developed by Reynolds et al. (1992). As noted by Fuller (1996), "The concept of Reynolds et al. (1992) could be used as a model, for assessments and strategies in other areas and for other species. The concept is good because it incorporates the best available ecological and management information and considers a variety of

species and forest conservation issues." These WGLR guidelines can be developed in an adaptive management framework and modified, as regional data become available.

6.0. PHASE II – HABITAT-BASED MONITORING

If goshawk habitat can be well-defined and demographic data are available from several study areas for an analysis of population trends [see DeStefano (1998) for further discussion of the value of long-term studies at multiple study areas], we recommend beginning development of a model (or models) that predicts the relationships between preferred nesting and winter habitat and population trends and/or performance. The model could ultimately be used to define critical goshawk habitat, which is an area that provides resources for goshawk population persistence in the WGLR. Identification of habitats that are required for population persistence requires linking habitat data with data on population performance in these habitats (Roloff and Haufler 1997).

Similar to the spotted owl monitoring plan (Lint et al. *in press*), we propose that the initial stages of model development be focused on searches for relationships between various measures of demographic performance and vegetative characteristics at multiple spatial scales. Habitat variables that appear related to demographic outcomes could be further examined to determine if habitat thresholds exist beyond which goshawk demographic performance begins to decline. The overall objectives of this exercise could be to develop models that predict occupancy, distribution and demographic performance of goshawks based on vegetative characteristics assessed at a variety of spatial scales.

For example, we know that for many species reproductive performance depends on the ecological attributes of the breeding area holders as well as the attributes of the breeding area (Newton 1989, 1991). As a result, most offspring in a population are produced by a small percentage of the breeding areas (the high quality or source breeding areas) and the majority of breeding areas rarely produces any young (ephemeral or sink breeding areas). One exploratory analysis that could be done in the model development stage would be to determine if habitat features differ between high quality and ephemeral breeding areas. This initially could be done by classifying a sample of breeding

areas with long-term ($\geq$ 5 yr) reproductive success data as high quality or ephemeral. However, ultimately recruitment (which is a function of reproductive success, survival, and dispersal) should be the demographic parameter of choice for this analysis because reproductive success is not a sufficient index of population persistence. The results of this type of analysis could be used to identify critical goshawk nesting habitat within the WGLR.

This predictive model would need to be refined and tested to examine relationships between habitat data and population size or other relevant demographic parameter. The models would have to be tested in areas that were not used to develop the model (validation areas). Such comparisons would help determine to what degree study areas represent the ecoregions, forest types, land ownerships, management strategies and ecological conditions in the regional range of the goshawk. Minimally, model validation would require a survey to determine distribution and occupancy of goshawks in the validation areas based on standard survey protocols. The density and distribution of pairs observed could be compared with predicted values from the habitat models. The degree of correspondence between predicted and observed occupancy is a measure of the extent to which the model is valid and reliable. Ideally, model validation could also involve a survey to understand the demographic performance of goshawks in the validation areas. The amount of time required for model validation would be a function of how much time is required to estimate demographic performance precisely and accurately. The degree of correspondence between predicted and observed values for productivity and turnover rates necessary for model acceptance could be addressed during validation. The results of these validation studies will be used to refine the existing models and develop "improved" ones for predicting the occupancy and distribution of goshawks in all ecological conditions, land ownerships and management strategies throughout the WGLR.

If these models can predict goshawk population performance, then monitoring programs could switch emphasis from population-based monitoring to habitat-based monitoring. If habitat models do not adequately predict population performance, population-based monitoring would need to be continued and the habitat relationship information would need to be re-evaluated.

The rationale for switching to habitat-based monitoring is simple and has been clearly

articulated by Roloff and Haufler (1997) and Lint et al. (*in press*). Due to resource limitations,

monitoring programs should emphasize the ecosystem rather than specific species. Assuming the

goshawk is an umbrella species (Simberloff 1998)**,** habitat-based monitoring of this species could be

used to monitor ecosystem health. It also affords the opportunity to assess other species and

communities that occur in the same landscape. The type of modeling we are recommending for Phase

II would integrate our knowledge of goshawk relationships with its environment into a single

indicator variable. If this approach was successful, we could decrease our emphasis on expensive

demographic monitoring and rely upon habitat condition to provide us with knowledge of population

condition and trend. Use of predictive models would also allow a more proactive management

program and permit prospective views of likely change rather than retrospective assessments of what

happened.

Some possible, but unverified limitations to a strictly habitat-based approach to monitoring

may exist that must be addressed in the design of Phase II. These include:

1. Some unknown proportion of the variation in goshawk population dynamics may not be
   driven by changes in habitat amount and distribution (for example, population
   fluctuations due to behavioral and age-related influences); and

2. Changes in habitat may not predict population responses to other stressors (for example,
   contaminants, competitive interactions, predation).

If habitat features do not drive goshawk population dynamics and forest management practices are not

a primary stressor of goshawk populations, a strictly habitat-based monitoring program may have

limited ability to predict changes in goshawk demographic performance.

7.0. IMPLEMENTATION OF THIS PLAN

The purpose of this research and monitoring plan is to provide a regional context for

developing a strategy for goshawk research and monitoring in the WGLR. It is to be used as an aid in

setting priorities, to provide a regional context for existing and future projects, and to enhance data

compatibility of current and future research and monitoring programs. We do not intend this to be a

prescription for all WGLR goshawk studies. Thus, we wrote it as a conceptual document, not as a "cookbook" set of methods that can be used in the field to direct goshawk data collection.

Further, whether and how a regional research and monitoring program for goshawks is implemented in the WGLR is beyond the control of the authors of this report. Rather, federal and state conservation agencies, non-governmental organizations, the forest products industry, tribal organizations, the research community, and other interested and vested parties will set research and monitoring priorities for goshawks in the WGLR. These same entities will be instrumental in securing (or not securing) the resources necessary to conduct research and monitoring. We have, however, tried to evaluate the current state of knowledge regarding goshawks in the WGLR, and identify knowledge gaps. Further, based on input from stakeholders, we have tried to address major issues regarding filling knowledge gaps in a manner that will provide the basis for making science-based conservation decisions relative to goshawks. We hope also, that we have provided a regional context for current and future research and monitoring efforts for goshawks in the WGLR.

It is currently not known whether existing data are representative of the WGLR breeding goshawk population—no regional datasets exist (See Section 2.2). Using existing data to make management decisions in the WGLR must be done cautiously because data may not be representative at the regional scale and because few data exist. As part of this monitoring program, existing datasets should be compared with data known to be representative. If found to be comparable, they could be incorporated into the regional dataset, resulting in increased power. However, the risks of using potentially biased data to make management decisions are that the decisions may be wrong. For example, if we only search for goshawk nests in mature forest and then analyze the habitat of that sample of nests, goshawks will be described as only using mature forest. But, if we had surveyed for nests using the aforementioned stratified random sampling approach we might find many nests in younger forest, which would provide a different interpretation of their habitat use patterns. Alternatively, we might only find goshawks in younger forest because mature forest doesn't exist in the landscape and the birds are currently nesting in sub-optimal habitat. Whether the risk associated with use of potentially biased data is acceptable needs to be evaluated and incorporated into

management decision processes.   Also, meta-analyses should be used to objectively and quantitatively evaluate the goshawk data from other regions to determine their applicability to this region.

With these considerations in mind, we propose development of a two-phase plan for monitoring goshawk population trends in the WGLR. Phase I would involve; (1) initiating standardized population surveys and evaluating the most efficient techniques for locating nesting goshawks within the WGLR, (2) determining habitat use and preferences, (3) developing regional databases on temporal and spatial patterns of goshawk habitat, and (4) developing preliminary habitat models based on meta-analyses of existing goshawk data. Phase II would involve developing a predictive model of critical goshawk habitat, testing and refining the model, and shifting emphasis to monitoring habitat rather than goshawk populations directly. In association with habitat monitoring, Phase II would also include periodic assessment of occupancy of goshawk habitat by goshawks. The procedures used to monitor goshawk population trends during Phase I of the WGLR research and monitoring program would be a function of the resources allocated to this program. We did not estimate the costs of each of the approaches because this is beyond the scope of this project. However, we think a cost analysis is necessary as part of the evaluation of the alternatives outlined in this document. In assessing costs, considerations should also be made for collecting data on other forest-dwelling raptor species. The task force could design a forest-raptor monitoring and research program, which would reduce costs compared to developing programs separately for each species. Based on our review of existing information on WGLR goshawks and the research and monitoring priorities set by stakeholders, we suggest the following as potential approaches (outlined in Figs. 1 and 2) to be used to collect data from which to base informed conservation decisions.

1) Determine year-round range and develop regional survey strategies for locating goshawks (Phase I)

2) Identify an approach to obtain a representative sample of breeding birds and use this sample to monitor population trends using either a survey or demographic approach or both (Phase I).

3) Conduct meta-analyses of existing goshawk habitat and demographic data and develop preliminary models that hypothesize the linkages between habitat and demographic performance (Phase I).

4) Use the sample of breeding birds to evaluate year-round habitat use and preferences (Phase I).

5) Relate the regional habitat information to population performance by modifying existing models or developing new models if earlier models prove inappropriate (Phase II).

6) Implement periodic population-based monitoring to document continued population persistence of goshawks and to revise habitat-based models (Phase II).

Within this general approach to goshawk monitoring and research, there are a number of important considerations that we now reiterate. First, population monitoring based on a static sample of breeding areas is not sufficient to adequately monitor regional goshawk populations. Monitoring of breeding areas needs to include a strategy that results in a sample representative of the regional breeding population of goshawks. This could be accomplished using stratified random sampling. Standard procedures need to be used to determine site occupancy, and these need to include searching large areas (1-1.5 km distance from the most recently occupied nest) for alternative nests. The extent of breeding dispersal among breeding areas by adult goshawks needs to be incorporated into monitoring, and new sites regularly need to be searched for breeding areas. Breeding birds could be marked in a manner that allows subsequent identification of individuals, and coupled with intensive reobservation efforts, resulting data could be used to estimate adult survival using Jolly-Seber models (DeStefano et al. 1994, Kennedy 1997). In combination with estimation of fecundity and juvenile survival (via radio telemetry), these data could be used to estimate rate of change of population size (λ or r), and may offer insight into factors affecting changes in population size. Disadvantages of this approach are that large sample sizes of birds are required to precisely estimate survival, and breeding adults must be marked and reobserved in subsequent years—efforts requiring considerable resources.

Second, if preliminary results indicate goshawk densities are as high or higher than what has been reported for Wisconsin (Rosenfield et al. 1996), monitoring breeding densities using quadrat sampling and/or call broadcast surveys and the area occupied technique could be implemented. This approach would also require a significant commitment of resources, but has the highest potential to track population changes and result in representative regional samples of goshawk breeding areas that could be used to evaluate demographics and factors affecting demographics. This survey approach has statistical power comparable to the demographic approach and would monitor population abundance directly, without development of a theoretical model of population dynamics. This approach is currently in the pilot study stage for Mexican spotted owls in the southwestern U.S. (Ganey et al. 1998).

Finally, the range of habitats used by the breeding population of goshawks in the WGLR is not well documented. Well designed sampling to locate breeding areas or to estimate breeding density should result in a representative sample of breeding areas, which could be used to characterize breeding habitat for goshawks. Coupled with radio telemetry and year-round monitoring of marked birds from these sites, resulting data could be used to develop and refine goshawk habitat relations at a number of spatial scales, ranging from trees that nests are placed in, to characteristics of stands used for breeding and foraging, to patterns in landscapes in which goshawk home ranges are located.

None of this is likely to happen in an organized fashion without participation and endorsement of stakeholders, including stakeholders who have not yet participated in development of a regional strategy. Managing goshawks regionally will require a management strategy similar to the one proposed by Grumbine (1997) for ecosystem management. The key to this type of management is interagency cooperation, which has been initiated for goshawks in the WGLR. We suggest that a task force be established and charged with agreeing on and implementing a strategy for goshawk monitoring and research in the WGLR. We further suggest that this task force use this document to identify research priorities in the region, address the relevant issues identified in this report, and review current data collection efforts to determine whether they are applicable to a regional monitoring program.

This task force should include, at a minimum, representatives of the forest products industry, the research community, state natural resources agencies, federal natural resources agencies, non-governmental organizations (including environmental organizations and falconry organizations), and tribal organizations. We further propose that this task force have the following characteristics:

- Relatively small size (< 10 members), with representation for all stakeholders. Partnerships become unwieldily if the number of participants is too high. If this is a problem and the region would rather err on the side of inclusiveness, large groups must break into sub-groups and each work on a particular task associated with the implementation of this plan (Grumbine 1997).

- Authority to commit significant resources to a regional strategy.

- A timeline in which a strategy is to be developed and implemented.

- Ability to allocate resources via a competitive bid or comparable process based on a request for specific work necessary for strategy implementation.

Finally, we have likely failed to address all of the issues relative to goshawk research and monitoring in a regional context for the WGLR. We view this concept document as a beginning, and not an end, to the development of a regional research and monitoring strategy—we encourage improvement.

8.0. LITERATURE CITED

Ayers, L. W. and S. H. Anderson. 1999. An aerial sightability model for estimating ferruginous hawk population size. *Journal of Wildlife Management* 63:85-97.

Bailey, R.G. 1995. Description of the ecoregions of the United States. 2nd ed. USDA Forest Service Miscellaneous Publication 1391, Washington, D.C.

Bart, J. and D.S. Robson. 1995. Design of a monitoring program for northern spotted owls. Pages 75-81 *in* C. J. Ralph, J. R. Sauer and S. Droege, editors. Monitoring bird populations by point counts. USDA Forest Service General Technical Report PSW-GTR-149, USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

Bednarz, J.C., D. Klem, J.R., L.J. Goodrich and S.E. Senner. 1990. Migration counts of raptors at Hawk Mountain, Pennsylvania, as indicators of population trends, 1934-1986. *Auk* 107:96-109.

Beier, P. and J.E. Drennan. 1997. Forest structure and prey abundance in foraging areas of northern goshawks. *Ecological Applications* 7:564-571.

Belleman, B.A. 1998. Red-shouldered hawk breeding ecology and habitat use in central Minnesota. M.S. Thesis, University of Minnesota, St. Paul. 71pp.

Bierregaard, R.O. and T.E. Lovejoy. 1989. Effects of forest fragmentation on Amazonian understory bird communities. *Acta Amazonica* 19:215-241.

Block, W.M., F. Clemente, J.F. Cully, J.L. Dick, Jr., A.B. Franklin, J.L. Ganey, F.P. Howe, W.H. Moir, S.L. Spangle, S.E. Rinkevich, D.L. Urban, R. Vahle, J.P. Ward, Jr., and G.C. White. 1995. Recovery plan for the Mexican Spotted Owl (*Strix occidentalis lucida*). Vol. I. USDI Fish and Wildlife Service, Albuquerque, NM, USA.

Bowerman, W., S.R. Christiansen and W.L. Robinson. 1997. Current management and research on woodland raptors. Pages 11-12 *in* J. Noll West, editor. Proceedings of a workshop on the status of the northern goshawk in the midwest. Midwest regional raptor management and peregrine symposium, March 14, 1997, Milwaukee, Wisconsin. Unpublished FWS report.

Braun, C. E., J. H. Enderson, M. R. Fuller, Y. B. Linhart and C. D. Marti. 1996. Northern goshawk and forest management in the southwestern United States. Wildl. Soc Tech. Rev. 96-2:1-19.

Bright-Smith, D.J. and R.W. Mannan. 1994. Habitat use by breeding male northern goshawks in northern Arizona. *Studies in Avian Biology* 16:58-65.

Britten, M.W., P.L. Kennedy and S. Ambrose. *In press*. An evaluation of the performance and accuracy of small satellite transmitters. *Journal of Wildlife Management.*

Burke, D.M. and E. Nol. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding ovenbirds. *Auk* 115: 96-104.

Burnham, K.P., D.R. Anderson and G.C. White. 1996. Meta-analysis of vital rates of the northern spotted owl. *Studies in Avian Biology* 17:92-101.

Carey, A.B. 1995. Sciurids in Pacific northwest managed and old-growth forests. *Ecological Applications* 5: 648-661.

------------, Horton, S.P. and B.L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape characteristics. *Ecological Monographs* 62: 223-250.

Caughley, G., D. Grice, R. Barker, and B. Brown. 1988. The edge of the range. *Journal of Animal Ecology* 57:771-785.

Clark, J.R. 1997. Endangered and threatened wildlife and plants; 90-day finding for a petition to list the northern goshawk in the contiguous United States west of the 100th meridian. *Federal Register* 62(188):50892-50896.

-------------. 1998. Endangered and threatened wildlife and plants; notice of 12-month finding on a petition to list the northern goshawk in the contiguous United States west of the 100th meridian. *Federal Register* 63(124): 35183-35184.

Clark, J.S. 1990. Fire and climate change during the last 750 yr in northwestern Minnesota. *Ecological Monographs* 60:135-159.

Cook, J.G. and S.H. Anderson. 1990. Use of helicopters for surveys of nesting red-shouldered hawks. *Prairie Naturalist* 22:49-53.

Crocker-Bedford, D.C. 1990. Goshawk reproduction and forest management. *Wildlife Society Bulletin* 18:2262-269.

Davis, W.E. Jr. 1992. Are *Accipiter* populations in winter affected by bird feeders? *Bird Observer* 20:253-257.

Daw, S.K., S. DeStefano, and R.J. Steidl. 1998. Does survey method bias the description of northern goshawk nest-site structure? *Journal of Wildlife Management* 62:1379-1384.

DeStefano, S. 1998. Determining the status of the Northern Goshawk in the west: is our conceptual model correct? *Journal of Raptor Research* 32:342-348.

----------------, S.K. Daw, S.M. Desimone and E.C. Meslow. 1994. Density and productivity of northern goshawks: implications for monitoring and management. Studies in Avian Biology 16:88-91.

Detrich, P.J. and B. Woodbridge. 1994. Breeding area fidelity, mate fidelity, and movements of color-marked northern goshawks in the southern Cascades of California. *Studies in Avian Biology* 16:130132.

Dewey, S.R. 1999. Effects of supplemental food on parental care strategies and juvenile survival of northern goshawks. M. S. Thesis, Colorado State University, Ft. Collins, Colorado, USA.

Dick, T. and D. Plumpton. 1998. Review of research pertaining to the northern goshawk (*Accipiter gentilis atricapillus*) in the Western Great Lakes region. Unpublished report.

Doolittle, T. 1997. Goshawk winter movement study in northern Wisconsin. Page 6 *in* J. N. West, editor. Proceedings of a workshop on the status of the northern goshawk in the midwest. Midwest regional raptor management and peregrine symposium, March 14, 1997, Milwaukee, Wisconsin. Unpublished FWS report.

Erdman, T.C., D.F. Brinker, J.P. Jacobs, J. Wilde and T.O. Meyer. 1998. Productivity, population trend, and status of northern goshawks, *Accipiter gentilis atricapillus*, in northeastern Wisconsin. *Canadian Field-Naturalist* 112:17-27.

Forsman, E.D., S. DeStefano, M.G. Raphael and R.J. Gutiérrez, editors. Demography of the northern spotted owl. *Studies in Avian Biology* 17.

Franklin, A.B., D.R. Anderson, E.D. Forsman, K.P. Burnham, and F.W. Wagner. 1996. Methods for collecting and analyzing demographic data on the northern spotted owl. *Studies in Avian Biology* 17:12-20.

----------------, J.P. Ward, R.J. Gutiérrez, and G.I. Gould, Jr. 1990. Density of northern spotted owls in northwest California. *Journal of Wildlife Management* 54:1-10.

Frelich, L.E. 1995. Old forest in the Lake States today and before European settlement. *Natural Areas Journal* 15:157-167.

Fuller, M. 1996. Forest raptor population trends in North America. Pages 167-208 *in* R.M. DeGraaf and R.I. Miller, editors. Conservation of faunal diversity in forested landscapes. Chapman & Hall, London, U. K.

-----------, editor. 1997. Report of a workshop to develop a North American raptor monitoring

strategy. Unpublished report. U. S. Geological Survey – Biological Resources Division, Snake River Field Station, Boise, Idaho, USA.

------------ and J.A. Mosher. 1981. Methods of detecting and counting raptors: a review. Estimating numbers of terrestrial birds. *Studies in Avian Biology* 6: 235-246.

------------- and --------------. 1989. Raptor survey techniques. Pages 37-65 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline and D.M. Bird, editors. Raptor management techniques manual. National Wildlife Federation Scientific and Technical Series No. 10. National Wildlife Federation, Washington, D. C., USA.

Ganey, J.L. and J.L. Dick, Jr. 1995. Habitat relationships of the Mexican Spotted Owl: current knowledge. Recovery plan for the Mexican spotted owl (*Strix occidentalis lucida*). USDI Fish and Wildlife Service, Recovery plan for the Mexican spotted owl, Vol. II., Albuquerque, NM, USA.

_____, G.C. White, A.B. Franklin and J.P. Ward. 1998. Monitoring population trends of Mexican spotted owls in Arizona and New Mexico: a pilot study. Study No. RM-4251-xxx. Unpubl. Report Rocky Mountain Research Station, Flagstaff, AZ.

Gaston, K. 1994a. Measuring geographic range sizes. *Ecography* 17:198-205.

--------------. 1994b. Rarity. Chapman & Hall, London, U. K.

_____ and J.L. Curnutt. 1998. The dynamics of abundance-range size relationships. *Oikos* 81:38-44.

Geissler, P.H. and M.R. Fuller. 1987. Estimation of the proportion of an area occupied by an animal species. Pages 533-538 in Proceedings of the section on survey research methods of the American Statistical Association. American Statistical Association, Alexandria, Virginia, USA.

Gerard, P. D., D. R. Smith and G. Weerakkody. 1998. Limits of retrospective power analysis. *Journal of Wildlife Management* 62:801-807.

Gibbs, J.P., and S.M. Melvin. 1993. Call-response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 57:27-34.

----------. 1995. MONITOR (Version 6.2). Available at

http://www.im.nbs.gov//powcase/monitor.html.

Goodwin, P. and G. Wright. 1991. Decision analysis for management judgement. John Wiley & Sons,

Chichester, U.K.

Gotelli, N. 1998. A primer of ecology. Second Edition. Sinauer Associates, Inc., Sunderland,

Massachusetts, USA.

Gould, W.R. and M.R. Fuller. 1995. Survival and population size estimation in raptor studies: a

comparison of two methods. *Journal of Raptor Research* 29:256-264.

Grumbine, R.E. 1997. Reflections on "What is Ecosystem Management?" *Conservation Biology*

11:41-47.

Hall, L.S., P.R. Krausman and M.L. Morrison. 1997. The habitat concept and a plea for standard

terminology. Wildlife Society Bulletin 25:173-182.

Hatfield, J.S., W.R. Gould IV, B.A. Hoover, M.R. Fuller and E.L. Lindquist. 1996. Detecting trends

in raptor counts: power and Type I error rates of various statistical tests. *Wildlife Society Bulletin*

24:505-515.

Hengeveld, R. 1989. Dynamics of biological invasions. Chapman and Hall, London, U.K.

Iverson, G.C. and M.R. Fuller. 1991. Area-occupied survey technique for nesting woodland raptors.

Pages 118-124 in B. Giron Pendleton, D.L. Krahe, M.N. LeFranc, Jr., K. Titus, J.C. Bednarz,

D.E. Andersen, and B.A. Millsap, eds. Proceedings of the Midwest raptor management

symposium and workshop. National Wildlife Scientific and Technical Series 15.

Iverson, G.C., G.D. Hayward, K. Titus, E. DeGayner, R.E. Lowell, D.C. Crocker-Bedford, P.F.

Schempf and J. Lindell. 1996. Conservation assessment for the northern goshawk in southeast

Alaska. USDA Forest Service General Technical Report PNW-GTR-387.

Journal of Wildlife Management. 1995. Journal news. *Journal of Wildlife Management* 59: 196-198.

Joy, S.M., R.T. Reynolds and D.G. Leslie. 1994. Northern goshawk broadcast surveys: hawk response

variables and survey costs. *Studies in Avian Biology* 16:24-31.

Kaplan, E,L. and P. Meier. 1958. Nonparametric estimation from incomplete observations. *Journal of American Statistical Association* 53: 457-481.

Kennedy, P.L. 1998. Evaluating northern goshawk (*Accipiter gentilis atricapillus*) population trends: a reply to Smallwood and Crocker-Bedford. *J. Raptor Res*. 32:336-342.

------------------. 1997. The northern goshawk (*Accipiter gentilis atricapillus*): Is there evidence of a population decline? *J. Raptor Res*. 31:95-106.

-----------------, J.M. Ward, G.A. Rinker, and J.A. Gessaman. 1994. Post-fledging areas in northern goshawk home ranges. *Studies in Avian Biology* 16: 75-82.

---------------- and D.W. Stahlecker. 1993. Responsiveness of nesting northern goshawks to taped broadcasts of 3 conspecific calls. *Journal of Wildlife Management* 57:249-257.

Kenward, R.E., V. Marcström, and M. Karlblom 1993. Post-nestling behavior of Goshawks, *Accipiter gentilis* I. The causes of dispersal. *Anim. Behav*. 46:65-370.

Krebs, C.J. 1994. Ecology: the experimental analysis of distribution and abundance. 4th edition. Harper Collins College Publishers, New York, NY, U.S.A.

Lawton, J.H. 1993. Range, population abundance and conservation. *Trends in Ecology and Evolutionary Biology* 8:409-413.

Lebreton, J-D., K.P. Burnham, J. Clobert and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological Monographs* 62:67-118.

Lewis, S.J. 1998. Introduction and workshop objectives. Pages 1-3 *in* J. N. West, editor. Proceedings of a workshop on the status of the northern goshawk in the midwest. Midwest regional raptor management and peregrine symposium, March 14, 1997, Milwaukee, Wisconsin. Unpublished FWS report.

Lint, J., B. Noon, R. Anthony, E. Forsman, M. Raphael, M. Collopy and E. Starkey. 1997. Northern spotted owl effectiveness monitoring plan for the northwest forest plan. Unpublished Final Report, Intergovernmental Advisory Committee and Research and Monitoring Committee, Northwest Forest Plan.

Löfgren, O., Hörnfeldt, B. and B.-G. Carlsson. 1986. Site tenacity and nomadism in Tengmalm's owl (*Aegolius funereus* (L.)) in relation to cyclic food production. *Oecologia* 69: 312-326.

Looman, S.J., D.A. Boyce, Jr., C.M. White, D.L. Shirley, and W.J. Mader. 1985. Use of ultralight aircraft for raptor nest surveys. *Wildlife Society Bulletin* 13:539-543.

Madsen, S., D. Evans, T. Hamer, P. Hensen, S. Miller, S.K. Nelson, D. Roby and M. Stapanian. 1997. Marbled murrelet effectiveness monitoring plan for the northwest forest plan. Unpublished Final Report, Intergovernmental Advisory Committee and Research and Monitoring Committee, Northwest Forest Plan.

Marzluff, J.M., S.T. Knick, M.S. Vekasy, L.S. Schueck and T.J. Zarriello. 1997a. Spatial use and habitat selection of golden eagles in southeastern Idaho. *Auk* 114:673-687.

-----------------, B.A. Kimsey, L.S. Schueck, M.E. McFadzen, M.S. Vekasy and J.C. Bednarz. 1997b. The influence of habitat, prey abundance, sex and breeding success on the ranging behavior of prairie falcons. *Condor* 99:567-584.

McCullough, D.R., editor. 1996. Metapopulations and wildlife conservation. Island Press, Washington, D. C., USA.McGowan, J.D. 1975. Nesting habitats and reproductive success of goshawks in interior Alaska. Pages 147-152 *in* J.R. Murphy, C.M. White, and B.E. Harrell, eds. Population status of raptors. *Raptor Research Reports* 3.

McGrath, M.T. 1998. Northern Goshawk habitat analysis in managed forest landscapes. M.Sc. Thesis. Oregon State University, Corvallis, Oregon, USA.

McLeod, M.A. and D.E. Andersen. 1998. Red-shouldered hawk broadcast surveys: factors affecting detection of responses and population trends. *Journal of Wildlife Management* 62:1385-1397.

Meffe, G.K. and C.R. Carroll. 1994. Principles of Conservation Biology. Sinauer Assoc., Inc., Sunderland, Massachusetts, USA.

Mehlman, D.W. 1994. Rarity in North American passerine birds. *Conservation Biology* 8:1141-1145.

Millsap, B.A., P.L. Kennedy, M.A. Byrd, G. Court, J.H. Enderson, and R. Rosenfield. 1998. Scientific review of the proposal to de-list the American peregrine falcon. *Wildl. Soc. Bull*. 26: 522-538.

Mladenoff, D.J., G.J. Niemi and M.A. White. 1997. Effects of changing landscape patterns and U.S.G.S. land cover data variability on ecoregion discrimination across a forest-agricultural gradient. *Landscape Ecology* 12:379-396.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1992. Wildlife-habitat relationships: concepts and applications. University of Wisconsin Press, Madison, Wisconsin.

Newton, I., editor. 1989. Lifetime reproduction in birds. Academic Press, London, U. K.

------------. 1991. Habitat variation and population regulation in sparrowhawks. *Ibis* 133: 76-88.

------------ and P. Rothrey. 1997. Senescence and reproductive value in sparrowhawks. *Ecology* 78:1000-1008.

Niemi, G.J., J.M. Hanowski, A.R. Lima and D.J. Mladenoff. 1998. Biogeographic patterns of breeding birds in Minnesota. *Loon* 70:3-11.

Pollock, K.H., S.R. Wintersteun, C.M. Bunck, and P.D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. *Journal of Wildlife Management* 53: 7-15.

Postupalsky, S. 1997. A study of breeding northern goshawks in Michigan. Pages 13-14 *in* J. Noll West, editor. Proceedings of a workshop on the status of the northern goshawk in the midwest. Midwest regional raptor management and peregrine symposium, March 14, 1997, Milwaukee, Wisconsin. Unpublished FWS report.

Pradel, R., A.R. Johnson, A. Viallefont, R.G. Nager and F. Cézilly. 1997. Local recruitment in the greater flamingo: a new approach using capture-mark-recapture data. *Ecology* 78:1431-1445.

Ratti, J. and E.O. Garton. 1994. Research and experimental design. Pages 1- 23 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Reynolds, R.T. and S.M. Joy. 1998. Distribution, breeding area occupancy, dispersal, and demography of northern goshawks on the Kaibab Plateau, Arizona. Unpublished final report for Arizona Game and Fish, heritage Project No. I94045.

Raphael, M.G., R.G. Anthony, S. DeStefano, E.D. Forsman, A.B. Franklin, R. Holthhausen, E.C. Meslow and B.R. Noon. 1996. Use, interpretation, and implications of demographic analyses of

northern spotted owl populations. *Studies in Avian Biology* 17:102-112.

Reynolds, R.T., R.T. Graham, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce Jr., G. Goodwin, R. Smith, and E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. General Technical Report RM-GTR-217, USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO., USA.

Robinson, S.K. 1998. Another threat posed by forest fragmentation: reduced food supply. *Auk* 115: 1-3.

Roloff, G.J. and J.B. Haufler. 1997. Establishing population viability planning objectives based on habitat potentials. *Wildlife Society Bulletin* 25:895-904.

Rosenfield, R.N., J. Bielefeldt and R.K. Anderson. 1988. Effectiveness of broadcast calls for detecting breeding Cooper's hawks. *Wildlife Society Bulletin* 16:210-212.

---------------------, --------------, D.R. Trexel and T.C.J. Doolittle. 1998. Breeding distribution and nest-site habitat of northern goshawks in Wisconsin. *Journal of Raptor Research* 16:210-212.

---------------------, T.C.J. Doolittle and J. Bielefeldt. 1996. Status of forest-dependent raptors on the northern Highland/American Legion State Forest and the Bois Brule River State Forest: a preliminary study. Unpublished report.

Saint Paul Pioneer Press. 1998a. At loggerheads over Little Alfie. January 17, 1998.

-----------------------------. 1998b. U. S. Forest Service delays decision on Chippewa National Forest logging. April 8. 1998.

Schmiegelow, F.K.A., C.S. Machtans and S.J. Hannon. 1997. Are boreal birds resilient to forest fragmentation? An experimental study of short-term community responses. *Ecology* 78: 1914-1932.

Schwab, F.E. and A.R.E. Sinclair. 1994. Biodiversity of diurnal breeding bird communities related to succession in the dry Douglas-fir forests of southeastern British Columbia. *Canadian Journal of Forestry Research* 24: 2034 - 2040.

Siders, M.S. and P.L. Kennedy. 1994. Nesting habitat of *Accipiter* hawks: is body size a consistent predictor of nest habitat characteristics? *Studies in Avian Biology* 16:92-96.

-------------- and ------------------. 1996. Forest structural characteristics of accipiter nesting habitat: is there an allometric relationship? *Condor* 98:123-132.

Simberloff, D. 1998. Flagships, *umbrellas, and keystones: is single-species management passé in the landscape era? Biological* Conservation 83:247-257.

Smallwood, K.S. 1998. On the evidence needed for listing Northern Goshawks (*Accipiter gentilis*) under the Endangered Species Act: A reply to Kennedy. *Journal of Raptor Research.* 32:323-329.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Second Edition. W.H. Freeman and Co., New York, New York, USA.

Squires, J.R. and R.T. Reynolds. 1997. Northern goshawk (*Accipiter gentilis*). *In* A. Poole and F. Gill , editors. The Birds of North America, No. 298. The Academy of Natural Sciences, Philadelphia, Pennsylvania and The American Ornithologists' Union, Washington, D.C.

-------------- and L.F. Ruggerio. 1995. Winter movements of adult northern goshawks that nested in southcentral Wyoming. *Journal of Raptor Research* 29:5-9.

Squires, J.R. and L.F. Ruggerio. 1996. Nest-site preference of northern goshawks in southcentral Wyoming. *Journal of Wildlife Management* 60:170-177.

Stahlecker, D.W., P.L. Kennedy, A.C. Cully, and C.B. Kuykendall. 1989. Breeding bird communities of the Rio Grande Wild and Scenic River Area, New Mexico. *Southwestern Naturalist* 34:487-498.

Steidl, R.J., J.P. Hayes and E. Schauer. 1997. Statistical power analysis in wildlife research. *Journal of Wildlife Management* 61:270-279.

Sydeman, W.J., Penniman, J.F., Penniman, T.M., Pyle, P. and D.G. Ainley. 1991. Breeding performance in the western gull: effects of parental age, timing of breeding and year in relation to food availability. *Journal of Animal Ecology* 60: 135-149.

Taylor, B.L. and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the vaquita and northern spotted owl. *Conservation Biology* 7:489-500.

Tester, J.R. 1995. Minnesota's natural heritage. An ecological perspective. University of Minnesota Press, Minneapolis, Minnesota, USA.

Thompson, W.L., G.C. White and C. Gowan. 1998. Monitoring vertebrate populations. Academic
    Press, Inc., San Diego, CA, USA.

Titus, K. and M.R. Fuller. 1990. Recent trends in counts of migrant hawks from northeastern North
    America. *Journal of Wildlife Management* 54:463-470.

Tordoff, H.B. and P.T. Redig. 1997. Midwest peregrine falcon demography, 1982-1995. *Journal of
    Raptor Research* 31:339-346.

Vivrette, C.B., S. Struve, L.J. Goodrich, and K.L. Bildstein. 1996. Decreases in migrating sharp-
    shinned hawks (*Accipiter striatus*) at traditional raptor-migration watch sites in eastern North
    America. *Auk* 113:32-40.

Ward, J.P., Jr., A.B. Franklin, S.E. Rinkevich and F. Clemente. 1995. Distribution and abundance of
    Mexican spotted owls. USDI Fish and Wildlife Service, Recovery plan for the Mexican spotted
    owl, Vol. II., Albuquerque, NM, USA.

Ward, J.M. and P.L. Kennedy. 1996. Effects of supplemental food on size and survival of juvenile
    northern goshawks. *Auk* 113: 200-208.

Walters, C.J. and R. Green. 1997. Valuation of experimental management options for ecological
    systems. *Journal of Wildlife Management* 61:987-1006.

Watson, J.W., Hays, D.W. and D.J. Pierce. 1999. Efficacy of Northern Goshawk broadcast surveys
    in Washington State. *Journal of Wildlife Management* 63:98-106.

Weise, T. 1998. The goshawk in Michigan. Page 10 *in* J. N. West, editor. Proceedings of a workshop
    on the status of the northern goshawk in the midwest. Midwest regional raptor management and
    peregrine symposium, March 14, 1997, Milwaukee, Wisconsin. Unpublished FWS report.

West, J.N., editor. 1998. Proceedings of a workshop on the status of the northern goshawk in the
    midwest. Midwest regional raptor management and peregrine symposium, March 14, 1997,
    Milwaukee, Wisconsin. Unpublished FWS report.

White, G.C. and R.A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New
    York, New York, USA.

Wiebe, K.L. and K. Martin. 1998. Age-specific patterns of reproduction in white-tailed and willow ptarmigan *Lagopus leucurus* and *L. lagopus. Ibis* 140: 14-24.

Wilcove, D.S. and J.W. Terborgh. 1984. Patterns of population declines in birds. *American Birds* 38:10-13.

Woodbridge, B. and P.J. Detrich. 1994. Breeding area occupancy and habitat patch size of northern goshawks in the southern Cascades of California. *Studies in Avian Biology* 16:83-87.

9.0. TABLES AND FIGURES

Table 1. Ballot used at the Stakeholder's Meeting for ranking information needs on goshawks in the western Great Lakes region.

	RATING			
TOPIC	**Very Important**	**Moderately Important**	**Not Important**	**No Opinion**
DEMOGRAPHY	N/A	N/A	N/A	N/A
Identify spatial population boundaries				
Identify seasonal population boundaries				
Regional population trends (temporal changes in productivity, density and/or survival)				
Degree of population isolation				
Is the population irruptive?				
Distributional changes?				
Identify sources and sinks				
DIRECT POP'N FACTORS THAT INFLUENCE POP'N	N/A	N/A	N/A	N/A
Identify causes of mortality				
Influence of falconry				
Influence of contaminants				
Influence of predation				
Influence of competitors				
HABITAT	N/A	N/A	N/A	N/A
Identify goshawk habitat	N/A	N/A	N/A	N/A
Breeding				
Winter				
Migration				
What is the spatial distribution of goshawk habitat?				
What are temporal changes in goshawk habitat?				
PREY				
Evaluate potential prey abundance				

Table 1. cont.

FACTORS THAT INFLUENCE HABITAT	N/A	N/A	N/A	N/A
Forest Management				
Recreation				
Urbanization				
Other human disturbance factors				
OTHER TOPICS	N/A	N/A	N/A	N/A
Importance of non-regional data				
Develop a regional management plan				
Additional Topics not covered in ballot (list below and rank)				

Table 2. Stakeholder[1] rankings of information topics applicable to management of northern goshawks in the western Great Lakes Region.

TOPIC	SCORE 1 (19)[2]	RANK 1[3]	SCORE 2 (10)[4]	RANK 2	AVG. RANK
DEMOGRAPHY					
Identify spatial population[5] boundaries	1.47	6	1.6	4	5
Identify seasonal population boundaries	1.21	8[6]	1.4	5	6.5
Regional population trends	1.84	3	1.8	2	2.5
Degree of population isolation	1.05	9	0.8	11	10
Is the population irruptive/cyclic?	1.21	8	1.2	7	7.5
Distributional changes?	1.11	9	1.1	8	8.5
Identify sources and sinks?	Not incl.[7]	N/A[8]	1	9	9
DIRECT FACTORS THAT INFLUENCE POPULATIONS					
Identify causes of mortality	Not incl.	N/A	1.7	3	3
Influence of falconry	0.74	11	0.6	12	11.5
Influence of contaminants	0.47	13	0.3	13	13
Influence of predation	1.42	7	1.4	5	6
Influence of competitors	Not Incl.	N/A	0.9	10	10
HABITAT					
Identify Goshawk Habitat					
Breeding habitat	1.89	2	2	1	1.5
Winter habitat	1.68	4	1.7	3	3.5
Migration habitat?	0.63	12	1	9	10.5
Spatial distribution of goshawk habitat		N/A	1.8	2	2
Temporal changes in goshawk habitat	Not Incl.	N/A	1.8	2	2
PREY					
Evaluate potential prey abundance	Not Incl.	N/A	1.3	6	6
FACTORS THAT INFLUENCE HABITAT					
Forest management	1.89	2	2	1	1.5
Recreation	Not Incl.	N/A	1.1	8	8
Urbanization	0.95	10	0.8	11	10.5
Other Human Disturbance Factors	Not incl.	N/A	1.1	8	8
IMPORTANCE OF NON-REGIONAL DATA	0.95	10	0.8	11	10.5
DEVELOP A REGIONAL MANAGEMENT PLAN	1.53	5	1.3	6	5.5

Table 2. cont.

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[1] The stakeholders were representatives of organizations involved with goshawk management in the WGLR. See text for a list of the stakeholders.

[2] This is the weighted score (W_T) for this topic from Ballot 1. Parenthetic values represent the number of ballots completed at the meeting.

[3] This is the rank of the score presented in ascending order.

[4] This is the weighted score (W_T) for this topic from Ballot 2. Parenthetic values represent the number of ballots returned by mail.

[5] Topics with a ranking <5 are indicated in bold. These are considered the top information priorities identified at

[6] Topics with identical scores were ranked as a tie.

[7] Not incl. = this topic was added to the second ballot based on written comments on Ballot 1 and discussions at the Stakeholder's Meeting.
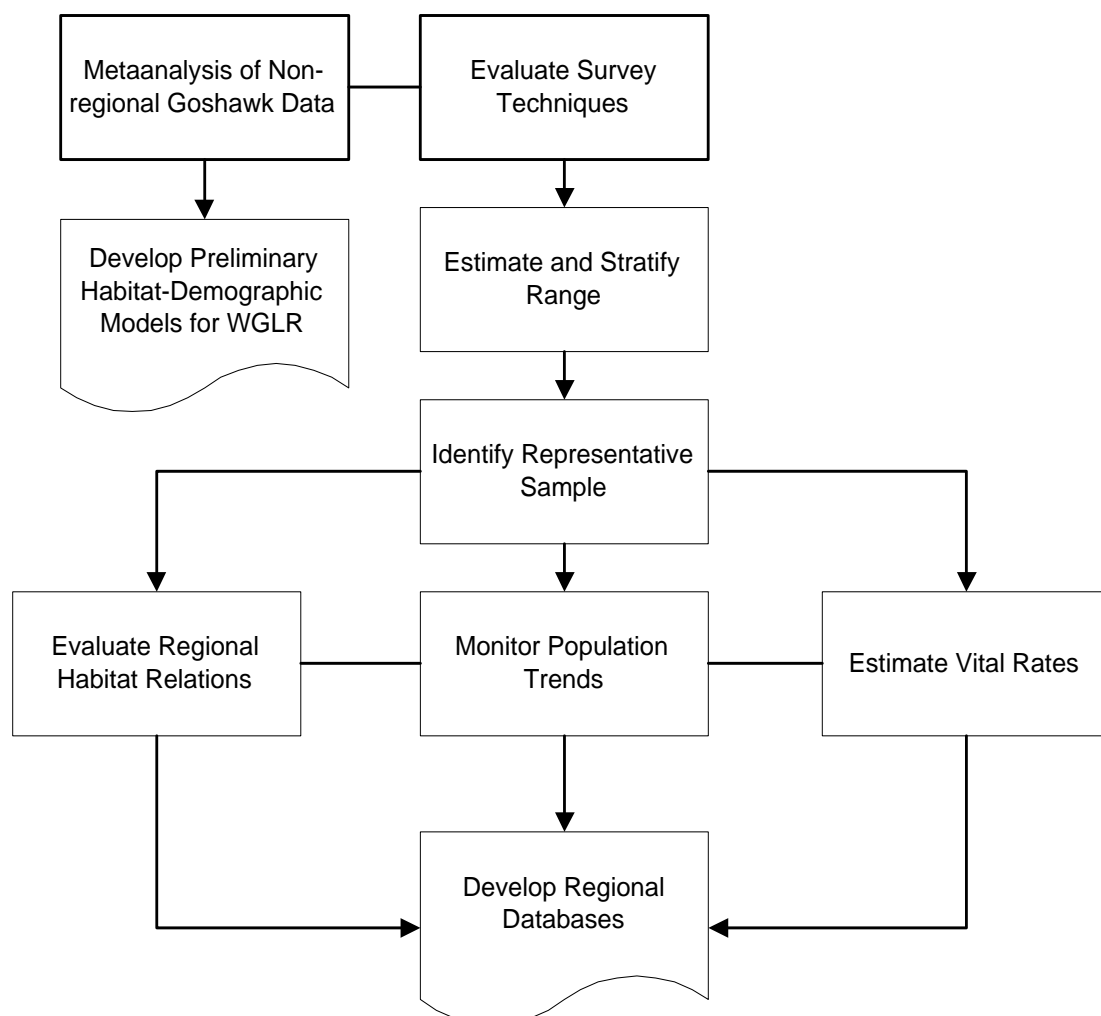
[8] N/A = not applicable.

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┌──────────────────────┐        ┌──────────────────────┐
│  Metaanalysis of Non-│────────│  Evaluate Survey     │
│  regional Goshawk Data│       │  Techniques          │
└──────────────────────┘        └──────────────────────┘
            │                               │
            ▼                               ▼
┌──────────────────────┐        ┌──────────────────────┐
│  Develop Preliminary │        │  Estimate and Stratify│
│  Habitat-Demographic │        │  Range               │
│  Models for WGLR     │        └──────────────────────┘
└──────────────────────┘                    │
                                             ▼
                            ┌──────────────────────┐
                            │ Identify Representative│
                            │ Sample               │
                            └──────────────────────┘

┌──────────────────────┐  ┌──────────────────────┐  ┌──────────────────────┐
│  Evaluate Regional   │  │  Monitor Population  │  │  Estimate Vital Rates│
│  Habitat Relations   │  │  Trends              │  │                      │
└──────────────────────┘  └──────────────────────┘  └──────────────────────┘
                                     │
                                     ▼
                          ┌──────────────────────┐
                          │  Develop Regional    │
                          │  Databases           │
                          └──────────────────────┘
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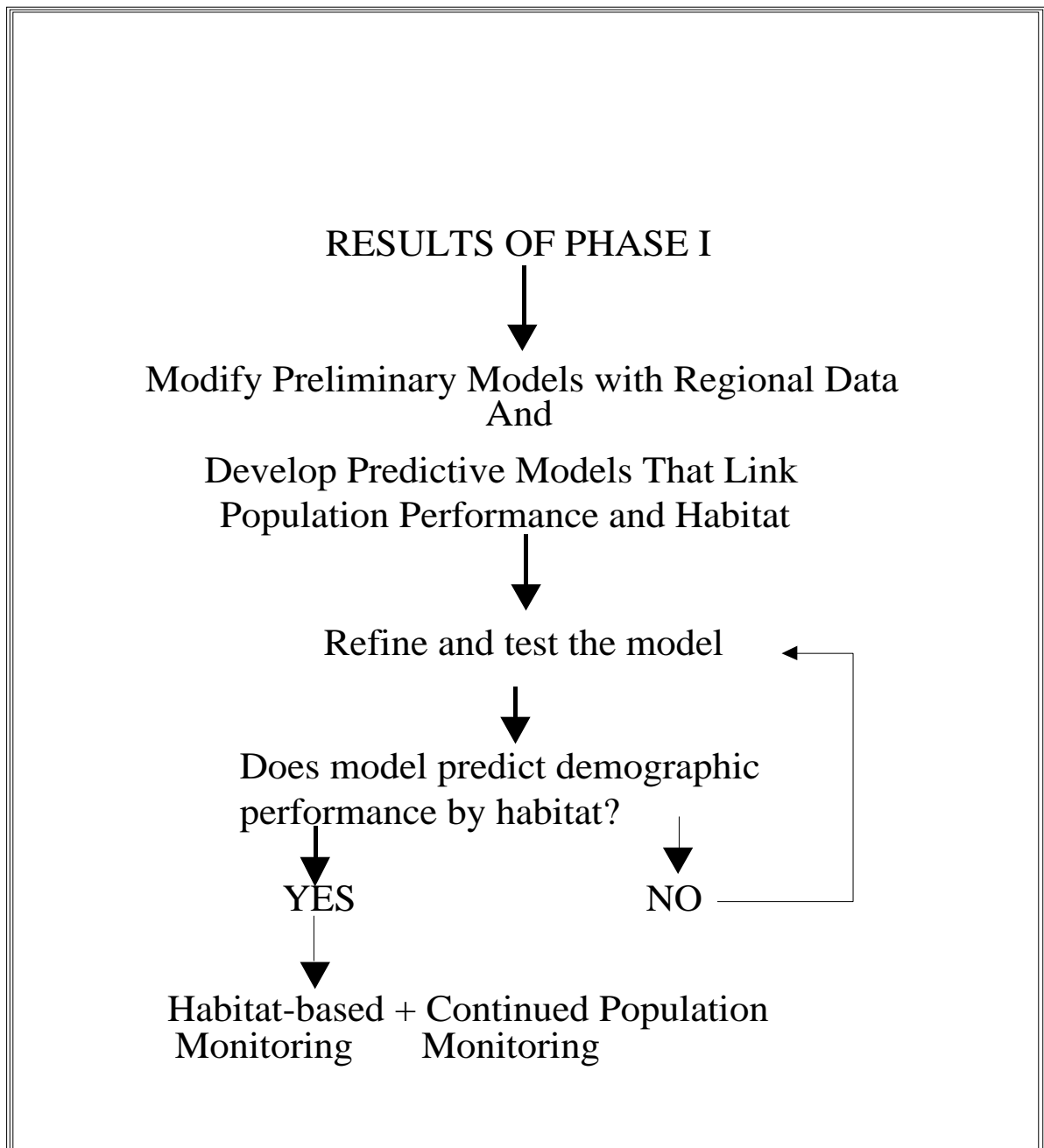
Fig. 1 Phase I of the Northern Goshawk research and monitoring program in the Western Great Lakes Region.

RESULTS OF PHASE I

Modify Preliminary Models with Regional Data
And

Develop Predictive Models That Link
Population Performance and Habitat

Refine and test the model

Does model predict demographic
performance by habitat?

YES   NO

Habitat-based + Continued Population
Monitoring   Monitoring

Fig. 2. Phase II of the Northern Goshawk research and monitoring program for the Western Great Lakes region.

A. Estimated breeding density for Western Great
   Lakes Region northern goshawks

B. 2X estimated breeding density for Western
   Great Lakes Region northern goshawks

5 YEARS

20 YEARS
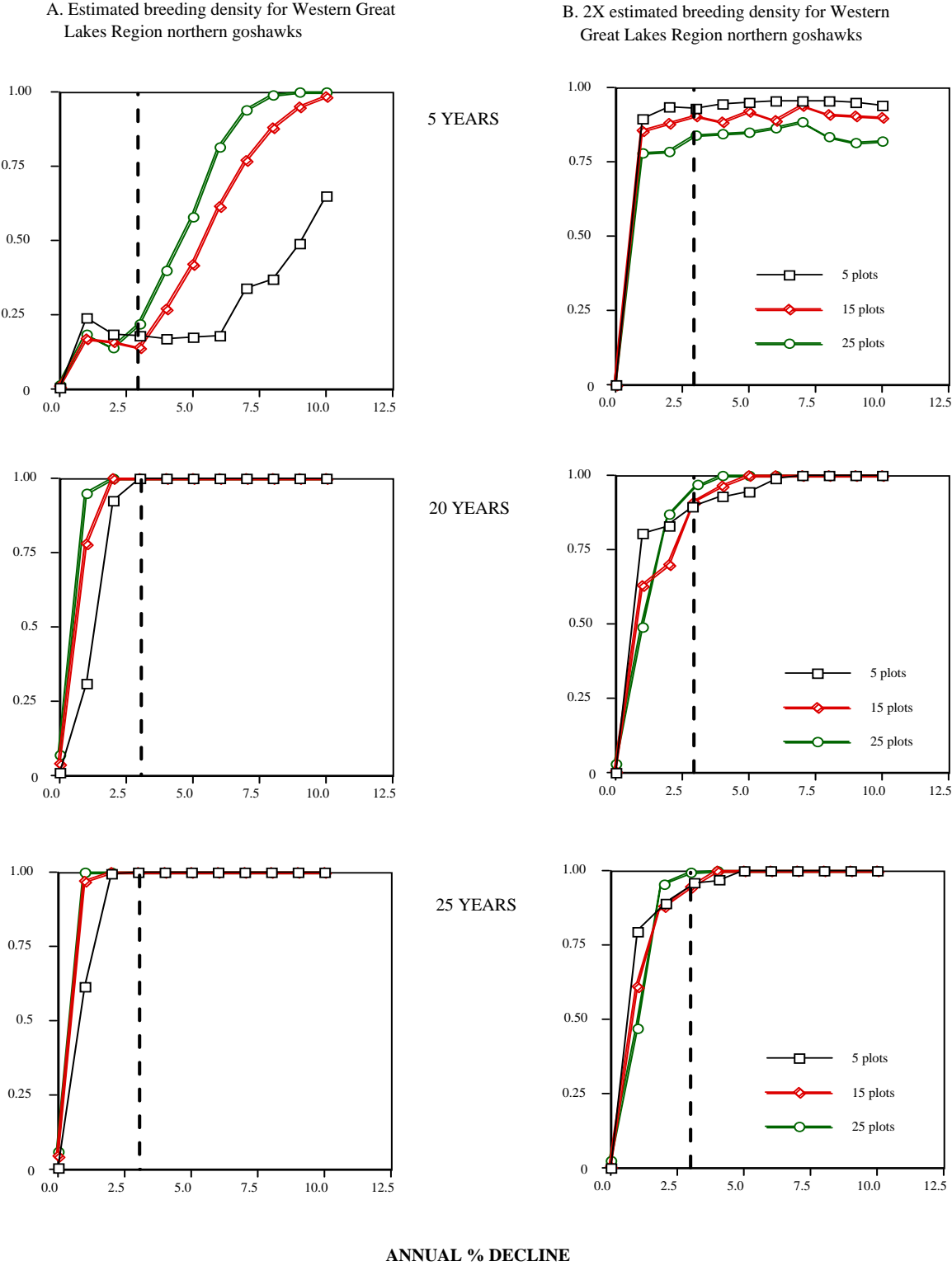
25 YEARS

ANNUAL % DECLINE

Figure 3. Results of power simulations for quadrat-based sampling to estimate trends in abundance of breeding northern goshawks in the WGLR. Power curves were constructed using program MONITOR (Gibbs and Melvin 1993, Gibbs 1995) based on 500 simulations. See text for a description of assumptions and variance estimates used in simulations. Simulations were conducted assuming breeding density estimated in Wisconsin (A) by Rosenfield et al. (1996) and twice the breeding denisty (B) estimated in Wisconsin. Dashed vertical line indicates an annual rate of decline equivalent to a 50% population decline over a 25-year period.
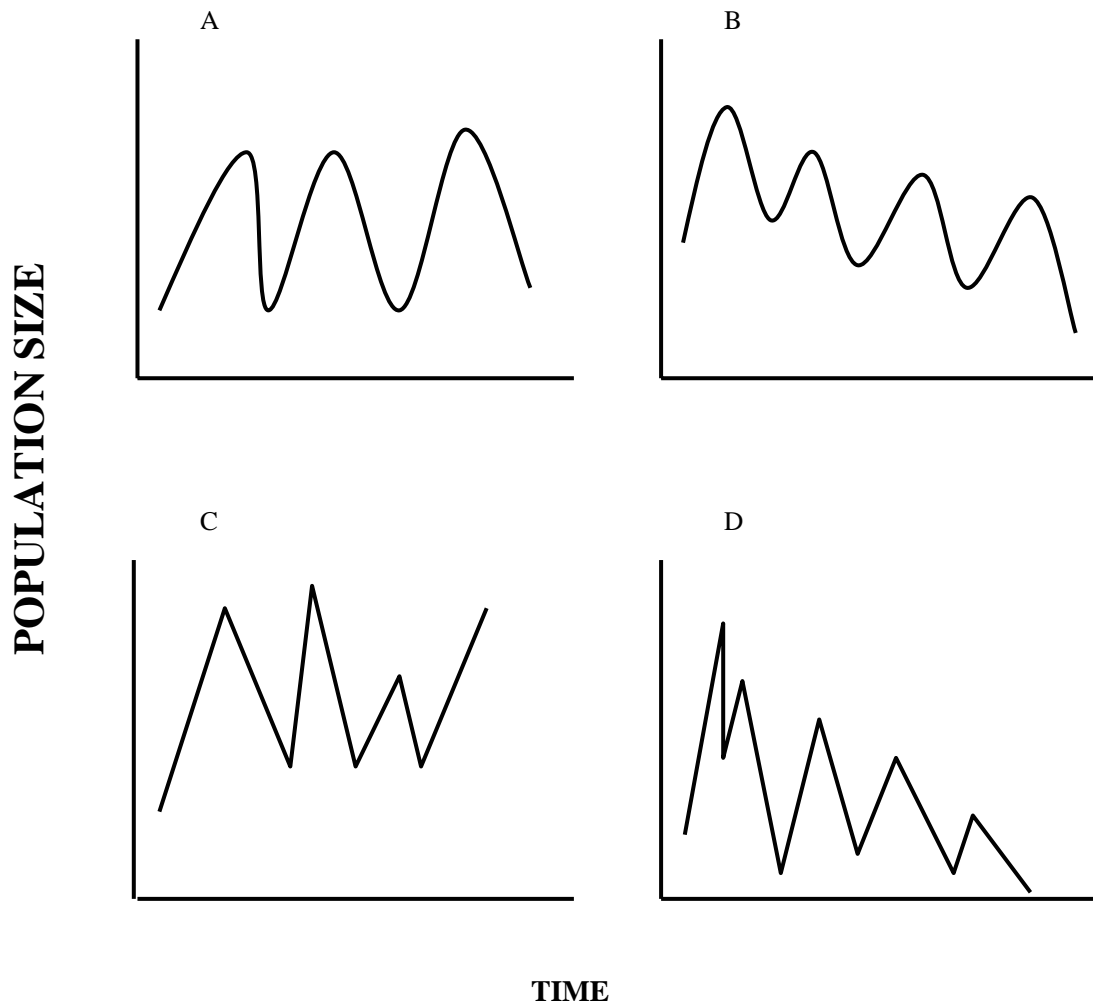
Figure 4. Examples of the potential interaction of population cycles, fluctuations and varying rates of change (stable and declining populations) on population trajectories of goshawks: A) cyclic and stable; B) cyclic and declining; C) irruptive (fluctuating) and stable; and D) irruptive and declining.

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