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ASSESSMENT OF GOSHAWK NEST AREA HABITAT USING STAND DENSITY INDEX

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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

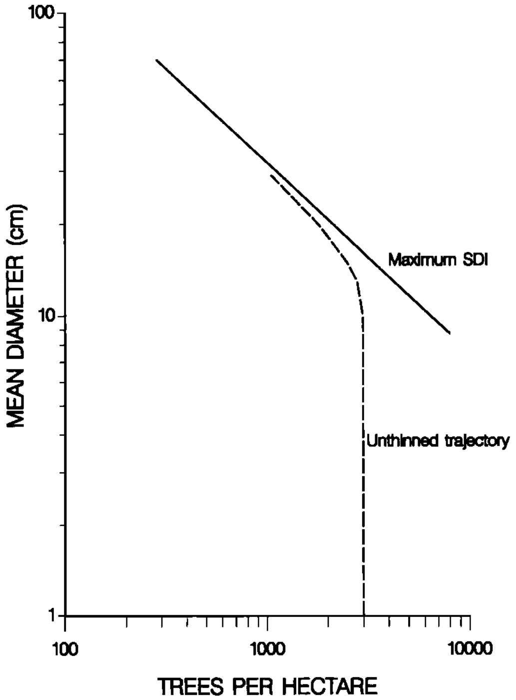

FIGURE 1. Relationship between mean tree size and density on log-log scales. The dashed line represents changing mean size and density for a hypothetical self-thinning Douglas-fir stand.

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

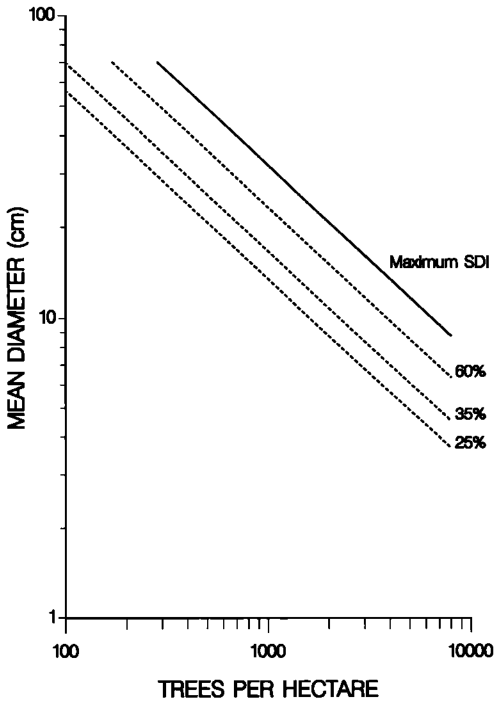

FIGURE 2. Relative density lines indicating 25%, 35%, 60% and 100% of the maximum stand density.

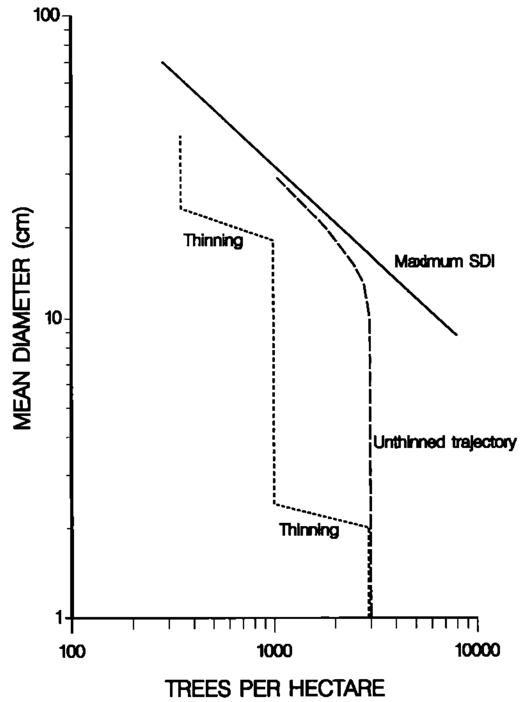

FIGURE 3. Two hypothetical stand density management regimes for Douglas-fir: one represents a natural, unthinned regime; the other includes two planned thinnings.

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

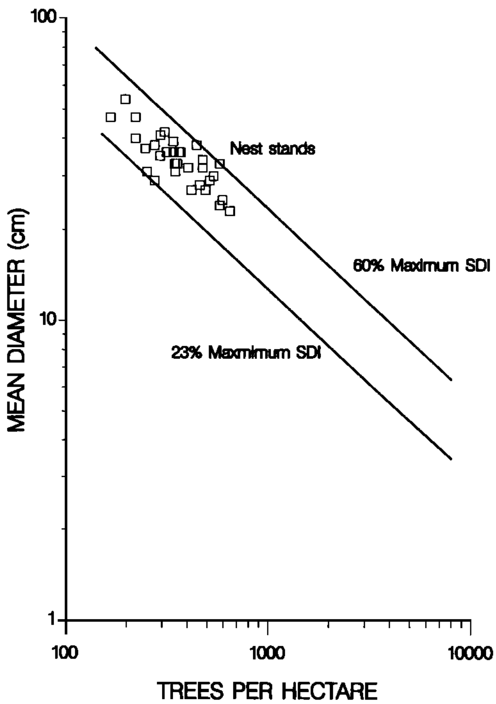

FIGURE 4. Goshawk nest stand data for Douglas-fir stands in southeastern Idaho. The data are bounded by lines representing 23% and 60% of the maximum SDI, which correspond to the minimum and maximum observed relative stand densities.

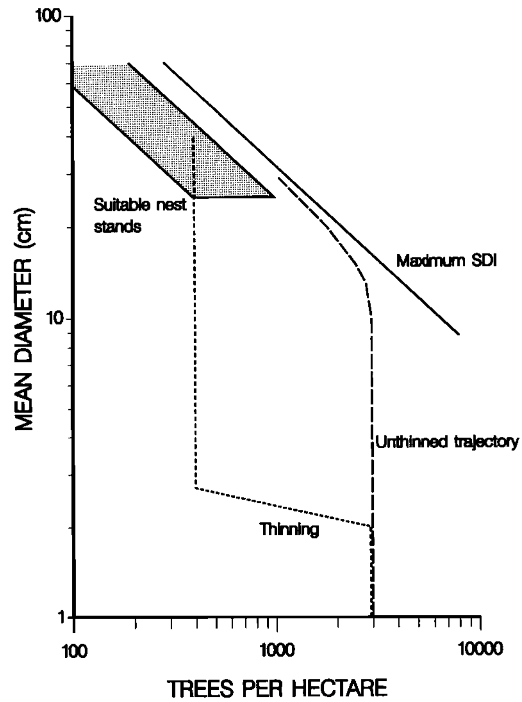

FIGURE 5. Two hypothetical stand density management regimes for Douglas-fir. The shaded area denotes target goshawk nest area structure.

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 silvicultural 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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