THE NORTHERN GOSHAWK: ECOLOGY AND MANAGEMENT

WILLIAM M. BLOCK, MICHAEL L. MORRISON, AND
M. HILDEGARD REISER, EDITORS

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William M. Block, Michael L. Morrison, and
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Cover drawing of Northern Goshawk and snowshoe hare by John Schmitt

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Edited by

John T. Rotenberry
Department of Biology
University of California
Riverside, California 92521

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LIST OF AUTHORS

RICHARD L. BASSETT
USDA Forest Service
Southwestern Region
517 Gold Ave., SW
Albuquerque, NM 87102

MARC J. BECHARD
Raptor Research and Technical Assistance Center
Department of Biology
Boise State University
Boise, ID 83725

WILLIAM M. BLOCK
USDA Forest Service
Rocky Mountain Forest and Range Experiment Station
2500 S. Pine Knoll Dr.
Flagstaff, AZ 86001

CLINT W. BOAL
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

THOMAS BOSAKOWSKI
Department of Biological Sciences
Rutgers University
Newark, NJ 07102
(present address:
Beak Environmental Consultants
12931 NE 126 Pl.
Kirkland, WA 98034)

DOUGLAS A. BOYCE, JR.
USDA Forest Service
Southwestern Region
517 Gold Ave., SW
Albuquerque, NM 87102

DONALD J. BRIGHT-SMITH
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721
(present address:
Department of Zoology
Duke University
Durham, NC 27708-0325)

EVELYN L. BULL
Pacific Northwest Research Station
1401 Gekler Lane
La Grande, OR 97850

SONYA K. DAW
Oregon Cooperative Wildlife Research Unit
Nash 104
Oregon State University
Corvallis, OR 97331

STEVEN M. DESIMONE
Oregon Cooperative Wildlife Research Unit
Nash 104
Oregon State University
Corvallis, OR 97331

STEPHEN DESTEFANO
Oregon Cooperative Wildlife Research Unit
Nash 104
Oregon State University
Corvallis, OR 97331

PHILLIP J. DETRICH
US Fish and Wildlife Service
Rm. E-1803
2800 Cottage Way
Sacramento, CA 95825

FRANK I. DOYLE
Kluane Lake Research Station
Mile 1054
Alaska Highway
Yukon Y1A 3V4

JAMES A. GESSAMAN
Department of Biology
Utah State University
Logan, UT 84322

RUSSELL T. GRAHAM
USDA Forest Service
Intermountain Research Station
1221 South Main
Moscow, ID 83843

PERRY J. HARDIN
Department of Geography
690 SWKT
Brigham Young University
Provo, UT 84602

CHRISTINA D. HARGIS
Department of Fisheries and Wildlife
Utah State University
Logan, UT 84322-5210
(present address:
USDA Forest Service
Intermountain Research Station
860 N. 1200 E.
Logan, UT 84321)

JANET E. HOHMANN
Pacific Northwest Research Station
1401 Gekler Lane
La Grande, OR 97850

CARL JOHANSSON
Department of Zoology
574 WIDB
Brigham Young University
Provo, UT 84602

SUZANNE M. JOY
USDA Forest Service
Rocky Mountain Forest and Range
Experiment Station
240 West Prospect
Fort Collins, CO 80526

JOHN J. KEANE
Department of Avian Sciences
University of California
Davis, CA 95616

PATRICIA L. KENNEDY
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, CO 80523

DOUGLAS G. LESLIE
USDA Forest Service
Rocky Mountain Forest and Range
Experiment Station
240 West Prospect
Fort Collins, CO 80526

ROBERT J. LILIEHOLM
Department of Forest Resources
Utah State University
Logan, UT 84322-5215

JAMES N. LONG
Department of Forest Resources and Ecology
Center
Utah State University
Logan, UT 84322-5215

R. WILLIAM MANNAN
School of Renewable Natural Resources
University of Arizona
Tucson, AZ 85721

CLINTON MCCARTHY
Custer National Forest
Billings, MT 59103

E. CHARLES MESLOW
Oregon Cooperative Wildlife Research Unit
Nash 104
Oregon State University
Corvallis, OR 97331

MICHAEL L. MORRISON
Department of Environmental Science, Policy,
and Management
University of California
Berkeley, CA 94720
(present address:
School of Renewable Natural Resources
325 Biological Sciences East
University of Arizona
Tucson, AZ 85721)

SUSAN PATLA
Department of Biological Science
Idaho State University
Pocatello, ID 83209

RICHARD D. PERLOFF
Inyo National Forest
Mammoth Lakes, CA 93514

M. HILDEGARD REISER
USDA Forest Service
Rocky Mountain Forest and Range
Experiment Station
2500 S. Pine Knoll Dr.
Flagstaff, AZ 86001

RICHARD T. REYNOLDS
USDA Forest Service
Rocky Mountain Forest and Range
Experiment Station
240 West Prospect
Fort Collins, CO 80526

GEORGE A. RINKER
Department of Physics
Colorado State University
Fort Collins, CO 80523

MELISSA S. SIDERS
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, CO 80523
(present address:
North Kaibab Ranger District
P.O. Box 248
Fredonia, AZ 86022)

JAMES N. M. SMITH
Department of Zoology
6270 University Blvd.
University of British Columbia
Vancouver, British Columbia V6T 1Z4

ROBERT SPEISER
13 Beam Place
Haledon, NJ 07508

JOHANNA M. WARD
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, CO 80523
(present address:
Mariah Associates, Inc.
605 Skyline Dr.
Laramie, WY 82070)

CLAYTON M. WHITE
Department of Zoology
574 WIDB
Brigham Young University
Provo, UT 84602

BRIAN WOODBRIDGE
USDA Forest Service
Klamath National Forest
37805 Highway 97
Macdoel, CA 96058

JAMES V. YOUNK
Raptor Research and Technical Assistance
Center
Department of Biology
Boise State University
Boise, ID 83725

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Symposium Overview

INTRODUCTION

WILLIAM M. BLOCK, MICHAEL L. MORRISON, AND M. HILDEGARD REISER

Forestry practices conducted since European settlement of North America have come under scrutiny, particularly with respect to their effects on the structure and functioning of ecological systems. Typically, this scrutiny has focused on vertebrate populations. This was especially evident in the case of the Northern Spotted Owl (*Strix occidentalis caurina*). Prior to 1983, numerous researchers working independently were studying the factors responsible for apparent population declines within the range of the owl. Unfortunately, the results of these studies were scattered and as an integrated whole not generally available to decision makers and other researchers. It was not until the 1984 symposium on the Ecology and Management of the Northern Spotted Owl—held 19–23 June 1984 in Arcata, California, as part of the 54th meeting of the Cooper Ornithological Society—that researchers and managers shared their findings, identified critical information gaps, and outlined directions for future research. Even though the debate continues, the initial symposium established the foundation for a concerted research effort in the years following.

The current situation with the Northern Goshawk (*Accipiter gentilis*), a raptor typically dependent on mature forests, bears an uncanny resemblance to that of the Northern Spotted Owl a decade ago. Within the past five years, evidence has arisen to suggest that populations of Northern Goshawks are declining, particularly in the western United States. Presently, the Northern Goshawk is regarded as a management indicator species of specific habitat conditions in many regions of the U.S. Forest Service and is a Forest Service Sensitive Species within the Rocky Mountain and Intermountain regions. The United States Fish and Wildlife Service has been petitioned twice within the past three years to list the goshawk as threatened or endangered under the Endangered Species Act. Likely, a third petition will be filed in the near future.

Although researchers are engaged in studies examining goshawk biology, no comprehensive, integrated research agenda underlies those efforts. Consequently, we felt that it was timely to assemble information on the biology of the Northern Goshawk (especially western populations) to assess our current state of knowledge. Thus, the symposium, The Biology and Management of the Northern Goshawk, was held on 14–15 April 1993 in conjunction with the 63rd annual meeting of the Cooper Ornithological Society in Sacramento, California.

The objectives of the symposium were (1) to assemble researchers and managers from across the country to exchange information and discuss ideas on the biology and management of the Northern Goshawk, and (2) to publish a compendium of current information on goshawk biology and management as a proceedings from the symposium.

We first contacted individuals who were conducting goshawk research. A call for papers was distributed nationally to reach researchers that we failed to contact initially. Our efforts resulted in a symposium that included 31 oral presentations.

Some of the results reported herein are from studies still in progress. Given the experience with the protracted debate over the Northern Spotted Owl, however, we felt that it was timely to publish these proceedings. To guarantee quality in these proceedings, all papers were required to go through a rigorous peer-review process and were held to the standards applied to submissions to *The Condor*. These 22 papers summarize the current state of knowledge on goshawks within the scientific and management communities. Sharing this information will allow researchers to critically evaluate past work, identify knowledge gaps, and develop strategies to focus on those needs in future studies.

These proceedings are presented in three sections. *Research Approaches and Management Concepts* contains overviews of research and management for goshawks, forest management to provide goshawk habitat, and field techniques. *Resource Ecology* focuses largely on habitat use at spatial scales ranging from landscapes to microhabitats. Also included are food habits papers. The section on *Population Ecology* includes papers on reproductive rates, survival rates, turnover, and numerical responses of goshawks to prey abundance.

This collection of papers represents the current state of knowledge on Northern Goshawks. Our intent is for these proceedings to serve as a springboard from which researchers will criti-

cally evaluate their work and that of others, and provide direction for future research. Only through such actions can researchers provide the information needed to guide timely and appropriate management for the species.

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These proceedings represent the culmination of efforts by numerous people. We thank D. A. Boyce and R. T. Reynolds for helping to identify symposium participants. K. E. Sieving and A. P. Gomez ensured that the symposium ran smoothly with their excellent logistic support. B. Witsell deserves special recognition for help tracking manuscripts through the review process. Special thanks to J. Verner and other members of the local organizing committee of the 63rd meeting for their support of the symposium. J. T. Rotenberry especially deserves credit for ensuring that these proceedings met the high standards of *Studies in Avian Biology* publications. Financial support for the proceedings was provided by the USFS—Rocky Mountain Forest and Range Experiment Station, and USFS—Forest Environment Research.

We also thank the following reviewers who helped improve the quality of the papers contained within these proceedings: M. J. Bechard, J. C. Bednarz, P. Beier, P. H. Bloom, C. E. Bock, T. Bosakowski, D. A. Boyce, J. B. Buchanan, L. A. Brennan, E. L. Bull, D. Call, P. J. Detrich, S. DeStefano, C. B. Edminster, T. C. Edwards, T. C. Erdman, E. D. Forsman, M. R. Fuller, J. L. Ganey, T. L. George, R. T. Graham, T. G. Grubb, L. A. Hall, G. D. Hayward, R. L. Hutto, J. J. Keane, P. L. Kennedy, T. J. Kimmel, W. S. LaHaye, J. F. Lehmkuhl, D. L. Leslie, R. J. Lilieholm, P. N. Manley, R. W. Mannan, J. P. McTague, H. C. Mueller, C. H. Sieg, W. Shepperd, J. N. M. Smith, J. Squires, K. Steenhof, T. J. Tibbitts, K. Titus, J. P. Ward, C. M. White, G. C. White, B. Woodbridge, and C. J. Zabel.

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Research Approaches and Management Concepts

NORTHERN GOSHAWK ECOLOGY: EFFECTS OF SCALE AND LEVELS OF BIOLOGICAL ORGANIZATION

JOHN J. KEANE AND MICHAEL L. MORRISON

Abstract. We develop a conceptual framework that addresses the effects of scale and levels of biological organization on ecological studies. We specifically consider Northern Goshawk (*Accipiter gentilis*) ecology relative to this framework. Traditionally, ecological studies have emphasized phenomenological, rather than mechanistic, explanations of ecological phenomena. Emphasis has focused on describing the general patterns of "how" an animal interacts with the environment. Less effort has been directed towards determining "why" we observe particular patterns; that is, what are the basic biological and ecological reasons for the phenomena that we observe? In our study area in the Sierra Nevada, California, we observed both individual and seasonal variation in the size of goshawk home ranges. We are developing an energetics model for goshawks and conducting detailed studies of the prey species used by goshawks. We will use these data to build up from an intensive understanding of the factors influencing an individual to explain the patterns at the more extensive scales. We argue that the intensive and extensive data needs that are required to develop conservation strategies should be based on a mechanistic understanding of the patterns observed. Predictions derived from phenomenological models assume that the conditions on which the model was constructed do not change. However, conservation planning requires quantitative predictions for systems that are often dynamic in both space and time, such as forests managed for timber production. Thus, emphasis should be placed on developing a mechanistic understanding of particular ecological phenomena to improve the predictive ability of conservation planning.

Key Words: *Accipiter gentilis*; conservation planning; home range; levels of biological organization; Northern Goshawk; Sierra Nevada; temporal and spatial scale.

Data needs for conservation planning require intensive and extensive field studies (Verner 1992). Addressing these needs will require studies that are conducted over various spatial and temporal scales and at different levels of biological organization. For example, spatial scales can vary from the microhabitat of a specific foraging site up through the landscape level. Temporal scales can vary from the duration of a foraging bout up through annual and geologic time scales. Additionally, levels of biological organization can vary from individuals through populations, communities, ecosystems, and landscapes. Correspondingly, interpretations of the observations we make will vary depending upon the scale and level of biological organization investigated (O'Neill et al. 1986, Wiens 1989, Gavin 1991, Levin 1992, Morrison et al. 1992). Indeed, differing interpretations of ecological phenomena that result from research conducted at different scales and levels of organization have impeded ecological advancement (Wiens 1986, 1989). Therefore, it is imperative that researchers explicitly identify the scale and level of organization that they study and define the domain to which their results are applicable. Our objectives are to (1) present a conceptual overview that considers the effects of scale and level of biological organization on ecological studies, (2) develop a conceptual framework that addresses Northern Goshawk (*Accipiter gentilis*) ecology, (3) present an example of a study design for investigating goshawk ecology, and (4) make recommendations for future research.

CONCEPTUAL OVERVIEW

The choice of scale and level of organization to be studied depends on the question being asked and should correspond to the natural scales of the phenomenon being studied (O'Neill et al. 1986, Wiens 1989). For example, to determine the geographic breeding range of the Northern Goshawk in California, a researcher would be concerned with a regional spatial scale. Similarly, if the question of interest was related to the daily activity budget of a goshawk, then one would be concerned with detailed observations of individuals. If the question was related to the role of goshawk predation in structuring forest wildlife assemblages, then a community level approach might be most appropriate.

Any phenomenon can be studied from a variety of perspectives at different scales. For example, goshawk nest sites can be studied from a microhabitat perspective that might consider the structure, composition, and stand size of the forest immediately around a nest. Alternatively, goshawk nest sites could also be studied from a perspective that considers the abundance and distribution of suitable nest stands over the land-

scape. Although these examples are not mutually exclusive, they illustrate the need to define clearly the objectives and scale at which the results will apply.

The questions asked in ecological studies can be fundamentally classified as "how" and "why" questions (Gavin 1991). "How" questions focus on how organisms interact with the environment and address the proximate cause of an observed phenomenon. For example, there are numerous studies on how animals forage, and what types of prey they consume. Alternatively, "why" questions focus on why an organism behaves or is structured as it is and what the effects of these traits are on survival and reproductive success. "Why" questions address ultimate causation (Gavin 1991). Here, we are asking why the animal uses (or selects) the prey that it does—what are the basic, biological and ecological reasons for the phenomenon that we observe?

The question we are fundamentally interested in answering is what determines survival and fitness in an individual (Martin 1992). The acquisition of energy and nutrients is obviously a basic determinant of these parameters—but how do we best measure them? Most studies in wildlife ecology, citing time and budgetary limitations, search for indirect measures of these parameters. Conventionally, researchers have measured a subset of an animal's habitat, usually vegetation, and derive correlative relationships between habitat variables and their use by an animal or the presence (or abundance) of the animal. These studies examine habitat use and describe the habitats irrespective of how they contribute to fitness (i.e., habitat quality). In this paper we adopt the definition of habitat use described by Hutto (1985), as not connotating a conscious choice by an organism, but merely indicating the distribution of individuals through some mechanism.

Ecological studies have traditionally emphasized correlative or phenomenological, rather than mechanistic, explanations of ecological phenomena (Wiens 1992). A pattern is observed and is explained in terms of a theory that predicts a linkage between pattern and process. Whereas the pattern is empirically measured, the explanation of the process is inferential (Wiens 1992). Applications of predictions derived from phenomenological models are constrained by the range of spatial and temporal variation encompassed in the data from which the model was constructed. If a phenomenological model is based on a narrow range of spatial and temporal conditions, then predictions from the model are limited because they assume that conditions do not change and that the phenomena on which the model is constructed adequately represent the underlying causal mechanisms (Koehl 1989). Further, most studies center on a specific scale, usually without reference to any other scale.

We can thus recognize research as a process involving different levels of inquiry and scale along a continuum, from intensive to extensive, and micro- to macro-scale. The finer the resolution of the study (i.e., the finer the scale), the closer we address the ultimate reasons, or "why", an animal is doing what it does. A knowledge of "why" organisms behave as they do, based on an intensive, mechanistic understanding of a phenomenon, should be the ultimate goal of research (Gavin 1991). Correlative, descriptive studies are initially necessary to determine patterns, but should serve as starting points for developing a more mechanistic understanding of a phenomenon. An intensive, mechanistic understanding of "why" individual organisms behave as they do will provide a foundation in which to interpret processes at higher levels of organization (Gavin 1991), and to increase the predictive ability of models developed for conservation planning. However, a mechanistic understanding of cause and effect cannot be inferred from correlative studies. Cause and effect relationships can only be proven through controlled experimental manipulations (Sokal and Rohlf 1981, Morrison et al. 1992). Unfortunately, due to the complex nature of most ecological systems, it is difficult to conduct controlled experimental manipulations. Thus, field researchers are often limited to correlative, descriptive studies.

Conservation planning requires quantitative predictions over relatively long time intervals and often must focus on systems where conditions are dynamic (e.g., changing spatial patterns of forests related to management practices). Thus, the key to successful habitat management is to understand what specific components of a species habitat most directly influence survival and reproduction (Kenward and Widén 1989, Martin 1992, Morrison et al. 1992). As discussed by Martin (1992), fitness parameters provide insight into the evolutionary basis for habitat requirements and choices, the effects on population recruitment and demography, and the life history traits of species and their implications for management. Information on survival and reproduction can be gained from detailed, intensive study of the habitat relationships of individuals. Long term demographic studies of marked individuals can provide measures of survival and reproductive output that can address habitat quality. Similarly, intensive studies of individuals can provide insight into the specific components of a habitat that explain the observed

patterns of habitat use. For example, Newton (1986) experimentally determined that the addition of food to female European Sparrowhawks (*Accipiter nisus*) in food-poor areas during the pre-laying period resulted in a significant increase in clutch size and earlier laying dates. Earlier laying dates were associated with higher nest success rates relative to pairs that layed later. Thus, intensive study of individuals can provide direct measures of survival and reproduction that would not be evident from correlative vegetation-abundance studies. Additionally, processes that occur at the level of the individual can produce the patterns observed at higher levels of biological organization (Koehl 1989, Real and Levin 1991).

NORTHERN GOSHAWK ECOLOGY: CONCEPTUAL FRAMEWORK

Rather than fluctuating randomly, raptor populations are usually regulated either by resources (e.g., nest sites, habitat, food supply) and/or human factors (e.g., pollutants, disturbance, persecution) (Newton 1979, 1989a, 1991). There is no present information indicating that pollutants have had a significant effect on goshawk populations in North America (Snyder et al. 1973). The major threat to goshawks is the loss or degradation of mature forests used for nesting and foraging, primarily due to timber harvesting, as well as to livestock grazing in aspen nest stands (Bloom et al. 1986, Reynolds 1989, Reynolds et al. 1992). In this section we consider Northern Goshawk ecology relative to the conceptual overview developed above to identify the knowledge that can be gained from ecological studies at the various scales and levels of inquiry.

At the broadest scale goshawks are associated with forests and woodlands throughout the Holartic (Brown and Amadon 1968). Within North America, goshawks are found in a variety of forested vegetation types (Palmer 1988). Extensive studies conducted at this scale are typically concerned with estimating population density or home range sizes in various vegetation types. For example, Reynolds and Wight (1978) reported the density of nesting goshawks in three study areas in Oregon. Similarly, Crocker-Bedford (1990) reported the density of nesting goshawks on the Kaibab plateau in Arizona. The results of these types of studies are quantitative descriptions of the observed patterns, often explained in terms of an unmeasured factor such as prey abundance or distribution. Thus, these types of studies provide the necessary initial description of the pattern. However, because they are not based on an understanding of the underlying mechanisms, the predictive ability of models derived from these data will be constrained by the amount of spatial and temporal variation encompassed in the data set. If the complete range of conditions have been described, then the model should have some predictability. If the study is time- and site-specific, then the predictability of the model will decrease as conditions change from those upon which the model is based.

Newton et al. (1986) provided an example of an extensive study that incorporated a wide range of spatial and temporal variation. Additionally they measured factors that seemed important in explaining the observed patterns. They determined that the nesting densities of European Sparrowhawks varied between 12 study areas. Additionally, the variation was correlated with variation in prey density, which was related to land productivity, which in turn was associated with elevation and soil type (Newton 1986, 1989a).

Within a vegetation type, researchers typically focus on the use of various plant associations by goshawks relative to their abundance within some spatial area, such as the home range. In this paper we define vegetation type based on structure and general composition (e.g., mixed conifer forest type) and plant association as based on the dominant genera or species (e.g., a stand of white fir [*Abies concolor*] within the mixed conifer forest type). Studies at this scale usually present data as a proportion of time spent within different plant associations. Interpretations of such data are thus based on the scale at which the plant associations are defined. They do not necessarily have any direct relation to why the goshawk is using this vegetation; they are thus describing a pattern rather than addressing the cause for the behavior. The use of plant associations by goshawks could be related to the distribution and abundance of prey, microclimatic factors, concealment from predators, as a buffer from human disturbance, and/or various other factors. Thus, studies that do not address these phenomena at the appropriate level of inquiry relative to the question asked will certainly fail to tell us why goshawks are behaving in the manner that they do.

What we need, then, are studies that explain why the phenomena that we observe occurred. The only way to do this is to determine the ultimate reasons for the behaviors. Such studies require intensive analysis at the scale of the individual. Such an approach has a higher probability of being applicable to a range of plant associations and vegetative types than any other approach. This is because this fine level of inquiry addresses factors that directly influence the survival and fecundity of an individual bird—

habitat selection, energy balance, nutrient status, and the like. Such factors are likely to apply broadly to goshawks across their range; at least within a subspecies, all individuals will fall within a similar range of physiological abilities.

Intensive analyses address the specific, direct causes for a behavior, rather than acting as surrogates of the behavior as is the case for vegetation type. For example, what is the relationship between the size and type of prey available, and the energetic requirements and health of a goshawk? Does a female goshawk require a certain fat level to breed successfully? Such questions likely determine survival and fitness. For example, Kenward and Widén (1989) demonstrated that, given adequate hunting perches, food appeared to be the main factor determining winter habitat use by goshawks in central Sweden. In woodland habitat, goshawks foraged more often along woodland edge zones that were the preferred habitat of their prey, brown hares (*Lepus europeas*) and pheasants (*Phasianus* spp.). In boreal forest habitat, goshawks did not show a preference for edges and tended to hunt more in large patches of mature forest. The main prey in the boreal forest were squirrels (*Sciurus vulgarus*), which were most common and more evenly distributed in mature woodland. By adopting an intensive approach, Kenward and Widén were able to determine the main factor (prey distribution) that influenced habitat use and gain insight into why they observed the patterns of habitat use by goshawks that they did.

STUDY DESIGN: AN EXAMPLE

Currently we are conducting a study of Northern Goshawk ecology in the Lake Tahoe region of the Sierra Nevada, California. Our study area is ca. 1000 km ^{2} and ranges between 1700–2275 m elevation. Forest types at lower elevations range from dry, open stands of Jeffrey pine (*Pinus jeffreyi*) to mixed conifer stands composed of Jeffrey pine and white fir along with various site-specific combinations of sugar pine (*P. lambertiana*), incense cedar (*Calocedrus decurrens*), and red fir (*Abies magnifica*). These forest types are replaced at higher elevations by red fir and white pine (*P. monticola*). Lodgepole pine (*P. contorta*) stands occur on sites with higher soil moisture (Orr and Moffitt 1971).

As discussed above, interpretations of ecological phenomena can vary depending upon the scale and level of biological organization investigated. Thus, our approach is to examine goshawk ecology over a range of extensive and intensive scales and levels of inquiry. For example, at an extensive level we are quantifying the breeding density and home range sizes of goshawks over the landscape. Goshawks in our study area remain on their territories throughout the year, with increased home range sizes in the nonbreeding period. Radio-telemetry data from five pairs of goshawks during 1992 illustrated a range of both individual and seasonal variation in home range sizes (Table 1). Ninety-five percent minimum convex polygon home ranges averaged 18.8 km^2 (range 11.4–29.5) during the breeding period and 83.6 km^2 (range 13.4–154.3) during the nonbreeding period for males, whereas female home ranges averaged 12.8 km^2 (range 6.9–32.8) during the breeding period and 31.8 km^2 (range 12.2–40.1) during the nonbreeding period.

Home range sizes were compared between sexes within each season and within sex between seasons using Mann-Whitney U-tests (Zar 1984). The nonparametric Mann-Whitney U-test was used because the data did not meet the assumptions necessary for a parametric test (Zar 1984). No significant differences in home range size were found for male versus female breeding season ($P = 0.20$), male versus female nonbreeding season ($P = 0.20$), male breeding versus nonbreeding season ($P = 0.10$), and female breeding versus nonbreeding season ($P = 0.05$). However, the results of three of these tests were strongly influenced by an individual data point. For example, the pair #4 female had a breeding season home range of 32.8 km^2, whereas the other four females had breeding home ranges between 6.9–8.4 km^2 (Table 1). This female moved approximately eight km away from the nest area during the post-fledging period of the nesting cycle for 2–3 weeks and returned to the nest area just as the one fledgling was dispersing. The other females moved out of the immediate nest area but continued to return for prey deliveries during the post-fledging, pre-dispersal period (Keane, unpubl. data). Thus, the tests comparing male versus female breeding season and female breeding versus nonbreeding season were influenced by this data point. When this data point was excluded from the analyses, significant differences were found for both male versus female breeding season ($P = 0.02$) and female breeding versus nonbreeding season ($P = 0.02$) comparisons.

Therefore, other than for the pair #4 female, males had larger home ranges than females in the breeding season and females had larger home ranges in the nonbreeding season than in the breeding season. Similarly, the test for male breeding versus nonbreeding season home range size was strongly influenced by the pair #3 male, who decreased his home range size in the nonbreeding period (Table 1). We are not sure of the reasons why this was observed. The other four males increased home range size in the nonbreeding period (Table 1). If the nonbreeding season value for the pair #3 male is excluded

from the analysis, then males had larger nonbreeding than breeding season home ranges (P = 0.02).

In summary, males had larger breeding season home ranges than females, except for the pair #4 female. There were no significant differences in home range size between sex during the nonbreeding season. All individuals except one (pair #3 male) increased home range size in the nonbreeding period. Although females increased home range size in the nonbreeding period, they continued to return to, and center, their activities near the nest area (Keane, unpubl. data).

To understand why we observe the patterns of home range and habitat use that we do, we are adopting an intensive approach to identify the factors that influence individuals. Our goal is to understand the energy requirements of individual goshawks, their diets, and the distribution, abundance, and habitat relationships of prey in the study area to be able to build up from the intensive level to explain the patterns observed at the extensive scales and levels of inquiry.

We are attempting to construct a model of goshawk energetics to estimate the energy required both for survival and for breeding. Three methods that have been used to estimate energy requirements are time-budget models (Walsberg 1983), allometric scaling models (Nagy 1987), and the doubly-labeled water technique (Nagy 1987, Tatner and Bryant 1989). Time-budget models are based on determining the proportion of time spent by an organism in various activities and then summing the energetic cost of each activity to yield an estimate of energy expenditure. Allometric scaling models predict energy demands based on body mass, diet, and habitat. The doubly-labeled water method measures metabolic rate by determining the turnover rate of hydrogen and oxygen isotopes, injected in the form of water, through water and CO_2 loss from the organism.

Time-budget models can provide accurate measures of energy expenditure, but require the use of measured energy equivalents for each of the various activities, as well as detailed knowledge of the thermal environment around the organism (Weathers et al. 1984, Buttemer et al. 1986, Nagy 1989). Time-budget models that do not empirically determine energy equivalents for each activity, and use estimates derived from the literature, are subject to errors of 20–40%, which may be no better than the rough approximations available from allometric models (Weathers et al. 1984). We plan to measure time-activity budgets (Widén 1984) and to use the doubly-labeled water technique to measure the energetic requirements of breeding adult Northern Goshawks. This information, along with the caloric value of the various prey species, will enable us to estimate the amount of food necessary to support a pair of breeding goshawks.

TABLE 1. ESTIMATED SIZE (KM^2) OF HOME RANGES FOR FIVE MALE AND FIVE FEMALE NORTHERN GOSHAWKS IN THE LAKE TAHOE REGION, CALIFORNIA, DURING THE BREEDING AND NONBREEDING SEASONS, 1992–1993. HOME RANGE SIZES ESTIMATED AS MINIMUM CONVEX POLYGONS FROM RADIO TELEMETRY DATA. BREEDING: JUNE–15 AUGUST 1992; NONBREEDING: 15 AUGUST 1992–MARCH 1993

		Season			
		Breeding		Nonbreeding	
Pair no.	Sex	95%	100%	95%	100%
1	Male	15.6	22.8	39.4	164.2
	Female	8.4	10.1	37.1	42.4
2	Male	21.9	36.7	154.2	160.7
	Female	8.3	13.7	40.1	97.2
3	Male	15.8	25.6	13.4	58.1
	Female	6.9	9.2	38.5	90.3
4	Male	29.5	33.7	96.1	129.3
	Female	32.8	36.4	12.2[1]	29.5
5	Male	11.4	19.6	114.8	148.8
	Female	7.8	9.7	31.3	42.6

[1] Contact was lost with this individual on 22 December 1992.

In addition to measuring energetic requirements, we are conducting inventories of the prey species to measure their distribution, abundance, and habitat relationships. On six sites within goshawk home ranges on our study area we have established a grid of sample points 300 m apart along transect lines in the various plant associations present. About 300 points have been established throughout the study area. We are conducting monthly point counts to measure bird and Douglas squirrel (*Tamiasciurus douglasii*) abundance at about 175 of the sample points, chosen to represent the range of plant associations present. We also are studying the foraging behavior of avian prey species of goshawks to quantify their microhabitat use patterns. Small mammal live-trapping is being used to sample squirrel and chipmunk distribution, abundance, and habitat relationships. Pellet counts are being used to determine relative abundance and distribution of snowshoe hares (*Lepus americana*).

Data on prey abundance, distribution, and habitat relationships will be compared with data on home range size and foraging habitat use to determine if they explain the patterns that we observe. For example, changes in prey abundance could be the reason why goshawks expand home ranges in the nonbreeding season. Similarly, prey abundance could explain the use of the various plant associations, as well as annual variation in goshawk productivity. However, it

must be noted that measures of prey abundance and distribution do not necessarily provide a direct measure of prey availability (Hutto 1990). Hutto (1990) concluded that a fundamental obstacle to understanding the relationship between habitat use and food availability requires identifying the possible constraints on what subset of habitats and foods it is possible for a bird to use. By constructing an energetics model for goshawks we will be able to determine caloric needs and possible energetic constraints that influence goshawk ecology.

FUTURE DIRECTIONS IN GOSHAWK RESEARCH

We concur with Verner (1992) that both intensive and extensive field studies are needed to provide the critical data needed for conservation planning. We suggest that, rather than trying to synthesize the results of numerous time- and scale-specific studies at sometime in the future, coordinated efforts and funding be directed into a smaller number of more comprehensive studies that consider goshawk ecology over both intensive and extensive scales and levels of inquiry. Explicit within this approach would be a clear definition of goals and objectives that would serve to standardize procedures both within and between studies. Over the long term, this approach would increase efficiency in terms of funding expenditure and the generation of the critical data needed for conservation planning.

Integrating across scales and levels of organization would be a primary objective of this approach. At the landscape level, recent work indicates the importance of considering demographic rates (mortality, fecundity, dispersal, etc.) relative to the amount, configuration, and dynamics of habitat (e.g., Van Horne 1983, Gilpin 1987, Lande 1987, Pulliam 1988, Harrison 1991, Howe et al. 1991, Pulliam and Danielson 1991). A fundamental question at the population level is to determine the factor or interaction of factors that limit population density or size. As noted by Newton (1991), two populations can have identical demographic schedules even though they can differ significantly in density or size. Given that the probability of extinction due to chance is inversely related to population size (Goodman 1987), it is important to understand the factor or factors that limit population size. For example, Widén (1989) summarized the results of several studies of goshawk nest density and found that densities were higher in areas with greater food availability. He concluded that the evidence strongly indicated that goshawks are normally limited by food availability and that foraging habitat may be more important than nesting habitat for goshawks in boreal forests. Similarly, Doyle and Smith (this volume) documented the importance of annual variation in food availability on goshawk reproduction in boreal forests. Thus, a knowledge of the external factors that limit population size is required if the goal of a particular conservation strategy is to implement management practices to increase population size (Newton 1991). It must be clearly noted that higher levels of organization, such as "populations", are often artifacts constructed by researchers for management purposes. In some cases populations can be defined based on demographic data, particularly in relatively more isolated areas such as the goshawk population on the Kaibab Plateau (Reynolds et al. this volume). However, often the area used to define a "population" is determined by administrative or geographic convenience. For example, we might refer to the goshawk "population" of a specific ranger district without knowledge of immigration or emigration rates.

Studies of variation in demographic rates related to habitat variation clearly indicate the importance of considering the relationship between fitness and habitat quality (Van Horne 1983, Pulliam 1988). As discussed previously, detailed studies of individuals can provide insight into the factors that influence fitness and can be used to interpret processes observed at more extensive scales. At the individual level, the spatial scale of the nesting area and foraging areas are important determinants of fitness. For example, Newton (1989b) documented that territory quality was a major factor associated with lifetime reproductive success in sparrowhawks. Individuals on high quality territories exhibited increased longevity, which resulted in increased lifetime reproductive success relative to individuals on lower quality territories.

Detailed, long-term investigations of individuals are also necessary to determine relationships between habitat quality and fitness. For example, Schnell (1958) and Boal and Mannan (this volume) provide detailed dietary studies from individual pairs of nesting goshawks. Similarly, Widén (1989) investigated habitat use by goshawks in relation to forest structure and prey abundance. Regarding nesting habitat, Woodbridge and Detrich (this volume) addressed habitat quality through a study of marked individuals that considered long-term territory occupancy rates across time and spatial scales that ranged from nest trees to nest stand size to clusters of nest stands.

To implement the approach we advocate would require initiating a long term demographic study of marked individuals. Within this demographic framework, intensive studies of individuals could

be conducted that address the factors that influence fitness. This is the approach we have taken in our study of goshawk ecology in the Sierra Nevada. Similarly, Reynolds et al. (this volume) have taken this approach for their study of goshawk ecology on the Kaibab Plateau in Arizona. Based on an understanding of goshawk ecology over a variety of scales and levels of organization it might then be feasible to conduct especially insightful experimental manipulations. Silvicultural prescriptions could then be evaluated in an adaptive management context (Walters 1986, Walters and Holling 1990, Irwin and Wigley 1993) as to their effect on goshawk foraging and nesting habitat at the individual level and to their effect on the population at the landscape level. The results from studies such as that we outline would yield the extensive level data necessary for demographic analyses, as well as, provide the intensive level data needed to understand why goshawks do what they do.

It might be argued that, despite the apparent merits of the approach we outline, funding seldom will be available to support these kinds of intensive studies. Most wildlife research dollars traditionally support graduate students for 1–3 years of work. We argue that it would be better for such students to determine the factors that ultimately relate to survival and reproduction of only a few pairs of goshawks than it would be to produce yet another study of home range that is time- and site-specific. The former addresses ultimate causation and can build towards a more thorough understanding of goshawk biology, whereas the latter provides only a broad-scale, time- and site-specific description of a pattern and must speculate as to the cause and effect relationships.

In conclusion, there is an increased demand for critical data to design conservation plans for the Northern Goshawk. Rather than reinventing the wheel, goshawk researchers should reap the benefits of the valuable lessons learned in conservation planning for the Northern Spotted Owl (*Strix occidentalis caurina*) (Thomas et al. 1990, Carey et al. 1992, Verner 1992, Verner et al. 1992, Harrison et al. 1993), specifically, that the data most vitally needed for conservation planning require both intensive and extensive field studies. In meeting these data demands, researchers should strive to understand the causal mechanisms underlying the patterns observed.

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SUSTAINING FOREST HABITAT FOR THE NORTHERN GOSHAWK: A QUESTION OF SCALE

RUSSELL T. GRAHAM, RICHARD T. REYNOLDS, M. HILDEGARD REISER, RICHARD L. BASSETT, AND DOUGLAS A. BOYCE

Abstract. The nest area, post-fledging family area, and foraging area are critical home range components for maintaining Northern Goshawk (*Accipiter gentilis*) populations. Each of these forest components has a specific purpose in the life history of the Northern Goshawk and each contains several important attributes, ranging from forest structure to forest floor characteristics. The way in which home range components in a forest regenerate, develop, and die is highly variable, both temporally and spatially. Therefore, forests need to be regenerated and tended to ensure that a portion of a goshawk's home range is in old forests indefinitely. This can be best accomplished by analyzing and managing large tracts of forests as sustainable ecological units rather than managing smaller tracts of forests as individual home ranges.

Key Words: *Accipiter gentilis*; ecosystem analysis; forest management; home ranges; Northern Goshawk; sustainability; vegetative structural stage.

The Northern Goshawk (*Accipiter gentilis*) is a top-level consumer that occupies many forest types in the western United States. However, in some localities there are indications that populations are declining because of habitat loss due to tree harvesting (Herron et al. 1985, Crocker-Bedford 1990). Because little information exists on the number of breeding pairs in these forests, it is prudent to identify and conserve goshawk habitat to prevent populations from declining or individuals from becoming isolated. The identification and conservation of every goshawk home range is important (Reynolds et al. 1992). Forest management recommendations that sustain forest composition and structure necessary for goshawk habitat have been developed (Reynolds et al. 1992). These recommendations were primarily for use in the southwestern United States but they are being adapted for use in other areas of the West.

The nesting home range of goshawks contains three components: the nest area, the post-fledging family area, and the foraging area, each with its individual characteristics and management requirements. Forest management recommendations for the goshawk were developed on the premise that considerable information was available on nesting habitats (Schnell 1958, Reynolds and Meslow 1984). Throughout the western United States goshawks are known to nest and hunt successfully in a wide variety of forest types and structures (Fischer 1986, Kenward and Widén 1989), indicating that foraging habitat may be as closely tied to prey availability as to forest structure or composition. Another important component of goshawk habitat is the area surrounding the nest that is used by fledglings until they are no longer dependent on the adults for food. This intensively used area has been termed the post-fledging family area or PFA (Reynolds et al. 1992). If goshawks winter on or near their nesting home ranges, it should be possible to maintain goshawk populations by maintaining these three habitat components. This paper describes the difficulties of implementing the goshawk recommendations (Reynolds et al. 1992) and provides suggestions for analyzing and managing sustainable ecological units rather than individual goshawk home ranges.

NESTING HOME RANGE COMPONENTS

Nest areas have been thoroughly studied and are readily identified by vegetation structure (Reynolds et al. 1982, Reynolds 1983). Nest areas include one or more forest stands, several nests, and several landform characteristics. The size and shape of nest areas depend on topography, and on the availability of dense patches of large trees ranging in size from 8 to 12 ha. Within a given forest type, characteristics of nest areas can vary depending on forest productivity (defined as the amount of vegetation a site can support and how quickly it accumulates). Nest areas within highly productive forests have more trees and denser canopies than nest areas in less productive forests. Similarly, tree ages in a nest area can be highly variable, depending on forest type. For example, aspen (*Populus tremuloides*) and lodgepole pine (*Pinus contorta*) are much shorter-lived than western hemlock (*Tsuga heterophylla*) or western redcedar (*Thuja plicata*).

Surrounding the nest area is the PFA and foraging area mosaic. The PFA is a 170-ha (range = 120–240 ha) mosaic of large trees, large snags, midaged forests, small openings with a herbaceous understory, and large, downed logs. The foraging area is 2200 ha (range = 2000–2400 ha)

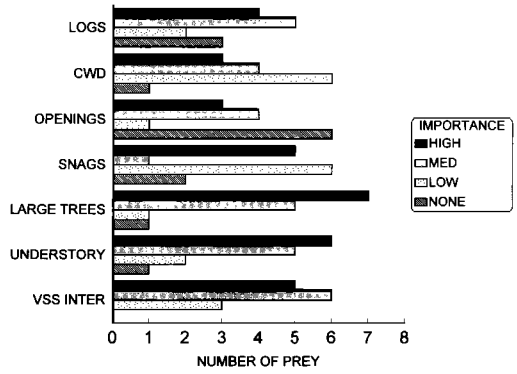

FIGURE 1. Relative importance of special habitat attributes for maintaining sustainable populations of 14 selected northern goshawk prey (Reynolds et al. 1992). Logs = downed logs >45 cm in diameter; CWD = coarse woody debris >7.5 cm in diameter; opening = breaks in forest canopy; snags = dead trees >45 cm in diameter and >9 m tall; large trees = live trees > 45 cm in diameter; understory = presence of herbaceous and shrubby species; VSS inter = interspersion of vegetative structural stages.

of forest that provides the food base for nesting goshawks. This area contains the habitat for larger birds and mammals that serve as prey. A wide variety of these animals are found in the diets of goshawks. They vary from mourning doves (*Zenaida macroura*) and Steller's jays (*Cyanocitta stelleri*) to chipmunks (*Tamias* spp.) and red squirrels (*Tamiasciurus hudsonicus*). The foraging area provides conditions for these animals to thrive, and also provides opportunities for the goshawk to hunt and capture them.

The foraging area is similar in structure to the PFA, with large trees, openings, snags, and downed logs interspersed throughout. An important component of both the PFA and foraging area is the development of hypogeous (underground) fungi, whose fruiting bodies provide food for many small animals. Many of these fungi are also ectomycorrhizal symbionts that play an important role in the uptake of water and nutrients by forest plants. Moreover, these organisms have a positive relationship with the amount of organic materials (e.g., humus, decayed wood) in the forest floor and surface mineral soils (Harvey et al. 1987). Therefore, maintaining ectomycorrhizae habitat through forest management practices will contribute to both the maintenance of forest vegetation and populations of small animals in both the PFA and foraging area.

RECOMMENDED FOREST CONDITIONS

Goshawks prey on over 50 species of birds and mammals throughout their western range. Reynolds et al. (1992) selected 14 prey species that were of particular importance to the goshawk in the Southwest. Using the habitat characteristics associated with high, medium, and low populations of these 14 species, they summarized the importance of snags, downed logs, woody debris, openings, large trees, understory vegetation, and interspersion of forest vegetative structural stages (VSS) in goshawk foraging areas. VSS is a generalized description of forest age and tree size (diameter) from seedling to old forests (see Thomas et al. 1979, Reynolds et al. 1992 for further discussion on forest structural stages). The six VSS for southwestern forests were defined as grass/forb/shrub, seedling, young forest, midaged forest, mature forest, and old forest. Large trees, understory herb and shrub development, and the interspersion of the VSS were the most important characteristics for maintaining high and medium populations of goshawk prey (Fig. 1).

Also important to the prey are the amount and characteristics of the VSS in the foraging area. Reynolds et al. (1992) determined that midaged to old forests were the most important of the VSS for maintaining medium and high populations of goshawk prey (Fig. 2). The prey needed to maintain medium and high populations of goshawks required a minimum of a 2800 ha landscape of midaged, mature, and old forests, interspersed with openings and patches of small trees (saplings and young trees). This analysis showed the importance of VSS, but did not quantify the distribution of the VSS needed in the PFA and foraging area.

DISTRIBUTION OF VSS

The structure of naturally occurring forests depends on the rate of regeneration, growth, and mortality of forest vegetation and all of the interactions affecting these processes. In western hemlock and similar forest types, it usually takes less than 3 years for new seedings to become established after a disturbance (Haig et al. 1941). Trees may take more than 25 years, however, to become established in some ponderosa pine (*Pinus ponderosa*) forests (Pearson 1950). Forest growth is also highly variable, depending on forest type, site quality, and forest density (Schmidt 1988, Edminster et al. 1991). Natural life expectancy can be as brief as 10 years for Gambel oak (*Quercus gambelii*) to more than 450 years for Engelmann spruce (*Picea engelmannii*), even though 80-year-old Gambel oak and 600-year-old Engelmann spruce have been reported (Brotherson et al. 1983, Alexander and Shepperd 1990). Fire, insects, and diseases also play important roles in the longevity of western forests.

Although late-seral and old forests are pre-

ferred for goshawk habitat, forest vegetation is not constant but is dynamic and ever changing. Moreover, trees are mortal. They die, regenerate, and grow, making it impossible to maintain all, or even a majority of a forest in late-seral and old stages. Because of the dynamic nature of forests, transitional structural stages must be present to continuously replace these old forests. Therefore, to sustain goshawk habitat in southwestern ponderosa pine forests, approximately 10 percent of the forest needs to be regenerated every 20 years. This assumes 20 years for tree establishment and a moderate level of forest density control occurring naturally by either fire, wind, snow, or by human management. Because of tree growth rates, approximately 19% can be maintained as young forest, 17% as midaged forest, 20% as mature forest, and 24% as old forest in which trees over 200 years old may exist (Bassett et al., this volume).

In shorter-lived lodgepole pine and aspen forests or in a western hemlock forest where longevity is longer the VSS distribution required to sustain these forests would be different than those required for a ponderosa pine forest. Because the VSS distribution required to perpetuate a forest varies by forest type and density, Reynolds et al. (1992) generalized the distribution of VSS for forests in the Southwest. These generalized VSS distributions are 10% in regeneration openings, 10% in saplings, 10% in young forests, 20% in midaged forests, 20% in mature forests, and 20% in old forests. Therefore, the distribution of VSS for sustaining goshawk habitat in the Southwest was not related to the goshawk or its prey, but was based on the forest productivity, dynamics, and biological limitations.

Combining the habitat attributes (e.g., snags, downed logs) (Fig. 1) and the desired VSS distribution (Fig. 2), a desired forest structure for maintaining a prey base for goshawks was determined. This information, in combination with the knowledge of the nesting habitat preferred by the goshawk, led to recommended management and forest conditions for the nesting home range components of nest, PFA, and foraging areas (Reynolds et al. 1992).

SUSTAINING GOSHAWK HABITAT

Because of the suspected loss of goshawk habitat (Crocker-Bedford 1990), sustaining the recommended VSS distribution is the management objective for most areas that contain goshawks. Present forest conditions can be compared to the desired distribution of VSS for each nesting home range, and appropriate management strategies can be developed to sustain the desired forest structure. For example, if the present conditions of a foraging area in a single-species forest (e.g., ponderosa pine) had an excess of mature and old forest compared to the desired VSS distribution, regeneration could be planned to ensure a continual movement of trees through the VSS (Fig. 3). Alternatively, if young and midaged forests were in excess, these VSS could be thinned, freeing them to grow into the mature and old forest size-classes (Fig. 3). These examples of management options for sustaining goshawk habitat are for single-species forests with relatively simple structures.

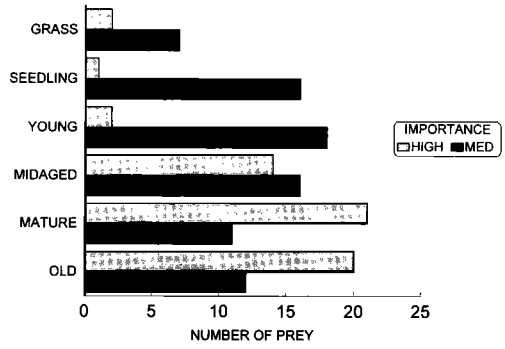

FIGURE 2. Relative importance of vegetative structural stages for habitat of selected prey species (Reynolds et al. 1992). The VSS were defined as grass = grass/forb/shrub and trees <2.5 cm in diameter; seedling = 2.6–13 cm trees; young = 14–30 cm trees; midaged = 31–46 cm trees; mature = 47–61 cm trees; old = >62 cm trees.

During the past 200 years most of the forests of the Southwest have been influenced by fire suppression, timber harvest, and grazing by both domestic animals and wildlife (Dieterich 1983, Brawn and Balda 1988, Stein 1988). These influences have affected forest successional processes, creating forests that often have high tree densities, multiple forest canopies, and species compositions outside the range of natural variability, making them susceptible to disease and insect attack, and to forest replacing wildfires (Habeck and Mutch, 1973). If the recommended VSS distribution for the goshawk is applied based on the proportion of the foraging area in the various vegetative structural stages without regard to species composition, treatments could create an unstable forest environment. For example, if the present forest conditions showed an excess of mature and old ponderosa pine over a smaller size class of white fir (*Abies concolor*) and there was a shortage of midaged and young trees compared to the desired forest structure, the preferred treatment could be to remove the large ponderosa pine, making the distribution conform to the desired VSS. But the consequences of these actions would be a justification to harvest the large trees, creating a forest prone

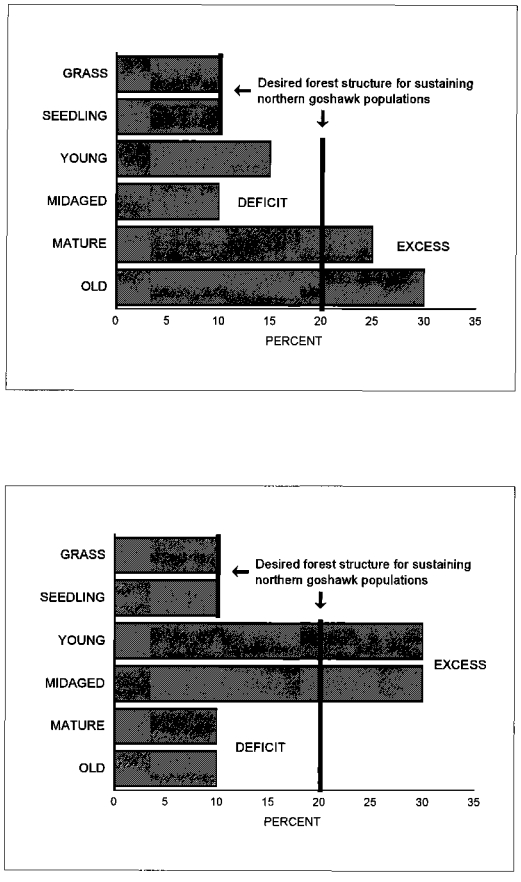

FIGURE 3. The top figure illustrates the distribution of the vegetative structural stages (VSS) for a hypothetical goshawk foraging area compared to the desired distribution as presented by Reynolds et al. (1992). The example shows an excess of trees in the mature and old-forest classes and a deficit in the young and mid-aged forest classes. Management activities in a forest with this structure could be designed to develop more young and midaged forests through regenerating a portion of the mature and old classes. The lower figure illustrates a forest structure that would benefit from thinning of the young and midaged VSS encouraging the development of mature and old VSS.

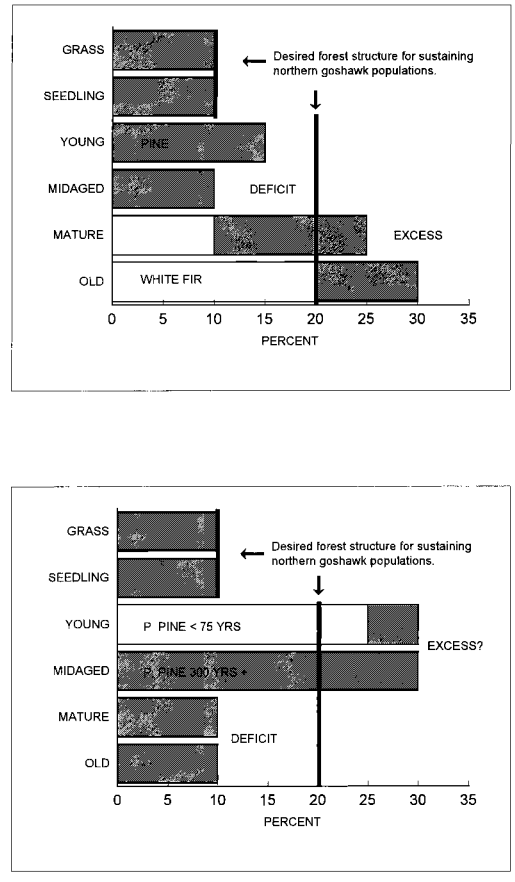

FIGURE 4. The distribution of the vegetative structural stages (VSS) for a hypothetical goshawk foraging area compared to the desired distribution as presented by Reynolds et al. (1992). The top example shows an excess of trees in the mature and old forest classes but a portion of these classes are white fir, a species prone to disease and insect attack. If the ponderosa pine were removed, leaving these trees, an undesirable and unstable forest susceptible to insect and disease attack and stand replacing fires would result. The bottom example shows an excess of trees in the young and mid-aged VSS but a portion of the trees are older than the life expectancy for ponderosa pine. If these trees were thinned, they probably would not grow to become large old trees.

to insect and disease attack, overcrowding, catastrophic wildfire, and other changes outside the range of natural variability (Habeck 1990) (Fig. 4).

In addition, the VSS classes are based on tree diameter and assume a good correlation between tree diameter and age, (e.g., the larger the tree is, the older it is). This is not always the case, as tree growth can stagnate when forest densities remain high for long periods (50 years or more). Small-diameter lodgepole pine, ponderosa pine, western hemlock, and western redcedar trees can easily be old (Pearson 1950, Lotan and Perry 1983, Graham 1988). If the VSS distribution had an excess of "young and midaged" trees that were actually old, thinning these old trees in the expectation they will become large old trees would not sustain the desired forest (Fig. 4)

Goshawks are habitat generalists and live in a variety of forest types such as aspen, lodgepole pine, ponderosa pine, western hemlock, western redcedar, Douglas-fir (*Pseudotsuga menziesii*),

and several other western forest types. For example, the VSS distribution for maintaining a lodgepole forest might contain 5% in openings, and because of the biological limitations of this forest type only 10% might be maintained in old forests. To insure that at least 440 ha of a foraging area is always in old forests, a larger amount of younger and midaged transitional vegetation structures would be needed, increasing the total size of the foraging area. Therefore, forest type, length of the regeneration period, tree growth rate, and tree longevity will dictate how much area is required to insure enough old forest is available to supply the prey base for a goshawk family.

SPATIAL ARRANGEMENT OF FORAGING AREAS

Reynolds et al. (1992) recognized that the extent of overlap between foraging areas for adjacent pairs of goshawks is unknown. When PFAs are closely arranged, it is impossible to establish separate 2200-ha foraging areas for each PFA. In this situation, managers tend to reduce the size of the foraging areas but continue to prescribe a balanced VSS distribution on areas as small as 600 ha. This approach simplifies the application and verification of the VSS recommendations, but does not consider that the rationale for the VSS distribution is to regenerate and provide transitional vegetation structures to maintain a large component of old forests in each foraging area. Also, this approach divides the forest into small, discrete units that may be isolated from other portions of the forest limiting the ability for goshawks to forage for food. In addition, there is probably some physical, biological, or climatic reason why the nest areas were clustered.

A better approach to managing adjacent nest areas and associated foraging areas that overlap is to group them into larger management units, balancing the VSS distribution for the entire unit, yet maintaining the integrity of the recommendations. For example, if three nest areas were grouped, a 7000-ha unit might be formed; six nest areas could be grouped to form a 12,000-ha unit. These management units could be variable in size with boundaries defined by vegetation changes, physiographic differences, or some other well-defined structural division. This approach would be better than trying to manage an ever-changing forest of small, potentially fragmented foraging areas.

FOREST DYNAMICS

The forests of the West are changing every day. In the 10,000 years since the Pleistocene, over 2000 fires could have burned in a ponderosa pine forest if the fire return interval was five years, and over 20 forest-replacing fires could have occurred if the interval was 500 years. Surface fire intervals in much of the ponderosa pine and lodgepole pine forests were less than five years, but in the lodgepole pine forests stand replacement fires occurred every 40 to 100 years (Arno 1980). Likewise, the sizes of forest patches caused by fires varied, as did such things as the frequency of large scale bark beetle epidemics. To a limited extent, the natural range of these processes can be determined for many western forests. By understanding the range of natural conditions to which the goshawk, its prey, and all of the other plants and animals in an ecosystem are adapted, better management strategies can be devised. Not only will they sustain the goshawk but they may also perpetuate the ecosystem components associated with the goshawk.

ECOSYSTEM ANALYSIS

Instead of managing goshawk home ranges or even groups of goshawk home ranges, it would be more ecologically sound to develop management strategies for large geographic areas (approximately 100,000 ha). The goshawk recommendations produced by Reynolds et al. (1992) were an attempt to manage forests on a landscape level, but they have been criticized for not considering many of the other animals and plants in the ecosystems of the Southwest.

Determining the historical variation of vegetation structures for large geographic areas in the Southwest and comparing them to the existing conditions might offer a rational, ecological method of planning management of these forests. This comparison could consider abiotic and biotic components at various scales (e.g., watershed to river basin) and time period (e.g., 100 years in the past to 100 years in the future). Using these types of coarse filter analyses the Nature Conservancy has estimated that 85 to 90 percent of the species might be saved this way (Hunter et al. 1988).

Therefore, instead of analyzing 2200-ha goshawk foraging areas independently or grouping home ranges, it would be more ecologically sound to manage and analyze landscapes. Small 2200-ha forest landscape units would not contain many ecosystem processes and are not large enough to contain the natural range of variation of insect outbreaks or stand-replacing fires. Also, the 2200-ha foraging areas may be too small to support a goshawk family year-round. Therefore, if the goshawk is going to be sustained in the West, more than nesting home ranges need to be considered. Entire ecological units need to be analyzed and managed across vegetation types, land ownership, and political boundaries.

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ASSESSMENT OF GOSHAWK NEST AREA HABITAT USING STAND DENSITY INDEX

ROBERT J. LILIEHOLM, JAMES N. LONG, AND SUSAN PATLA

Abstract. The manipulation of stand density to create a specified stand structure in the future represents a powerful tool in wildlife habitat management. Controlling stand density, and ultimately stand structure, through initial tree spacing and/or subsequent thinning is critical to achieving many specific stand management objectives. Indices of relative stand density, based on average tree size (e.g., mean weight, volume, height, or diameter) and stand density (e.g., trees per hectare) are useful in characterizing current and future stand structure. This paper describes Reineke's stand density index (SDI), and demonstrates its application to the management of Northern Goshawk (*Accipiter gentilis*) nest area habitat.

Key Words: *Accipiter gentilis*; Douglas-fir; Northern Goshawk; *Pseudotsuga menziesii;* Reineke's stand density index; thinning; wildlife.

Setting aside specific habitat for threatened, endangered, and sensitive wildlife is often only a temporary protection measure because plant communities are dynamic and change over time. Furthermore, natural disturbances such as fire and hurricanes often transcend protected area boundaries. While maintaining existing suitable habitat is an important component of species management, increasing populations or providing for the long-term viability of a species requires that suitable habitat be created and/or maintained in the landscape in anticipation of succession and natural disturbance. Because suitable habitat may require decades or even centuries to develop, proactive management requires careful planning that considers how plant community structure changes through time and how such changes affect habitat suitability.

Northern Goshawks (*Accipiter gentilis*), the largest of the North American *Accipiter* hawks, occur across the northern hemisphere in coniferous and mixed forests (Wattel 1981). The goshawk is a species of increasing concern due to possible population declines, and the association of nesting goshawks with late successional forest (Shuster 1980, Hayward and Escano 1989, Reynolds 1989, Crocker-Bedford 1990) indicates a potential sensitivity to management practices that alter existing mature and old-growth forest. As a result, managers need recommendations on how to create and maintain suitable nesting habitat as part of broader habitat management strategies for maintaining goshawk populations.

Silviculturists routinely control stand density to influence tree species composition, stand structure, tree bole shape, rate of tree diameter growth, and stand growth (Daniel et al. 1979). Although these factors are important for meeting objectives of producing timber commodities, they may also be important determinants for producing wildlife habitat.

In studies of wildlife habitat, stand basal area (per-hectare cross-sectional area of the trees in a stand measured at breast height, 1.3 m above the ground) is often used as a measure of stand density. Basal area, however, is of limited use in characterizing stand structure because it fails to convey information on the relationship between tree density and tree size (Daniel et al. 1979, Wilson 1979). McTague and Patton (1989) found that stand basal area, by itself, describes wildlife cover poorly and suggested Reineke's (1933) stand density index (SDI) as a potentially better tool. Smith and Long (1987) used SDI to characterize the structure of lodgepole pine stands for elk hiding and summer thermal cover guidelines. Moore and Deiter (1992) found SDI to be a better predictor of understory forage production in ponderosa pine (*Pinus ponderosa*) stands than basal area. Lilieholm et al. (1993) used SDI to integrate timber and goshawk habitat objectives in the management of Douglas-fir stands.

This paper describes the use of SDI as a method to assess goshawk nest area habitat and guide management practices intended to create forest stand structures similar to those found in nest areas. While other factors such as slope, aspect, distance to water, nest area size and spacing, and foraging habitat must also be considered (Hennessy 1978, Shuster 1980, Reynolds 1983), this approach recognizes the importance of controlling stand structure as a necessary condition of nesting habitat. Indeed, Newton (1986) found stand structure and density to be the most important factors determining stand suitability for nesting goshawks.

MODELING THE DEVELOPMENT OF FOREST STRUCTURE WITH STAND DENSITY INDEX

Controlling stand density through initial tree spacing and/or subsequent thinning is critical to

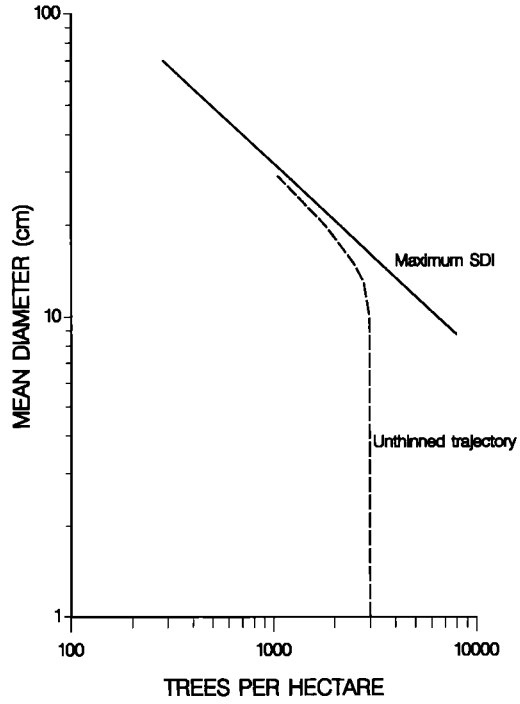

FIGURE 1. Relationship between mean tree size and density on log-log scales. The dashed line represents changing mean size and density for a hypothetical self-thinning Douglas-fir stand.

achieving many stand management objectives. Various indexes of relative density have been developed to characterize current and future stand structure. Typically these expressions of relative density integrate average tree size (e.g., mean weight, volume, height, or diameter) and stand density (e.g., trees per hectare) (Curtis 1971, Drew and Flewelling 1979, Wilson 1979).

One widely used index of relative density is SDI. SDI represents a quantitative measure of stand density that is based entirely on average tree size and density (Long 1985, Long and Daniel 1990). SDI expresses the density in trees per hectare (TPH) that a stand would have if its quadratic mean stand diameter (DBH_Q) were 25 cm. SDI is calculated as:

$$SDI = TPH(DBH_Q/25)^{1.6}$$

A similar relationship between mean size and density is observed for many herbaceous and tree species and is commonly referred to as the "−3/2 power law" in the forest ecology literature. Plotting quadratic mean diameter and trees per hectare on log-log scales reveals a maximum size–density line with a slope of approximately −0.625 (the solid line in Fig. 1). The dashed line on the diagram traces the development of an individual hypothetical stand through time. The stand begins its development near the horizontal axis of Figure 1. Note that the newly established stand has a high stocking rate (3000 TPH) and small average diameter (1 cm). As the stand develops and individual trees grow, mean size increases. As the stand continues to grow, competition-induced mortality results in decreased stocking, indicated by the movement of the trajectory upward and to the left (i.e., continued increase in mean size and decreasing density with the onset of self-thinning).

The size–density relationship described above is largely independent of site quality and stand age. While the slope of the maximum density line is assumed to be constant, its level or distance from the origin will vary for different tree species. For example, the maximum size–density lines for shade-tolerant species are typically higher than those of shade-intolerant species, and the maximum size–density lines for coniferous species are typically higher than those of hardwood species (White and Harper 1970).

Because SDI is largely independent of site quality, stand age, and stand development history, it can be used to compare the relative densities of different stands of the same species directly (Daniel et al. 1979). Density comparisons between stands of different species can be made with $SDI_{\%MAX}$, a ratio of the observed SDI and the maximum SDI (SDI_{MAX}) for the species:

$$SDI_{\%MAX} = [SDI/SDI_{MAX}] \cdot 100$$

Three threshold $SDI_{\%MAX}$ values are commonly used to guide stand management prescriptions (Long 1985). An $SDI_{\%MAX}$ of 25% approximates the onset of inter-tree competition, canopy closure, and the beginning of self-pruning (i.e., the death of branches in the lower crown). An $SDI_{\%MAX}$ of 35% approximates the lower limit of full site occupancy. An $SDI_{\%MAX}$ of 60% is associated with substantially reduced tree vigor and the onset of tree mortality induced by inter-tree competition (Fig. 2).

Silviculturists can use these thresholds to design treatments to guide stand development to meet various stand management objectives. For example, a density management regime could be designed to capture the volume production potential of a site by keeping a stand above the $SDI_{\%MAX}$ of 25% (i.e., full site occupancy) and below the $SDI_{\%MAX}$ of 60% to avoid competition-induced mortality (Long 1985).

In addition, a wide variety of stand structures could be developed using SDI as a guide. For example, a Douglas-fir (*Pseudotsuga menziesii*) stand currently having a DBH_Q of 1 cm and 3000 TPH will follow a typical self-thinning trajectory if left undisturbed (Fig. 3). An alternative stand

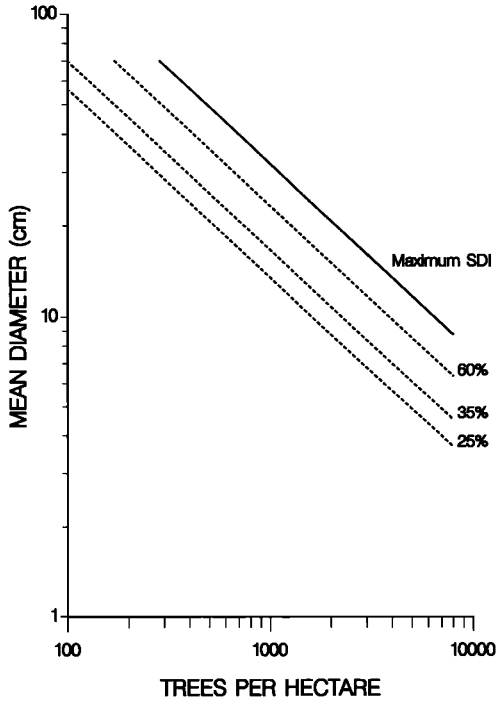

FIGURE 2. Relative density lines indicating 25%, 35%, 60% and 100% of the maximum stand density.

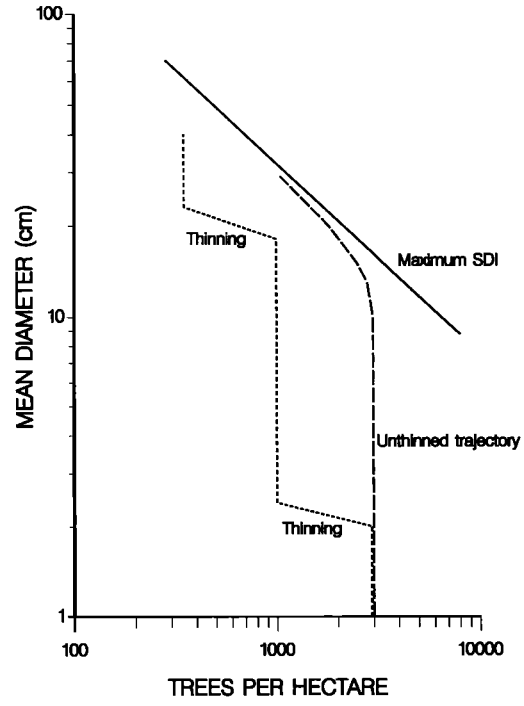

FIGURE 3. Two hypothetical stand density management regimes for Douglas-fir: one represents a natural, unthinned regime; the other includes two planned thinnings.

development trajectory would result from a thinning treatment that reduces density to 1000 TPH, followed by a later thinning that reduces density to 325 TPH. These two density management regimes will lead to fundamentally different future stand structures. For example, the unthinned regime will result in a stand with many relatively small diameter, slow growing trees with small live crowns. In contrast, the thinning regime will result in a stand with relatively large, deep crowned, fast growing trees.

APPLICATIONS TO GOSHAWK NEST AREA REQUIREMENTS

While goshawks nest in many forest types, the vegetative structure and topographic-context of nest areas are relatively consistent (Hayward and Escano 1989), with nests typically built in mature stands and located in trees ranging from 20–75 cm DBH (Eng and Gullion 1962, McGowan 1975, Reynolds 1975, Moore 1980, McCarthy et al. 1989).

A typical nest area is a 8–10 ha forested area of similar structure surrounding the nest tree (Reynolds et al. 1992). Stand densities average 450 TPH and range from 270 to 1530 TPH (Reynolds et al. 1982), and canopy cover ranges from 40 to 89 percent, with the higher portion of the range preferred (Hennessy 1978, Moore 1980, Shuster 1980, Hall 1982, Hayward and Escano 1989, McCarthy et al. 1989). Nest sites typically have an open understory, although variable conditions have been reported (Reynolds et al. 1982, Crocker-Bedford and Chaney 1988).

To apply SDI to the management of goshawk nest area habitat, it is first necessary to describe the range of stand structural conditions that are considered to be suitable nesting habitat. For example, Figure 4 shows data from 31 goshawk nest areas in Douglas-fir forests on the Targhee National Forest in Idaho. Nest area data are based on a 20-m radium plot centered on the nest tree; SDI calculations are based on trees greater than 17.8 cm DBH. The DBH_Q of the nest areas ranged from 25–47 cm. The lower limit of this range could be used to establish a minimum DBH_Q for goshawk nesting habitat in these forests. Similarly, the nest areas all lie between $SDI_{\%MAX}$ limits of 23 and 60, suggesting a range of relative densities for habitat based on stand structure.

Once an appropriate range of stand structures describing nest area attributes for a given forest type and area have been delineated, minimum DBH_Q and upper and lower levels of SDI could guide management practices to ensure the continual availability of stands suitable for nesting

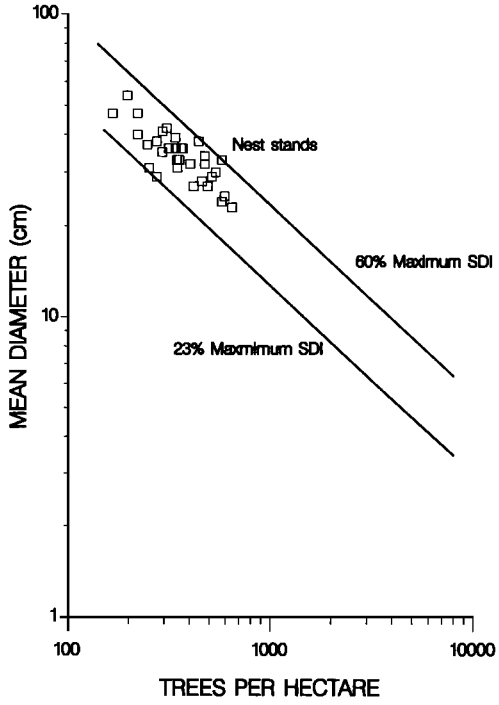

FIGURE 4. Goshawk nest stand data for Douglas-fir stands in southeastern Idaho. The data are bounded by lines representing 23% and 60% of the maximum SDI, which correspond to the minimum and maximum observed relative stand densities.

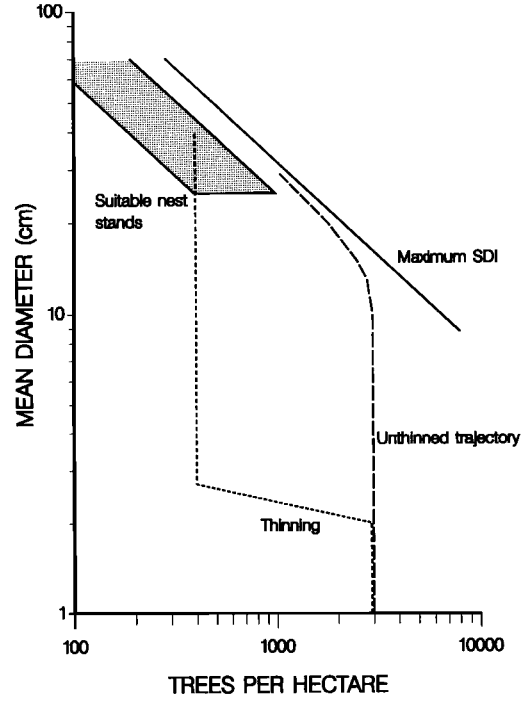

FIGURE 5. Two hypothetical stand density management regimes for Douglas-fir. The shaded area denotes target goshawk nest area structure.

goshawks. For example, management regimes for Douglas-fir forests similar to those found on the Targhee could be developed using the data presented above. If the stand has no artificial or natural stocking control (e.g., thinning, fire, snow, wind), it will result in a typical self-thinning trajectory and will probably fail to provide structure suitable for goshawk nesting (Fig. 5). By thinning the stand at an early age, the stand will likely develop with diameters and relative densities that will provide goshawk nesting habitat. Subsequent thinnings could be used to maintain the stand within this range of suitable relative densities as described in Lilieholm et al. (1993).

An additional result of early thinning is that it will promote rapid individual tree growth, which can substantially reduce the time required for the stand to achieve the minimum DBH_Q (McCarter and Long 1986). For example, assuming a moderately productive forest with a site index of 25 m, the unthinned alternative may require nearly 90 years to achieve a DBH_Q of 25 cm. In contrast, the lower relative densities associated with the thinning alternative would result in a DBH_Q of 25 cm when the stand was about 65 years old.

DISCUSSION

One of the fundamental concepts in silviculture is that site occupancy must be at least broadly related to the size and number of trees on a unit area, and that a given degree of site occupancy can result from either many small trees or fewer large trees. SDI is one of several commonly used expressions of relative density that effectively integrates mean size and density (e.g., Curtis 1982, West 1982). The ecological importance and silvicultural utility of expressions of relative density such as SDI rest on the proposition that stands with the same relative density, regardless of differences in age, site quality, or mean size and density, have equal levels of competition, site occupancy, and other important population-level attributes such as crown closure, self-pruning, and differentiation of crown classes (Reineke 1933, Curtis 1970, Drew and Flewelling 1979, Smith and Long 1987).

An important aspect of habitat management is the design and implementation of strategies to achieve desired future stand conditions. Depending on the specific requirements of species and the objectives of management, desired future conditions may represent a wide range of stand structures. Designing effective and efficient sil-

vicultural prescriptions requires accurate predictions about future stand development. SDI allows characterization of important elements of both current and future stand structure. The mean tree size and density of stands representing suitable habitat (e.g., active goshawk nest areas) can be used as target stand structures and models of desired future condition.

The manipulation of stand density to create a specified stand structure in the future represents a powerful tool in wildlife habitat management. This certainly appears to be true for goshawks, given the importance of stand structure in determining nest area suitability. Thinning can be used to place a dense young stand on a trajectory designed to produce a target DBH_Q and SDI (Fig. 5). This sort of management strategy could be effective in increasing the amount of suitable habitat or even providing it in areas where none currently exists. Implicit in this argument is the assumption that the important elements of stand structure are not directly dependent on stand age (e.g., goshawks respond to tree size and density rather than a stand's actual age).

The method presented provides necessary but probably not sufficient habitat requirements for nesting goshawks, since providing stand structure suitable for nesting is but one of several habitat needs. Other important considerations include the availability of foraging habitat and possibly water, human disturbance, nest predation, topographic location and features, and intra and inter-specific competition for nests and nesting areas (see, for example, Shuster 1977, Hennessy 1978, Call 1979, Jones 1979, Reynolds 1983, Hayward and Escano 1989, Crocker-Bedford 1990, and Reynolds et al. 1992). Biological constraints may influence applications as well. For example, increased risk of bark beetle attacks above certain combinations of diameter and stand density would affect the range of trajectories considered (Cochran 1992).

The spatial and temporal distribution of nest areas must also be considered. For example, planning for potential goshawk nest areas should include alternate nesting sites because goshawks seldom use the same nest tree in consecutive years, but rather rotate between two or three alternate nests located either within the same stand or in other stands (Crocker-Bedford and Chaney 1988). Reynolds et al. (1992) suggest the provision of at least three suitable nest areas within each goshawk home range. Furthermore, to provide future nesting opportunities, managers must ensure that potential goshawk nest areas are at various stages of development so that as nest areas grow out of suitability or are otherwise lost, new areas are ready to take their place. In this role, SDI may also be useful in extending stand structure to mosaics of small groups within home ranges and even nest areas (Long and Daniel 1990, Cochran 1992).

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NORTHERN GOSHAWK BROADCAST SURVEYS: HAWK RESPONSE VARIABLES AND SURVEY COST

SUZANNE M. JOY, RICHARD T. REYNOLDS, AND DOUGLAS G. LESLIE

Abstract. We examined responses of Northern Goshawks (*Accipter gentilis*) to taped broadcast calls of conspecifics in tree-harvest areas and around alternate goshawk nests on Kaibab National Forest, Arizona, in 1991 and 1992. Forest areas totaling 476 km² were systematically surveyed for goshawks. Ninety responses by adult and juvenile goshawks were elicited and 15 active nests were located. No difference in response rates between sexes was detected. Adult males, however, tended to approach the broadcaster without vocalizing, whereas adult females approached while vocalizing. Our success in finding active nests after getting responses from females was greater than after male responses. Goshawks responded more often to broadcasts during the nestling (2.0 responses/100 stations) than fledgling (1.0 responses/100 stations) period. During the fledgling period, adults were more likely to respond to broadcasts than juveniles. Total costs associated with our surveys for goshawks were $58–82 per km² and $4.15–5.80 per broadcast station, depending on salaries.

Key Words: *Accipiter gentilis*; broadcast surveys; Kaibab Plateau; Northern Goshawk; vocalization.

In the southwestern United States, Northern Goshawks (*Accipiter gentilis*) use ponderosa pine (*Pinus ponderosa*), mixed coniferous-deciduous forests, spruce-fir, and pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands. These forests are subject to structural and compositional changes due to plant growth and succession, and to various natural (e.g., fire) and anthropogenic (e.g., tree harvest, grazing) disturbances that may affect goshawk reproductive success (Reynolds 1983, 1989; Crocker-Bedford 1990, Reynolds et al. 1992). In 1982 the Southwestern Region of the USDA Forest Service designated the goshawk as a sensitive species. Reynolds et al. (1992) suggested habitat-management strategies for both goshawks and their prey in ponderosa pine and mixed-species forests. The first step in the management of habitat for goshawks is locating their nests.

Broadcasting of raptor vocalizations has been used to locate goshawk nests (Kimmel and Yahner 1990, Mosher et al. 1990, Kennedy and Stahlecker 1993). Broadcasts elicit vocal and/or visual cues of raptors, which can then be followed with nest searches. During the 1991–1992 breeding seasons we conducted broadcast surveys for goshawks on 12 proposed tree-harvest areas on the North Kaibab Ranger District (NKRD) in northern Arizona.

METHODS

SURVEY AREA

Areas surveyed for goshawks were on the Kaibab Plateau, Coconino County, Arizona. The Plateau is bounded by escarpments and steep slopes that descend into the Grand Canyon of the Colorado River on the south side and desert scrublands elsewhere. Forested areas on the NKRD, which encompasses the northern portion of the Plateau, total approximately 3000 km² (Rassmussen 1941). Forests on the Kaibab Plateau consist of a band of pinyon-juniper (1103 km²) at elevations between 1830–2075 m, ponderosa pine forests (624 km²) between 2075–2500 m elevation, and mixed-conifer forests (*Abies concolor, Picea engelmannii, Populus tremuloides, Pseudotsuga menziesii*) (605 km²) above 2500 m (Rasmussen 1941). A complete description of the study area was provided in Reynolds et al. (this volume).

BROADCASTS

We used a modification of the Kennedy and Stahlecker (unpubl. data) broadcast protocol to survey for goshawks. Goshawk vocalizations were broadcast from stations established on parallel transects, and their responses were followed by searches for active nests (containing eggs or young). Responses were classified as (1) vocalization only, (2) sighting only, or (3) vocalization and sighting. We used cassette players (1991 surveys) and portable, long-range callers (1992 surveys) to broadcast goshawk vocalizations. Cassettes were played at a volume that produced a sound audible to the human ear at a minimum of 150 m from the source. Rain, winds exceeding 20 km/h, and occasional vehicle traffic resulted in delay or termination of the survey effort because of the interference with response detection.

Surveys were only conducted during the nestling and fledgling periods when goshawk response rates to broadcasts are highest (Kennedy and Stahlecker 1993). Alarm calls were used during the nestling period and food-begging calls during the fledgling period. For broadcast transects, boundaries of all tree-harvest areas were transcribed onto 7.5-min USGS quadrangle maps. Transects were then drawn with an east-west or north-south orientation depending on topography and accessibility, with both ends of all transects extended 800 m beyond the harvest area boundaries. Distances between transects and stations, as described in Kennedy and Stahlecker (unpubl. data), were modified to increase the theoretical coverage of broadcasts from 78.5 to 90.6% of surveyed areas (Fig. 1). Modifications were that parallel transects were 260 m (vs. 300 m) apart;

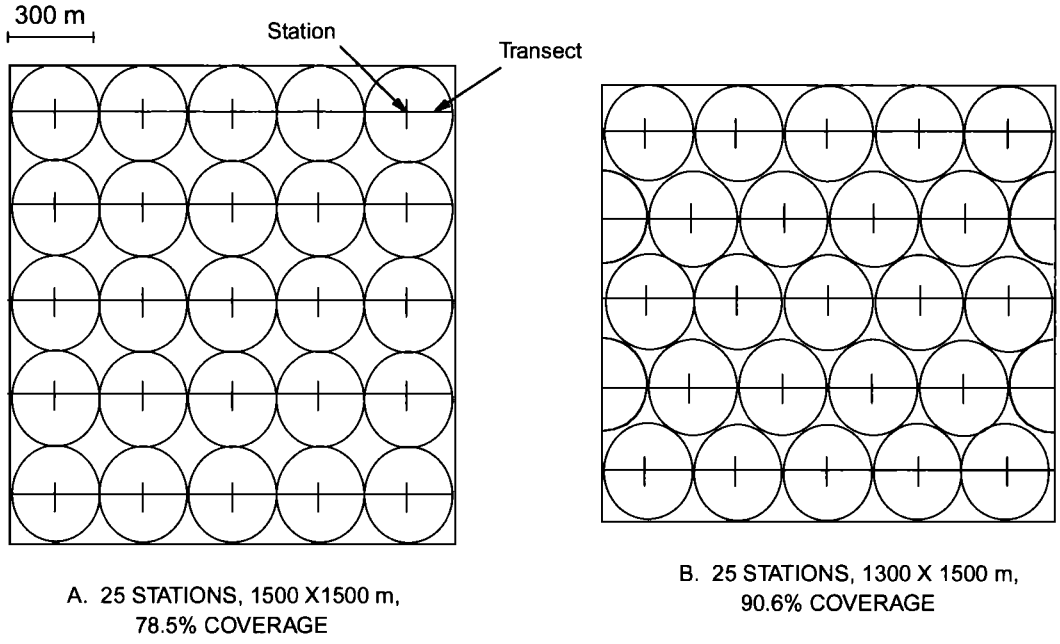

FIGURE 1. Theoretical area of coverage (circles) using (A) Kennedy and Stahlecker's (unpubl. data) transect and station layout, vs. (B) the modified layout used in this study.

and broadcast stations were 300 m (vs. 150 m) apart on each transect and were staggered by 150 m on adjacent transects.

All broadcast stations within 800 m of active nests were deleted from the survey effort. In addition, we did not survey stations in large, treeless openings (diameter > 400 m), on sheer canyon walls, or in stands of Gambel's oak (*Quercus gambelii*), New Mexican locust (*Robinia neomexicana*), or pinyon pine-Rocky Mountain juniper (*J. scopulorum*) that did not contain large ponderosa pine.

Prior to surveys, broadcast personnel were trained in the broadcast technique, field methods, and identification of the calls and physical characteristics of goshawks, Cooper's (*A. cooperii*), Sharp-shinned (*A. striatus*), and Red-tailed (*Buteo jamaicensis*) hawks, and goshawk mimics (e.g., *Cyanocitta* spp.). Observers used the 7.5-min USGS maps with marked transects and stations in the field. At each station, the surveyor broadcasted three times in three directions. First, the surveyor rotated 60° right or left (determined randomly) from the direction of travel, played the taped goshawk vocalization for 10 sec, and then listened and searched in all directions for hawk responses for 30 sec. The broadcast and observation procedures were then repeated two more times after rotating 120° from the previous broadcast. Broadcasts were conducted from 3 June to 12 August between 08:00 and 16:30 MDT.

To avoid misidentifying broadcasts of co-workers, surveyors worked at least two transects apart. When they elicited a response, the following were noted: transect, station, habitat, time, species, sex and age of the hawk, response type, bearing, and estimated initial distance to the responding hawk. All goshawk, and Cooper's, Sharp-shinned, and Red-tailed hawk vocalizations and sightings detected between stations were also recorded. All responses by *Accipiter* spp. were immediately followed with a search for nests within a 200-m radius of the response. Responses by the same species at consecutive stations on a transect were treated as one response.

In 1992, broadcast surveys outside timber harvest areas were conducted within 2 km of three goshawk nests that were active in 1991 but inactive in 1992 to search for alternate nests. An alternate nest is one of several nests used within a goshawk's home range (Reynolds and Wight 1978). In each area, transect and station layout and the protocol described above were used.

Hawk Responses

Chi-square goodness of fit tests (Ott 1984) were used to test the frequency of goshawk responses between sexes, ages (adult, juvenile), nesting stages (nestling, fledgling) (weighted by the number of stations surveyed during stage), and type of vocalizations broadcasted (alarm, food-begging) (weighted by number of stations surveyed with that vocalization) against the null hypothesis of equal frequencies between categories. During 1992 the alarm call was inadvertently used during the first nine days of the fledgling stage. To determine the effect of this, we performed simultaneous tests (Goodman 1964) of response rates to (1) alarm call use (2110 stations) during the nestling stage, (2) alarm call use (1058 stations) during the fledgling stage, and (3) food-begging call use (3681 stations) during the fledgling stage, after standardizing by number of stations surveyed in each category. We also tested whether the

success of finding a goshawk nest in follow-up nest searches was independent of the hawk's sex and response type. To examine trends in response parameters, Fisher's Exact test (Proc FREQ; SAS Institute 1987) was used in multi-way comparisons of (1) response type (vocal non-approach, silent approach, vocal approach) by sex, by age, by nesting stage, and by type of broadcast vocalization; and (2) sex of the responder by nesting stage, and by type of vocalization broadcast. We did not test for differences in goshawk response frequency among times of day. Kimmel and Yahner (1990) found that response rates were independent of time of day.

Among-species comparisons of responses of goshawks, and Cooper's, Sharp-shinned, and Red-tailed hawks included the frequency of response type, habitat in which the response occurred, and mean distance from broadcast station to responding individual. In multi-species comparisons, Fisher's Exact Test (Proc FREQ; SAS Institute 1987) was used to test for differences among frequencies of response variables, and the Kruskal-Wallis Test (Proc NPAR1WAY; SAS Institute 1987) was used to test for differences in mean response distances among species.

Survey Effort and Associated Costs

We estimated the effort (surveyor-hours) and costs of using the broadcast survey procedure only during 1992 broadcast surveys. Our estimates included preparing survey maps, training, commuting, conducting surveys, daily data transcription to master 7.5-min maps, testing and maintaining equipment, data entry, checking and analysis, and reporting of results. Expenses are based on salaries, vehicle rents and mileage, and equipment costs and maintenance.

RESULTS

In 1991 we surveyed proposed tree-harvest sites (total area = 183.7 km^2) in the Big Burro, Jack, Jolly, Burnt Saddle-Sowat, Lookout Canyon, Paris, and Stina areas. In 1992 we surveyed proposed tree-harvest sites (total area = 219.5 km^2 + 45.2 km^2 beyond harvest boundaries) in the West Lake, Holy Rock, Road Hollow, Lost Canyon, and Taters areas. A total of 6477 stations were covered requiring 1579 hours of survey time. An additional 27.8 km^2 (391 stations) were covered during surveys for alternate nests.

Hawk Responses

In 1991, 41 goshawk responses were detected during broadcast surveys (2749 broadcast stations, 676 survey-hours) on the seven tree-harvest areas, resulting in 1.5 responses per 100 stations surveyed, 0.2 responses per km^2 surveyed, and 1 response per 16.5 hours of survey time. In 1992 surveys (3728 stations, 903 survey-hours) 48 goshawk responses were detected on five tree-harvest areas, resulting in 1.3 goshawk responses per 100 stations surveyed, 0.2 responses per km^2 surveyed, and 1 response for every 18.8 hours of survey time. One goshawk response was recorded during the 1992 surveys for alternate nests.

TABLE 1. Frequency of Adult Northern Goshawk Responses by Sex to Different Broadcast Vocalizations and during Different Nesting Stages in Broadcast Surveys on the Kaibab Plateau, Arizona, 1991–1992

Variable	Responses	
	Male	Female
Vocalization broadcast		
Alarm call	21	15
Food-begging call	6	6
Nesting stage		
Nestling	15	11
Fledgling	12	10

Six and nine active goshawk nests were located during broadcast surveys in 1991 and 1992, respectively. In each year, one of these nests had already been found by a non-broadcast surveyor (Reynolds et al., this volume), but was found again by a naive broadcast surveyor. Thus, one nest was found for every 458 stations covered, 30.6 km^2 surveyed, and 112.7 survey hours in 1991; in 1992, one nest was found for every 414 stations, 29.4 km^2, and 100.3 survey hours. In addition, the number of Cooper's and Sharp-shinned hawk responses during 1991 and 1992 were 14 and 8, and 15 and 6, respectively. Two Cooper's and six Sharp-shinned hawk, and two Cooper's and three Sharp-shinned hawk nests were found during follow-up searches in 1991 and 1992, respectively.

Mean estimated hatching and fledging dates at goshawk nests were 8 June and 17 July in 1991, and 1 June and 5 July in 1992, respectively. In 1991 broadcasting occurred during 18 days (37 surveyor-days) of the nestling period and 31 days (86 surveyor-days) of the fledgling period. In 1992 broadcasting occurred during 19 days (77 surveyor-days) of the nestling period and 26 days (117 surveyor-days) of the fledgling period. Broadcasts of the goshawk alarm call were replaced by broadcasts of the food-begging call on 22 July 1991 and 16 July 1992, coinciding with the latest egg-hatching dates of 24 July 1991 and 15 July 1992.

There was no significant difference in response frequency between adult male and female goshawks ($\chi^2 = 0.75$, df = 1, P = 0.386) during 1991 and 1992 broadcast surveys. Furthermore, the frequency of response by sex (in 32 cases the sex could not be determined) was not affected by the type of vocalization broadcasted (N = 48, Fisher's Exact test, P = 0.741) or stage of nesting (N = 48, Fisher's Exact test, P = 1.000) (Table 1).

TABLE 2. FREQUENCY OF NORTHERN GOSHAWK RESPONSE TYPES BY SEX, AGE, NESTING STAGE, AND BROADCAST TYPE DURING BROADCAST SURVEYS FOR NORTHERN GOSHAWKS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992. N = NUMBER OF STATIONS SURVEYED

Variable	Response type		
	Vocal non-approach	Silent approach	Vocal approach
Sex			
Male	1	17	8
Female	3	3	15
Age			
Adult	4	12	11
Juvenile	9	0	3
Nesting stage			
Nestling (N = 2129)	9	15	17
Fledgling (N = 4739)	18	13	14
Vocalization broadcasted			
Alarm call (N = 3168)	12	23	23
Food-begging call (N = 3700)	15	5	8

Response type, however, differed between the sexes (N = 47, Fisher's Exact test, P = 0.001) (Table 2); males often approached silently, whereas females most often approached and vocalized. More active nests were found in follow-up searches to responses by females (N = 8 nests of 21 responses) than males (N = 3 nests of 27 responses) (N = 48, Fisher's Exact test, P = 0.040).

During the fledgling stage, adults responded to broadcasts more often than juvenile hawks (χ^2 = 7.05, df = 1, P = 0.008; N = 29 and 12 responses, respectively). Also, adults were more likely to approach the broadcaster (either vocalizing or silent) than juveniles (N = 93, Fisher's Exact test, P < 0.001) (Table 2).

During both years, more stations were surveyed during the fledgling (4739 stations) than the nestling (2129 stations) stage. After adjusting for these differences, goshawks responded more often during the nestling stage (42 responses per 2129 stations) than the fledgling stage (48 responses per 4739 stations) (χ^2 = 10.33, df = 1, P = 0.001), whereas response type was independent of nesting stage (N = 86, Fisher's Exact test, P = 0.202) (Table 2).

The number of stations surveyed with the alarm and food-begging calls also varied (alarm call = 3168 stations, food-begging call = 3700 stations). After adjustment, goshawks responded more often to the alarm (N = 59 responses/effort) than food-begging (N = 31 responses/effort) call (χ^2 = 13.69, df = 1, P < 0.001). Response type (4 of 90 responses were unclassified) was not independent of the type of call broadcasted (N = 86, Fisher's Exact test, P = 0.008) (Table 2). Alarm calls more commonly elicited a silent approach or vocal approach, whereas food-begging calls more often elicited vocalization with no approach. More nests were found during follow-up searches to vocal approaches (N = 31 nests) than to vocal non-approaches (N = 27 nests) or silent approaches (N = 28 nests) alone (N = 86, Fisher's Exact test, P = 0.029).

The overall chi-square among the three categories of call-use by nesting stage (alarm call during the nestling stage, alarm call during the fledgling stage, and food-begging call during the fledgling stage) was significant (χ^2 = 14.90, df = 2, P = 0.013). Response rates were significantly higher using the alarm call during the nestling stage than using the food-begging call during the fledgling stage. However, goshawk response rates using the alarm call during the fledgling period were not significantly different from using the food-begging call during the fledgling period, nor did the former differ from using the alarm call during the nestling period.

Overall, the frequency of response types among the three species of *Accipiter* did not differ (N = 123, Fisher's Exact test, P = 0.208), nor did they differ between any *Accipiter* and Red-tailed Hawks (Fisher's Exact test, P > 0.016, Bonferroni significance level, for all pairwise tests). However, when responses were partitioned by habitat (ponderosa pine, mixed-conifer forests), the frequency of responses among all species differed (N = 210, Fisher's Exact test, P = 0.014) (Table 3). Goshawk and Cooper's and Red-tailed hawks responded more often in ponderosa pine forest, whereas Sharp-shinned Hawks responded more often in mixed-conifer forests. Mean response distance was not equal among species (P

TABLE 3. FREQUENCY OF NORTHERN GOSHAWK, COOPER'S HAWK, SHARP-SHINNED HAWK, AND RED-TAILED HAWK RESPONSES BY HABITAT DURING BROADCAST SURVEYS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992

	Species			
Habitat	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk	Red-tailed Hawk
Ponderosa pine	50	17	5	62
Mixed-conifer	38	7	9	22

< 0.001); Red-tailed Hawks responded at distances greater than any of the *Accipiter* (P < 0.016, Bonferroni significance level, in all pairwise tests) (Table 4). Response distances did not differ among the *Accipiter* species (P = 0.492).

SURVEY EFFORTS AND ASSOCIATED COSTS

In 194 surveyor-days during 1992, observers surveyed 3728 stations (265 km² of transects) for a mean survey effort of 19.3 (SD = 6.8) stations per day. Of the 4832 established stations (343 km²), 1104 stations (78.4 km²) were not surveyed because they occurred in non-forested habitat or were within 800 m of an active goshawk nest.

Eleven observers spent 0.5–10.0 h ($\bar{X}$ = 4.7 h, SD = 1.7) per day surveying for a total survey time of 903.1 h. Mean time required to broadcast, observe, and travel to the next station was 14.5 min per station. A mean of 8.4 h per day (SD = 1.7, total time = 1627 h) per observer was required to broadcast, commute to and from survey sites, update master survey maps, and test and maintain equipment. An additional 184 surveyor-hours were required for training personnel and 252 h were required on pre- and post-season tasks such as preparing survey maps, selecting personnel, data entry and verification, analysis, and report writing. Total personnel costs to complete broadcast surveys of the five tree-harvest areas surveyed in 1992 ranged from $4.15–5.80 per station and $58.50–81.85 per km² ($151.40–211.95/mi²) depending on salary (Appendix). Vehicle and equipment costs were $1.90 per station and $26.70 per km² ($69.30/mi²) surveyed.

DISCUSSION

HAWK RESPONSES

Response rates of goshawks to broadcasts did not differ between the sexes, but male and female behaviors differed when responding. As measured by their intensity of vocalization, females responded more aggressively than males. Males appeared to be more inquisitive than aggressive in their initial response, often approaching and retreating silently. The probability of finding a nest during follow-up searches to female responses was greater than for male responses. Females are more likely to be in the vicinity of their nests during early stages of brood-rearing whereas males are more likely to be away from nests foraging. However, because of potential bias in the misidentification of sex, and because males will respond from their nests, we recommend that equal effort be given to follow-up searches to responses by either sex.

Contrary to Kimmel and Yahner's (1990) report that no difference occurred in response rates between nesting stages, we found that goshawk responses rates were higher during the nestling than fledgling stage. No difference in response rates to the alarm and food-begging calls during the fledgling stage was detected during our surveys. Kennedy and Stahlecker (1993), however, detected fewer responses using the alarm call vs. the food-begging call during this period.

During the fledgling stage, adult response type (silent and vocal approaches to the observer) differed from juvenile response type (vocal non-approaches). This difference may reflect the inability of fledglings to fly well and a reluctance to leave the nest area. Juveniles vocally responded with both alarm and food-begging calls.

Response type to the calls broadcasted (alarm, food-begging), when both nesting stages were combined, differed. More approaches, with and without vocalization, were tallied in response to the alarm call whereas more vocalizations without approach were tallied to the food-begging

TABLE 4. MEAN INITIAL-RESPONSES DISTANCE, STANDARD DEVIATION, AND NUMBERS OF NORTHERN GOSHAWK, COOPER'S HAWK, SHARP-SHINNED HAWK, AND RED-TAILED HAWK RESPONSES TO BROADCAST SURVEYS ON THE KAIBAB PLATEAU, ARIZONA, 1991–1992

	Species			
Variable	Northern Goshawk	Cooper's Hawk	Sharp-shinned Hawk	Red-tailed Hawk
Mean response distance (m)	95.4	75.8	77.0	148.1
SD	87.5	71.1	73.5	121.3
No. of observations	90	26	14	89

call. This pattern reflects the tendency of adults to respond to the alarm call and juveniles to the food-begging call. A high number of vocal responses without approach were also tallied by Kennedy and Stahlecker (1993) during the fledgling stage.

Forests surveyed during 1991 and 1992 were primarily ponderosa pine and mixed-conifer. A greater proportion of goshawk, and Cooper's and Red-tailed hawk responses to goshawks vocalizations were obtained in ponderosa pine than in mixed-conifer forests. For Sharp-shinned Hawks, a greater proportion of responses were obtained in mixed-conifer forest. Mixed-conifer forests are often more structurally and floristically diverse than ponderosa pine forests and probably provide greater hiding cover for Sharp-shinned Hawk nests and higher densities of their prey. Initial response distance to broadcasts was greater for Red-tailed Hawks than any of the *Accipiter* spp. Red-tailed Hawks soar more often than the *Accipiter* and are easier to detect at greater distances.

We think that the Kennedy and Stahlecker (1993) protocol (with modifications described herein) is an effective means of locating goshawk, and Cooper's and Sharp-shinned hawk nests. Blind tests of the efficacy of the broadcast-survey method need to be conducted to determine the proportion of nests missed and the number of survey visits required to achieve an acceptable level of detection. Until such tests are performed, guidelines for surveying proposed tree-harvest areas should require two or more visits in separate years to increase the probability of goshawk detection. Tests of the efficacy of using goshawk vocalizations versus those of congeners to find Cooper's, Sharp-shinned, and Red-tailed hawk nests should be pursued.

Survey Effort and Associated Costs

Estimates of cost/effort of locating goshawk nests using methods similar to Kennedy and Stahlecker (1993) were not available for comparison with our estimates. Costs associated with surveying for goshawks (personnel, vehicle, and equipment) vary depending on survey effort and size of the survey area. If finding all goshawk nests is the objective of surveys, effort should not be compromised in order to cover larger areas.

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APPENDIX. PERSONNEL COSTS FOR CONDUCTING NORTHERN GOSHAWK BROADCAST SURVEYS PER BROADCAST STATION AND AREA, ON THE KAIBAB PLATEAU, ARIZONA, IN 1992

Variable	Personnel salary level		
	$7.50/hour	$8.50/hour	$10.50/hour
	Survey time only		
Per station[1]	$ 1.80	$ 2.05	$ 2.54
Per km^2 [2]	$ 25.60	$ 29.00	$ 35.80
Per mile^2 [3]	$ 66.30	$ 75.10	$ 92.80
	All survey-related tasks[4]		
Per station	$ 4.15	$ 4.70	$ 5.80
Per km^2	$ 58.50	$ 66.25	$ 81.85
Per mile^2	$151.40	$171.60	$211.95

[1] Costs determined over 3728 stations that required 903 surveyor-hours of broadcasting.
[2] Costs determined over 264.7 km^2 that required 903 surveyor-hours of broadcasting.
[3] Costs determined over 102.2 mi^2 that required 903 surveyor-hours of broadcasting.
[4] Costs determined over 2063 h required to survey 3728 stations (or 264.7 km^2, or 102.2 mi^2), prepare survey maps, train, travel daily to and from survey sites, conduct surveys, update of "master" survey maps (area covered daily), test and maintain equipment, enter, error-check and analyze data, and report results.

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A PHOTOGRAPHIC AND BEHAVIORAL GUIDE TO AGING NESTLING NORTHERN GOSHAWKS

CLINT W. BOAL

Abstract. Observations of behavioral and morphological development of nestling Northern Goshawks (*Accipiter gentilis*) were collected during three nesting seasons at 20 goshawk nests in northern Arizona. A photographic record of a single nestling goshawk's development was made. I combined descriptions of age-specific behaviors exhibited by nestlings with descriptions and photographs of nestling morphological development to construct an aging guide for nestling Northern Goshawks. Adult goshawk behaviors that relate to nestling age are also provided.

Key Words: *Accipiter gentilis*; age guide; nestling development; nestling behavior; Northern Goshawk.

Accurate estimates of the ages of nestling raptors are important for scheduling banding (Fyfe and Olendorff 1976) and assessing productivity (Moritsch 1983a, b; Steenhof 1987, Young and Kochert 1987). Photographic guides to morphological changes that occur as nestlings age have been developed for Prairie Falcons (*Falco mexicanus*), Red-tailed Hawks (*Buteo jamaicensis*), and Ferruginous Hawks (*B. regalis*) (Moritsch 1983a, b; 1985), but are unavailable for most species.

Because the behavior of young raptors is correlated with age (e.g., Ellis 1979), descriptions of age-specific behaviors coupled with pictorial and verbal descriptions of morphological changes provide a more robust guide to aging nestling raptors. In addition, the behavior of the adult female changes with the age of nestlings and may be useful in evaluating nestling ages.

Schnell (1958) provided a written description of the development of nestling Northern Goshawks (*Accipiter gentilis*) at a single nest. Observations of nestling development from several nests may provide a better understanding of the age ranges over which behavioral ontogeny occurs. I provide a photographic and behavioral guide to estimating the age of nestling Northern Goshawks.

STUDY AREA AND METHODS

The study was conducted on the North Kaibab Ranger District (NKRD), Kaibab National Forest, Coconino County, Arizona. The NKRD is an area of approximately 259,000 ha located on the Kaibab Plateau in northern Arizona. A detailed description of the study area is provided in Boal and Mannan (this volume).

Nest observations were conducted at 20 Northern Goshawk nests on the NKRD during the nesting seasons of 1990, 1991, and 1992. Information on the morphological and behavioral development of nestling goshawks was collected during 1539 hours of observation ($\bar{X}$ = 76.8 hour/nest ± 19.3 [SD]). These observations were made from blinds located on the ground or in trees a mean distance of 53 m (±17.6) from the nest trees. Observation periods began in the afternoon and continued until sundown, resuming at dawn until the time of initiation the previous day.

Photographs used in this guide are of the largest of 3 nestlings in a nest that was not part of my study, but was being used in a concurrent telemetry study (Bright-Smith and Mannan, this volume). I estimated the date of hatching as 20 June, based on behaviors exhibited by the nestlings and the adult female. I took photographs at 5-day intervals, starting with 5 days of age and continuing until 20 days of age.

At 18 days the adult female disappeared from the nesting area. Radio telemetry indicated the adult male goshawk remained in the nest area during the following

TABLE 1. GLOSSARY OF TERMS USED IN TEXT AND FIGURES

Auricular	The area of the invisible ear opening just posterior to the eye
Brancher	A young raptor that has left the nest but not the nest tree
Coverts	Small contour feathers of the wings and tail
Crown	The top of the head
Fledge	When a young bird leaves the nest tree of its own volition for the first time
Nape	The back of the head below the occipital portion of the skull
Pin feather	A growing feather that is encased in sheathing
Primaries	The outer flight feathers of the wing
Rapid peering	Rapid movement and readjustment of the head while visually focusing on an object
Remiges	Primary and secondary wing feathers
Rectrices	Tail feathers
Scapulars	Feathers located in the shoulder region
Secondaries	Inner flight feathers of the wing
Sheathing	Wax-like keratinous material that encases and protects newly developing feathers
Talons	The feet and claws of a hawk

days, but nest observations revealed that he did not care for the nestlings. At 20 days of age, the largest nestling, a male, attacked his siblings. He killed and cannibalized one sibling and forced the other to leave the nest and fall to its death (Boal and Bacorn, in press). The surviving nestling was removed from the nest and transferred to a wildlife rehabilitator for care. A photographic record was continued during captivity at 2-day intervals from 25 days of age to 39 days of age. Photographs of this bird were combined with the observational data from the other nests to provide this guide.

Table 1 contains a glossary defining morphological and behavioral terms used in describing ages of nestlings.

RESULTS

When a goshawk nest area is entered by humans during the first 5 days following hatching, adult females show a strong tendency to remain on their nests. Afterwards, females typically flush from nests, perch in nearby trees while vocalizing, and possibly make low passes at intruders. Adult male goshawks are rarely seen in the nest area except during food deliveries. After delivering food to the female away from the nest, males will often visit the nest briefly during the first 10 days following hatching.

It is difficult to determine the presence of nestlings prior to approximately 4 days old. At about 4 days of age nestlings begin attempting to defecate over the nest rim, and their presence is evidenced by minute specks of white excrement on the nest rim but not on the ground below the nest (Fig. 1). At about 9 days white-wash globs will be present on the branches and the ground below the nest (Fig. 2).

Nestlings remain totally white in their first natal down until 14–17 days when the gray second natal down and flight pin feathers begin to appear (Fig. 3). Scapular and covert feathers start emerging between 19 and 22 days (Fig. 4). Rapid and noticeable feather development begins at 24–26 days. At this age, scapular and covert feathers are visible, and the auricular area is covered with small black feathers (Fig. 5). At 28–30 days, dark feathers appear along the nape, but the crown is still downy. Feathering is also apparent along the

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FIGURE 1 (*top left*). Goshawks at 4–7 days post-hatching. *Morphological Characteristics:* Nestlings are small (approximately 13 cm long) and covered in white natal down. *Behavioral Characteristics:* Nestlings lie prostrate and usually out of view below the nest rim. Occasionally the tops of their heads may be seen, especially when the female is feeding them. Nestlings are poorly coordinated and move by scooting motions with the body in contact with the substrate. Nestlings may give whistle-like beg calls during feeding. Nestling hawks are able to excrete over the nest rim starting at 4–5 days old. Small dime-sized specks of white excrement may be visible on the sticks of the nest or against the tree trunk, but usually not on the ground. The adult female is almost continuously present and always broods the nestlings at night. She tends to remain motionless on the nest rather than flush and give the alarm call when the nest is approached.

FIGURE 2 (*bottom left*). Goshawk at 9–12 days post-hatching. *Morphological Characteristics:* Nestlings are 15–18 cm long and covered in white down. *Behavioral Characteristics:* Nestlings are most often lying in the nest cup out of view. Primary movements are to position themselves to be fed or to defecate over the nest rim. Movements are by scooting motions. Nestlings possess good head coordination when feeding, but are weak and often use their wings for balance and support when moving. Nestlings are able to excrete with greater power. Whitewash specks are numerous and obvious on the ground and branches below the nest. The adult female is usually present and broods the nestlings at night. She tends to flush from the nest and give the alarm call when the nest is approached.

FIGURE 3 (*top right*). Goshawk at 14–17 days post-hatching. *Morphological Characteristics:* Nestlings are approximately 20–23 cm long and have molted into their second natal down, which has a gray, woolly appearance. Auricular area is still downy. Pin feather development of the remiges and rectrices is apparent, especially when the wings are extended upward. As much as 1 cm of the feather may have erupted from the pin feather sheaths. *Behavioral Characteristics:* Nestlings are able to walk on their tarso-metatarsus while extending their wings for balance. They may stand for brief moments and look about the nest area. Nestlings begin making preening motions at their breast and wings.

FIGURE 4 (*bottom right*). Goshawk at 19–22 days post-hatching. *Morphological Characteristics:* Auricular area behind and below the eye is developing as a dark patch of small feathers. Remiges and rectrices are erupting from pin sheaths and contrast markedly with the body down. Greater coverts, upper tail coverts, and scapular feathers are starting to emerge and appear as dark dots against the body down. Close observations of the ventral feather tracts reveal dark pins beneath the down. *Behavioral Characteristics:* Nestlings can walk on their feet and usually do not use their wings for balance. They will stand for longer periods and preen. Nestlings rapidly flap their wings for short periods (3–5 seconds), especially following feeding. Nestlings may attempt to peck their own bites of food when the female is feeding them.

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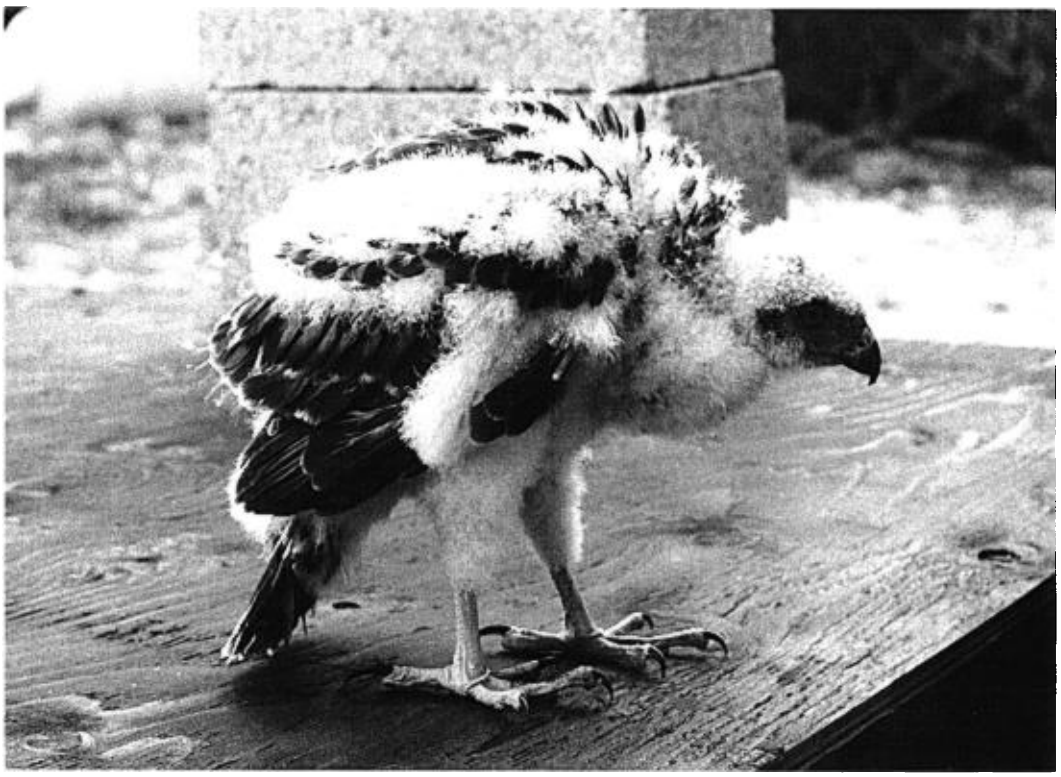

FIGURE 5. Goshawk at 24–26 days post-hatching. *Morphological Characteristics:* Auricular area is now covered with small black feathers. The head and neck are still downy, but sheathed feathers may be seen beneath the down. Scapular feathers and wing coverts are visible and contrast against the natal down. Feathers of the ventral tracts start emerging and under tail coverts may also appear. Nestlings are approximately ½ adult size. *Behavioral Characteristics:* Nestlings stand on the nest rim and observe the nest surroundings. They spend a great deal of time preening and wing flapping. Nestlings start stretching their feet and legs and making fists of the talons. They may start grabbing nest twigs with their feet. Nestlings may successfully feed themselves if the food has no skin or has been opened up by an adult. The adult female is usually in the nest area but does not brood or shelter nestlings at night except during wet or unseasonably cold weather.

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FIGURE 6 (*top right*). Goshawk at 28–30 days post-hatching. *Morphological Characteristics:* Dark feathers emerge along the nape, but the crown is still downy. Covert and scapular feathers fill in the upper wing and back areas. Breast feathers are filling in along the ventral tracts but the middle of the breast and belly is still downy. The under and upper tail coverts and legs are predominately downy, but a few feathers may be present. *Behavioral Characteristics:* Nestlings spend much of their time preening, and begin scratching their heads with their talons. Foot grabbing of nest twigs and other objects increases. Nestlings are very attentive to their surroundings and pay attention to adults exchanging prey away from the nest. Rapid peering and sleeping while standing are new behaviors exhibited during this stage. The adult female is rarely at the nest but is in the nest area and becomes defensive when the nest area is entered.

FIGURE 7 (*bottom right*). Goshawk at 32–34 days post-hatching. *Morphological Characteristics:* Dark feathers have emerged on the crown and are beginning to emerge at the corner of the mouth. The back and dorsal side of wings are 90% feathered. The breast is filling in with feather growth but is still downy in the center and on the belly. The undertail coverts have filled in and feathers will be emerging on the thighs. The underwing area is still downy. Rectrices are about ⅔ adult length. *Behavioral Characteristics:* Nestlings readily feed themselves when the female is not present and may fight aggressively over food. Nestlings will vigorously beat their wings while hopping and running across the nest. Nestlings may start branching at about 34–35 days.

sides of the breast (Fig. 6). At 32–34 days dark feathers emerge on the crown, and feathering of the legs is visible (Fig. 7). Body feathering is nearly completed at 36–38 days, but downy areas persist on the sides of the neck (Fig. 8). At 40 days the only visible down is along the underside of the wings (Fig. 9).

DISCUSSION

Moss (1979) described weight gain in nestling sparrowhawks (*A. nisus*) as being initially slow for 4–6 days, followed by a 10-day period of rapid weight gain, and then a return to slow weight gain. Though the periods will vary with different species, this is the general pattern of growth in nestling raptors. Food shortages can depress weight gain in nestling raptors (Newton 1986). Food deprivation during the 18–20 day age period may have affected negatively the growth and development of the photographed nestling. However, I estimate the nestling goshawk experienced food deprivation near the end of the rapid weight gain period (Moss 1979). Potential depression of the nestlings' development may have been minimized by the timing of the food shortage and the constant food supply provided by the rehabilitator. Fault bars, a likely side effect of food deprivation and stress, were not observed in the nestlings' rectrices after feather growth was complete (C. Van Cleeve, Icarus Foundation, pers. comm.). The photographic record agrees with the observational data of nestling development collected at the other nests used in this study.

Reported fledging ages of nestling goshawks are variable. Reynolds and Wight (1978) found that nestling goshawks in Oregon fledged at 34–37 days. Newton (1979) reported goshawks fledged at 40–43 days, and Brown and Amadon (1968) reported nestlings fledging as late as 45 days. Variation in fledging ages may be related to nestling condition, geographical location, or different definitions of branching and fledging. I define 'branching' as when a nestling leaves the nest but remains in the nest tree, and 'fledging' as when a nestling first leaves the nest tree on its own volition. Reynolds and Wight (1978) found that male nestlings develop and fledge earlier than females. In northern Arizona, male nestlings usually fledged at about 38 days (range = 36–40 days), whereas female nestlings fledged at 39–42 days.

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FIGURE 8 (*top left*). Goshawk at 36–38 days post-hatching. *Morphological Characteristics:* Nestling bodies are approximately 90% feathered, but downy areas remain along the side of the neck, in the thighs, and in the underwing covert area. Usually a tuft of down remains just above the cere on the otherwise feathered head. Rectrices are approximately ¾ full length. *Behavioral Characteristics:* All nestlings will be branching and some of the males may fledge from the nest tree. Nestlings/fledglings will fight aggressively over food at the nest but will still accept being fed by the adult female. Nestlings/fledglings will food beg for long periods.

FIGURE 9 (*bottom left*). Goshawk at greater than 40 days post-hatching. *Morphological Characteristics:* Nestlings/fledglings appear fully feathered, but downy areas persist along underwing covets. This is only visible when the wings are spread. The crop will also appear downy when the bird is gorged. Rectrices are still slightly short of full length. *Behavioral Characteristics:* Males should be fledged and females will usually fledge by 42 days old. Fledglings can often be located when they food beg from different locations in the nest stand. At about 45 days the adults will begin providing food at locations away from the nest.

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