APPENDIX D

Understanding HRV and PFC - The terms "historic (or historical) range of variation" (HRV) and "Proper (or properly) Functioning Condition" (PFC) are defined in the Glossary (Chapter 7) and additional clarification is found in many of the references, and specifically in the Committee of Scientists Report (USDA, 1999), the Region 4 Properly Functioning Condition Process Report (USDA Forest Service, 1998), Morgan et al. (1994), and Steele (1994).

Ecosystems vary in time and space with respect to composition, structure, processes, and patterns. This may be termed the natural range of variation (NRV). The HRV (historic range of variation) provides managers with an estimate of NRV and refers to ecosystem composition, structure, processes, and patterns for a specified time and a specified area. It is useful because it helps in understanding the dynamic nature of ecosystems, the current conditions in relationship to the past, and the possible ranges of conditions that are feasible to maintain (sometimes termed the "limits of acceptable change").

The potential for survival of native species may be reduced if their environment is pushed outside NRV. The assumption is that native species adapted to and (in part) evolved with the conditions and climatic patterns of the preceding several thousand years. These conditions led to patterns of landscape and ecosystem variation that were apparently self-sustaining. Successive generations of the same biota under more or less the same conditions give the best indication of sustainability. Managing ecosystems to be within HRV helps to insure that ecosystem elements and processes would not be lost or seriously compromised.

For this assessment, the time period from about 100 to 700 years before present is used for reference conditions, as it is probable that the full range of natural variation would have been spatially and temporally present within local ecosystems during this period. Conditions during this period are more readily determined than those of earlier times, and many biotic and abiotic components are more or less continuous to the present (e.g., most landforms, drainage patterns, and succession cycles of major forest types).

Ecosystems are in a properly functioning condition when, at any temporal or spatial scale, they are dynamic and resilient to perturbations to structure, composition, and processes of their biological or physical components. PFC is based on concepts initially developed and described for riparian ecosystems in Barrett et al. (1993), and further developed in the Region 4 Properly Functioning Condition Process Report (USDA Forest Service 1998), where the concept was applied to larger scales and upland ecosystems. PFC seeks to insure that all ecosystem structures and elements are provided for somewhere within each landscape (spatial), at all times (temporal), and are in a balanced mix (e.g. ‘‘boom and bust’’ cycles are reduced). This helps to insure sustainability of ecosystem process, structure, and composition within each landscape by seeking to insure that all ecosystem elements are present and functioning.

While HRV and PFC share many similarities, they do differ. PFC adds the elements of stability and balance, which are social desires. It is most applicable when applied at a large scale. PFC assumes that site conditions remain within HRV, while conditions at larger scales should contain a range of site conditions. Under PFC, the range of conditions should be more or less balanced with respect to structure, composition, age, and seral stage (this "balance" may not have been present at any one time under HRV). Because of this, management for PFC is generally more conservative than management for

HRV. While systems are within HRV if they do not exceed the historical range of conditions, they may still be outside of PFC if a balanced range of conditions is absent.

For the purposes of this analysis of effects, stand or project level HRV and PFC are assessed to determine if recommended treatments (standards and guidelines) fall within the parameters of these concepts. This is deemed appropriate, as treatment practices would be applied at the stand or project level, not at the landscape level. Landscape assessments would need to be used to coordinate project treatments to insure landscape level HRV and PFC parameters are not exceeded.

Canopy Closure and Stand Density Index - Canopy closure (or canopy cover) is an attribute considered important in mature and old forest ecosystems to various wildlife species. For the northern goshawk and its prey, it is desirable to manage mature and old forest structures generally in a groupy/clumpy pattern with large trees with interlocking crowns to provide shelter and provide for movement from tree to tree for small animals. Groups are generally 2-4 acres in size (other than lodgepole and aspen, which have larger patch patterns) and are comprised of clumps of trees with 2-9 trees with interlocking crowns in each clump. There is typically open space between groups and clumps, enabling goshawks to perch and hunt in a fine-scale mosaic of grouped/clumped trees and more open areas. Reynolds et al. (1992) recommended various minimum canopy closures for various VSS classes and species. Canopy closure values apply to the group, not the larger landscape. The intent with providing canopy closure recommendations was to obtain the necessary structure of mature and old trees with interlocking crowns (Richard Reynolds and Russ Graham 1999).

There are potential problems with using canopy closure as a management guideline. One is that there is no single consistent method to measure canopy closure. Methods vary from simple ocular estimates to measurements using a spherical crown densiometer to vertical canopy projections. Each method has its advantages. Ocular estimates are easily obtained but are the least consistent. Spherical densiometer readings give the most consistent readings, however, may be biased (Cook et al. 1995 and Nuttle 1997). The vertical canopy projection method may be most accurate when properly applied, but it is more time consuming to apply in the field and may not yield consistent estimates from one observer to the next. The vertical canopy projection method can be estimated using computer generated stand simulation through the Forest Vegetation Simulator (FVS) model (Crookston and Stage 1999). Reynolds et al. (1992) used the vertical canopy projection method, thus to be consistent with previous research pertaining to the goshawk, this analysis will also use vertical canopy projection.

A more difficult problem with assessing effects of using canopy closure guidelines is that the relationships between canopy closure and the more traditional stand density measurement tools of basal area and stand density index (SDI) are not well developed. These stand density measurement tools have long been used to assess growing conditions within stands. They provide scientifically sound tools to quantify competition, growth and yield, and susceptibility to insects. The ability to quantify these factors is essential to predict what the effects of management actions may be. Without a scientifically established relationship between canopy closure and these traditional measurement tools, managers would have to select from the best available relationship to apply the guideline, at least until such time as a scientifically accepted relationship has been developed.

A number of researchers and practitioners have developed relationship equations for specific forest cover types in specific areas using canopy closure and SDI. Most available work is specific to ponderosa pine in Region 3 (Arizona and New Mexico). Some of these relationships were developed using the FVS modeling, some with field data, and some with a combination. Only one research paper

was found that dealt with multiple species and used direct field measurements to correlate canopy closure and SDI (Smith and Long, unpublished). Managers would need to make the decision which science is most locally applicable, taking into account the statistical fit of the regression and other factors.

SDI provides the best scientific basis for assessing competition and stress within stands, and it can be directly converted to basal area for any specified average stand diameter. It can be used to assess stand growth and yield, competition, and susceptibility to insects. It is thus the preferred management tool. All forests are currently required by Regional policy to use SDI in the development of silvicultural prescriptions for managing forest vegetation.

Long (1985) developed a "practical approach to density management" using percent of maximum stand density index (SDI%max). This is a very useful concept to help understand stand growth and competition dynamics. SDI%max expresses the competition that occurs between trees within developing stands independent of other influences (such as drought, disease, insects, pollution, etc.). In his paper, Long developed SDI%max relationships to express competition within stands as follows:

- 25% SDI%max = full site occupancy by the forested component;
- 35% = onset of competitive interaction between trees;
- 60% = onset of self-thinning due to intra-tree competition (lower bound of the zone of imminent competition-induced mortality); and
- 80% SDI%max = average maximum density of self-thinning stands.

Once stands reach 80% SDI%max, competition for resources is extreme and has been high for an extended period. It is likely that trees growing under these conditions would not have the ability to respond to additional resources (sunlight, moisture, and nutrients) should disturbance events or management reduce stand density through removal of adjacent trees or vegetation.

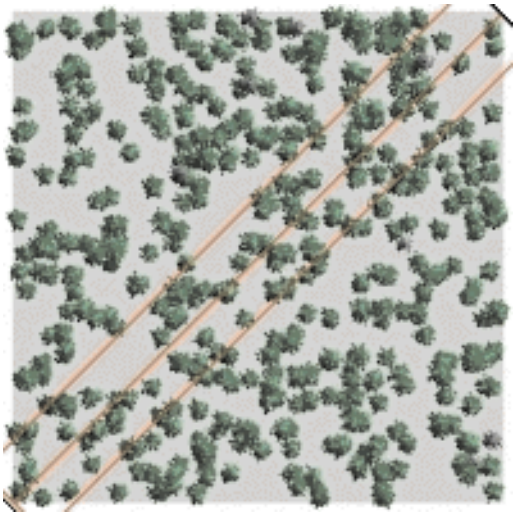
The Region 4 Properly Functioning Condition Process report (USDA Forest Service 1998) did not directly address canopy closure; it did discuss SDI. The PFC report applied concepts developed by Long (above) and literature on insect and disease risks and recommended maintaining stands below 50% SDI% max to maintain proper stand function and reduce overall risk of catastrophic disturbance events. For climax ponderosa pine sites, the Report recommend maintaining stands below 35% SDI%max. Climax ponderosa pine sites are treated differently because on these sites root competition is strong before crown competition occurs because of moisture limitations. Climax ponderosa pine sites in much of Utah could be easily thought of as ‘‘ponderosa pine woodlands’’ rather than "ponderosa pine forests."

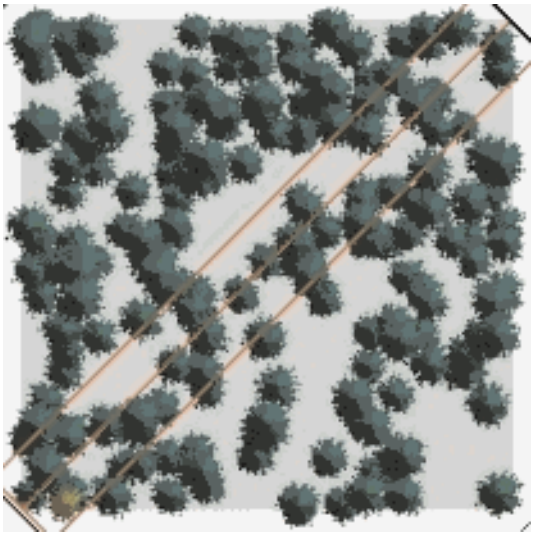
The recommended field methodology for measuring vertical canopy cover projection is: Using a line transect with points, canopy closure is measured by the group (which is made up of clumps). Transect lines should be run through the group and canopy readings should be taken at measured distances along each transect line. If the transect point is under the canopy of a tree or clump (under the drip-line), that reading counts as cover. If 10 readings are taken along a transect and 6 are below the canopy, the group would have 60% canopy closure. At least 3-4 transects should be run for each group to be measured and these transects averaged for the group. Transects may be run at various angles from a plot center or parallel to each other. They should start within the group. Readings along transects should be at predetermined distances.

As an estimate of canopy closure, the FVS model can be used in conjunction with local stand exam data. FVS will compute all the standard measures of density as well as canopy closure. Its companion program, the Stand Visualization Simulator (SVS), will present visual images of the modeled stands. The programs will do this for current conditions as well as future conditions, with or without management practices applied.

The images below are vertical canopy projections from the Stand Visualization Simulator. The data is from the Forest Vegetation Simulator. The three lines superimposed on the images represent potential transect lines. Cover is represented where these lines intersect a tree crown. Note the clumpy nature of trees within the groups (groups are represented by the 1-acre images).

The image to the right is a vertical projection of one acre of an 80-year old lodgepole pine stand containing 380 trees per acre, a basal area of 100 square feet per acre, a stand density index of 218 (31% of maximum), an average stand diameter of 6.4 inches, and a canopy cover value of 66%.





The image to the left is a vertical projection of a one acre group of Engelmann spruce. The group is 170 years old and contains 199 trees per acre, a basal area of 162 square feet per acre, a stand density index of 274 (41% of maximum), an average stand diameter of 12.2 inches, and a canopy cover value of 71%.