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Introduction

Ecologists and wildlife managers are increasingly confronted with the problems of predicting the value of surface cover as wildlife habitat and developing management alternatives to offset wildlife values lost because of land-use change. These problems have become urgent and more acute because of increased demand for products from the land and diminished fiscal and manpower resources for obtaining meaningful environmental information for the decision maker. This paper describes a relatively rapid, simple, and quantitative process for evaluating the quality of an area as wildlife habitat.

An assumption basic to this process is that a potential natural vegetation type (PNVT) (Küchler 1964) can serve as a bound for developing a habitat gradient model. The vegetative community could achieve a common structure throughout the PNVT, given sufficient time and satisfactory growing conditions. Presumably the wildlife community could also attain a common structure if the structure of the vegetative community became similar throughout the PNVT. This would occur because of a similar distribution of food sources, breeding substrates, cover conditions, and other habitat characteristics throughout the PNVT. Even though the structure of the vegetative community and the dependent wildlife community may never achieve this potential, the potential can be used as a baseline value for comparative purposes. The current vegetation types within a PNVT are the result of a variety of edaphic, traumatic, and man-induced factors. These current vegetation types vary in life stage and structure as well as in rates of energy fixation, energy flow, nutrient cycling, and other basic ecological criteria. These differences among current vegetation types result in a variety of available habitat conditions for wildlife and account for the fact that wildlife communities vary in structure between vegetative cover types within a PNVT.

Short and Burnham (1982) have developed a process for correlating wildlife species with the structure of vegetative communities. This process is dependent on the ways in which wildlife species use different layers of vegetation. The number of layers of vegetation (vegetative strata) present in a vegetative community has been shown to be significantly related to the number of species of breeding birds that will be present (Balda 1975). This positive relationship between numbers of species and complexity of vegetative structure has been observed for birds in a variety of North American habitats; e.g, in herbaceous, cedar field, and oak forest communities in New Jersey (Kricher 1973); in nine seral stages in the Georgia Piedmont (Johnston and Odum 1956); and in bare ground, shrub, and bottomland forest habitats on strip mined lands in Illinois (Karr 1968).

The total density of cover and the distribution of total cover between strata also contribute to the variation in structure between vegetative communities. Density of cover is measured as the total amount of cover or the sum of the vertical

projections of the canopy cover of each vegetative strata to the ground surface. Density of cover can exceed 100 percent if more than one stratum is present. The equitability of the distribution of vegetative cover between strata is determined by the foliar height diversity (FHD) measure of MacArthur and MacArthur (1961). The FHD measure has its highest value when cover is equally distributed between strata. Numerous studies have shown significant positive correlations between the FHD measure and the number of wildlife species present.

Wildlife species occupy specific niches within the structure of a vegetative community. The niche has been abstractly described as a response surface developed around a variety of resource gradients (Whittaker 1977). Variations between habitats in the presence and abundance of wildlife species can be related to the values of the different resource gradients within a vegetative community that are important to each species. Theoretically, it should be possible to develop a habitat gradient for a PNVT that would demonstrate the dependency of wildlife species on the values of the resource gradients that are present in the different vegetative communities. The presence and abundance of each wildlife species can be represented by a bell-shaped distribution curve somewhere along the habitat gradient (Levenson and Stearns 1980). The position of this curve corresponds to the acceptable values of the various resource gradients that are important to the species. When bell-shaped distribution curves are plotted for the total wildlife community, they should form a wildlife species gradient along the habitat gradient (Levenson and Stearns 1980).

The first objective of this paper is to demonstrate that a habitat gradient for a PNVT can be developed from information on the number of vegetative strata present, the total density of vegetative cover, and the distribution of vegetative cover between strata. This information, needed to position habitats along the habitat gradient, can be obtained by ground surveys or by estimating the structure of vegetative cover from carefully interpreted aerial photographs. The second objective of this paper is to demonstrate that the structure of vegetative communities, as indicated by their positions along the habitat gradient, is predictive of the number of wildlife species that can occur in these areas. Finally, the paper will discuss how the position a vegetative community occupies along a habitat gradient can be expected to vary following land use or management changes and how to predict the resulting impact on the wildlife community from the new position the habitat occupies along the gradient.

Methods

Guild Blocks

The relationship between wildlife species and vegetative strata can be expressed in terms of guild blocks (Short and Burnham 1982). Guild blocks are derived from two resource gradients that are universally important to terrestrial wildlife species. These gradients are: (1) physical positions within the structure of a vegetative community where food sources occur; and (2) physical positions within the structure of a vegetative community where breeding substrates occur.

Guild blocks for a vegetative community can be defined by constructing a matrix where the y-axis represents loci where food sources occur and the x-axis represents

loci where breeding occurs. The x-axis also contains a position for species that feed in the area but breed elsewhere. The number of available guild blocks will vary for different vegetative communities depending on the number of vegetative strata that are present. An upland grass community, for example, is described by a 3x3 matrix, with nine guild blocks available as wildlife habitat (Figure 1). These guild blocks describe, in a general manner, the ways in which wildlife can use the grassland community. For example, the guild block in the center of the matrix represents the habitat use pattern for those wildlife species that breed and feed on the ground surface. The matrix guild blocks are closely related to the general concept of life forms described by Thomas (1979).

A shrub steppe habitat includes an additional vegetative stratum, resulting in a 4x4 matrix that describes 16 ways in which wildlife can use this habitat. Habitats dominated by small trees, such as pinyons and junipers, are represented by a 5x5 matrix with 25 guild blocks. These small trees are classified as part of the shrub stratum based on their height. In terms of wildlife use, however, they are structurally intermediate between shrubs and large trees because they have a tree bole large enough to be used as a breeding or feeding substrate, or both, by excavators or cavity users.

Pole-sized trees in forest lands may be 10 to 20 m (33 ft. to 66 ft.) tall and still not have a tree bole of sufficient diameter to be used by wildlife as a breeding or feeding substrate. These habitats are also described by a 5x5 matrix because of the presence of a tree canopy. Habitats that contain mature trees with a bole large enough to be useful to wildlife are represented by a 6x6 matrix that contains 36 guild blocks (Figure 2).

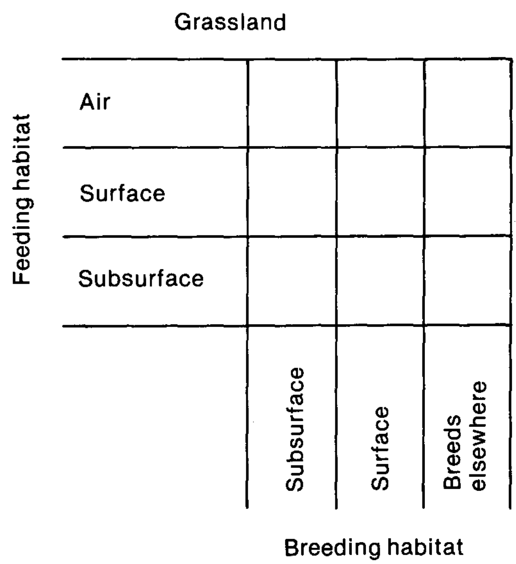


Figure 1. Nine guild blocks exist in upland grassland habitats. The guild blocks indicate the ways in which wildlife species can use grassland habitat.

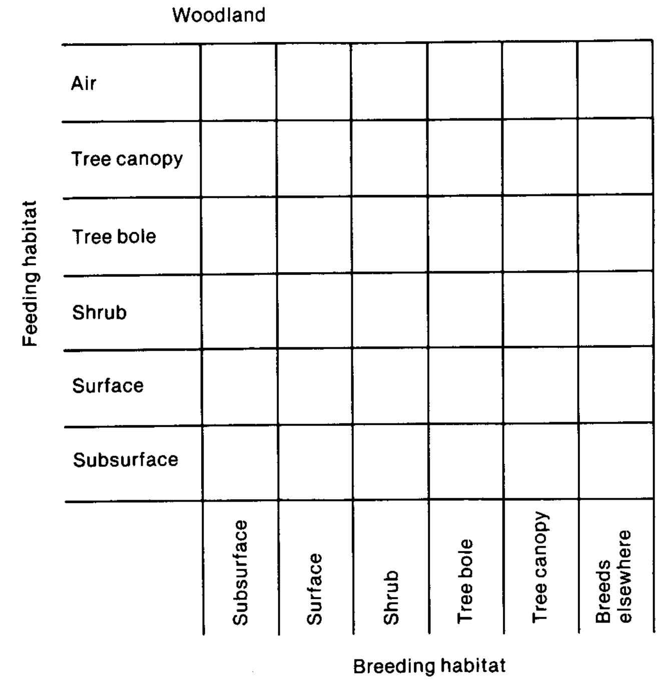


Figure 2. Thirty-six guild blocks exist in mature upland forest habitats. The guild blocks indicate the ways in which wildlife species can use forest habitat.

The guild block concept relates the occurrence of groups of wildlife species to major structural features of the vegetative community. The use of guild blocks does not permit a detailed description of the niche requirements of a particular species because all of the potentially important resource gradients are not included.

Structure of Vegetative Communities

The total percentage of cover and the equitability of cover between vegetative strata were determined for 10 vegetative communities on the U.S. Bureau of Land Management (BLM) Hualapai-Aquarius Planning Unit. This planning unit contains several different cover types within the Upper and Lower Sonoran Desert of westcentral Arizona (Table 1).

Vegetative structure was determined using the line transect toe point method from transects near the areas where faunal surveys occurred. Toe points were recorded about every four paces until at least 50 toe point hits on vegetation in a study site were tallied. The plant part or substrate encountered at each sample toe point was identified and recorded, as were plant hits in five ascending vertical strata. Plant hits were clumped into three strata: (1) a surface vegetation class ($\leq$ 0.6 m [2 ft.] tall); (2) a shrub midstory class ($>$ 0.6 m but $<$ 5 m [$>$ 2 ft. $<$ 16.4 ft.]); and (3) a tree canopy class ($\geq$ 5 m [16.4 ft] tall). These strata adequately

Table 1. Data from Arizona habitats used to develop the habitat gradient model.

	No. of guild blocks	Percentage of distribution by canopy class[a] <0.5	0.5–5m	>5m	Strata cover equitability[b]	Percentage of cover	Log (cover × equitability)	Habitat gradient value-guild blocks × log (cover × equitability)	No. herp. sp.[c]	No. bird sp.[d]	No. mammal sp.[e]	Total no. terrestrial sp.
Cottonwood-willow riparian	36	23.1	42.3	34.6	1.069	64.4	1.84	66.2	18	65	6	89
Pinyon-juniper	25	33.2	56.1	10.7	0.929	54.6	1.71	42.6	17	27	9	53
Closed chaparral	16	36.4	63.6		0.656	96.6	1.80	28.8	22	19	6	47
Open chaparral	16	61.0	39.0		0.669	51.9	1.54	24.6	11	22	5	38
Desert grassland	9	71.2	28.8		0.600	43.7	1.41	12.8	8	13	6	27
Joshua tree	16	63.1	35.1	1.8	0.730	42.6	1.49	23.9	12	20	8	40
Creosote bush	16	62.6	37.4		0.661	28.1	1.27	20.3	13	17	7	37
Saguaro-palo verde	25	54.5	45.5		0.689	40.2	1.44	36.1	23	33	6	62
Mesquite bosque	25	14.1	63.9	22.0	0.895	60.0	1.73	43.2	15	49	5	69
Juniper-mixed shrub	25	51.0	49.0		0.693	34.8	1.38	34.6	19	26	10	55

[a]From original data collected by Robert S. Hall and K. B. Jones.
[b]Uses Shannon formula (Shannon and Weaver 1963).
[c]Jones 1980.
[d]Hall 1980.
[e]Peck 1979.

partition the flora of the Sonoran desert. A ground surface stratum that extends to 0.6 m (2 ft.) above the surface approximates that used by MacArthur and MacArthur (1961). These authors also determined that a tree canopy stratum beginning at about 5 m (16.4 ft.) above the surface was useful for measuring foliar height diversity. The percentage of the sample points that encountered vegetation on the ground surface, in the shrub stratum, and in the tree canopy stratum were used to produce estimates of plant cover in each stratum. The total cover was determined by summing the percentage of cover recorded for each vegetative stratum present. Both percentage of total cover and the percentage of distribution of total cover between vegetative strata are recorded in Table 1.

The species of amphibians, reptiles, birds, and mammals present on each study site were determined with techniques described by Peck (1979), Hall (1980), and Jones (1980).

Results

The 10 Arizona study sites evaluated in this paper included a desert grassland community (nine guild blocks), four shrub dominated communities (16 guild blocks each); a riparian-mesquite bosque, a saguaro-palo verde community, and two communities with dwarf trees (25 guild blocks each); and a cottonwood-willow riparian treeland (36 guild blocks each). The saguaro, in the saguaro-palo verde habitat, was considered a tree without a canopy on the basis of its height and the use of its bole by wildlife.

The number of wildlife species that used the 10 habitat types throughout the year had a highly significant ($r = 0.98$) positive correlation with the number of guild blocks present (Figure 3). The variability in the number of species using habitats with equal numbers of guild blocks is largely accounted for when measures of total cover and equitability of cover between strata are considered in the model.

The variability in species richness between the 10 study sites was not significantly ($r = 0.28$) related to the relative amounts of cover. This occurs because two sites can have identical amounts of total cover with the cover restricted to only one stratum on one site and divided among several strata on the other site.

Species richness on the 10 study sites was correlated with the equitability measure ($r = 0.83$), because of the relationship between high equitability values and multiple strata, and with the product of total cover × equitability ($r = 0.64$). In both cases, however, the structural variables accounted for less than 70 percent of the variability in the prediction of the number of species that occurred on the study sites.

The product of number of guild blocks × percentage of cover × equitability of cover between strata produced a continuum or gradient of habitat conditions that illustrates the increase in species richness that occurs as habitats become more complex. The correlation coefficient between species richness and guild blocks × cover × equitability is $r = 0.89$.

A sigmoid species richness curve should exist for each group of habitats (9, 16, 25, or 36 guild blocks). The sigmoid curve for habitat types with little cover or low equitability of cover should indicate the presence of only a few species. The number of species represented by the sigmoid curve should increase as percentage of cover or equitability of cover increases. There is some maximum number of species that

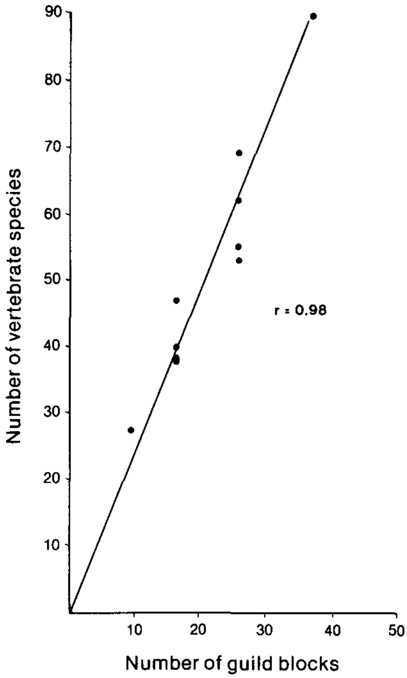


Figure 3. The number of guild blocks in 10 habitat types in westcentral Arizona is highly correlated ($r = 0.98$) with the number of wildlife species occurring in those habitats.

can exist in a particular habitat type. This maximum species richness or species packing should occur as the product of total cover and equitability of cover approaches the maximum for that habitat type.

The log transformation of the product of cover × equitability for the Arizona data was used to convert individual sigmoid curves for each habitat type into a single species richness gradient that corresponded to the habitat gradient, demonstrating the positive relationship between species richness and vegetative structure. The product of guild blocks and log (cover × equitability) accounted for about 93 percent of the variability ($r = 0.97$) in predicting the numbers of wildlife species present on the 10 study sites (Figure 4).

Discussion

Interpreting the Habitat Gradient

The habitat gradient potentially varies from simple ecosystems with little vegetation or structural diversity at one end to complex ecosystems with extensive vegetation and structural diversity at the other end. The extremes of the corresponding species richness gradient are few or no wildlife species where amount and diversity of vegetation is very low and a maximum number of species where

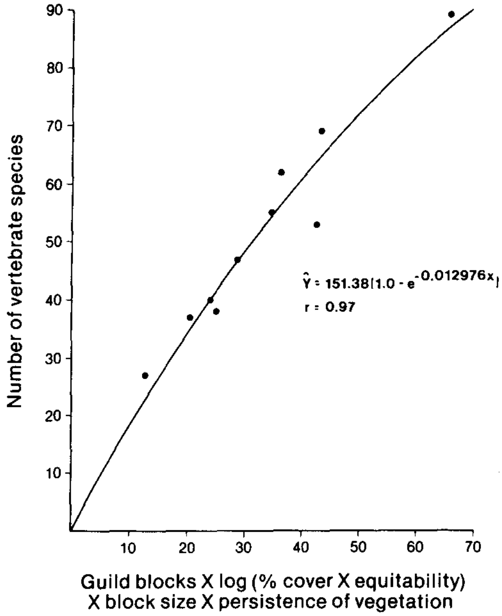


Figure 4. The relationship predicting species richness from the product of guild blocks × log (cover × equitability) × block size × persistence of vegetation for 10 habitat types in west-central Arizona (r = 0.97).

the structural diversity and complexity of vegetation is greatest. Because the habitat gradient has a defined end point, which represents optimal habitat conditions, intermediate habitats along the gradient can be compared with the optimal conditions to provide an index of relative habitat quality.

A change in the vegetative structure of a habitat results in a change in the position of the habitat along the gradient and causes the habitat to become suitable for a different group of wildlife species. A different series of species-habitat distribution curves are encountered that result in a different species richness value for the habitat. The objective of modeling habitat requirements for a species is to describe that species' bell-shaped distribution curve along the habitat gradient. Concepts in the species richness model are therefore just as applicable to studies of featured species as to studies of wildlife communities.

Additional Variables in the Habitat Gradient Model

Samson (1980) determined, on the basis of a literature review, that the size of islands of habitat can be used to predict the number of birds present in several temperate habitats. Species that are sensitive to habitat size tend to disappear as habitat becomes fragmented. Unfortunately, land use change often results in a reduction in habitat block size. Few studies have described the minimum block size necessary to provide suitable habitat for particular wildlife species. The block size multiplier must remain undefined until better predictors of the relationship

between habitat area and species richness are developed. This multiplier, however, is important in determining the value of land as wildlife habitat.

Persistence of surface vegetation is a multiplier which weights the effects of agriculture, other intensive management of surface vegetation, or natural ephemeral vegetation on the quality of wildlife habitat. Persistence considers the length of time the vegetation is present and the extent of cover. For example, the persistence multiplier for an agricultural cropland is:

6 months fallow because of autumn plowing 6 × 0 percent ground cover	= 0
1 month early growth × 5 percent ground coverage	= 5
1 month mid-growth × 25 percent ground coverage	= 25
1 month mid-growth × 50 percent ground coverage	= 50
1 month near mature growth × 80 percent ground coverage	= 80
2 months mature growth × 100 percent ground coverage	= 200
Average persistence	= 360 ÷ 12
	= 30%

Block size and persistence of surface vegetation are included in the wildlife habitate gradient model (Figure 4). Both multipliers in this example are 1.

The predictive relationship in Figure 4 indicates that those habitats along a habitat gradient for a PNVT that contain the most guild blocks will support the most wildlife species. If two habitats along a gradient have the same number of guild blocks available for wildlife use, the habitat with the greatest total cover and equitability of cover between strata, largest block size, and most persistent cover will support the most wildlife species and guilds.

The Habitat Gradient Model as an Index

Four different PNVT (Küchler 1964) are represented in the habitat gradient model described in Figure 4: (1) juniper-pinyon woodland; (2) grama-tobosa shrub-steppe; (3) creosote bush-bur sage; (4) and the palo verde-cactus shrub type. The variables included in the habitat gradient model were sufficiently critical to wildlife that a regional habitat gradient could be developed to represent the diverse vegetative structures encountered.

The habitat gradient model can be used to develop a habitat gradient within any single PNVT. There will always be an upper limit to the vegetative diversity that can be represented along any habitat gradient. This upper limit can be used as the denominator in proportions used to estimate habitat quality for any other point along the habitat gradient for the same PNVT (Figure 5). This denominator is calculated as: number of guild blocks for the climax vegetation in the PNVT × log (maximum cover that has been observed to be distributed equally between strata × maximum equitability value for the strata present in the climax vegetation) × large block size × maximum persistency of vegetative cover. The actual wildlife value for any current habitat within the PNVT can be used as the numerator in the proportion in order to develop an index. The proportion, expressed as a

$$\text{Wildlife habitat quality coefficient} = \frac{\text{Actual values}}{\text{Potential values}}$$

$$= \frac{\left[\begin{array}{c}\text{Number guild}\\ \text{blocks present}\end{array}\right]\left[\log\left(\begin{array}{c}\text{Density of}\\ \text{total cover}\end{array} \times \begin{array}{c}\text{Equitability of}\\ \text{cover between}\\ \text{strata}\end{array}\right)\right]\left[\begin{array}{c}\text{Habitat}\\ \text{block}\\ \text{size}\end{array}\right]\left[\begin{array}{c}\text{Persistence}\\ \text{of cover}\end{array}\right]}{\left[\begin{array}{c}\text{Number guild}\\ \text{blocks in}\\ \text{potential}\\ \text{vegetation}\\ \text{type}\\ 9 = \text{grassland}\\ 16 = \text{shrubland}\\ 25 = \text{small trees}\\ 36 = \text{treeland}\end{array}\right]\left[\log\left(\begin{array}{c}\text{Maximum}\\ \text{density of}\\ \text{vegetation in}\\ \text{potential}\\ \text{vegetation}\\ \text{type}\\ 100\%\text{ if one}\\ \text{stratum}\\ 150\%\text{ if two}\\ \text{or three}\\ \text{strata}\end{array} \times \begin{array}{c}\text{Maximum}\\ \text{equitability}\\ \text{coefficient}\\ \\ 0.1\text{ if one}\\ \text{stratum}\\ 0.69\text{ if two}\\ \text{strata}\\ 1.10\text{ if three}\\ \text{strata}\end{array}\right)\right]\left[\begin{array}{c}\text{Habitat}\\ \text{block}\\ \text{size} = 1\end{array}\right]\left[\begin{array}{c}\text{Persistence}\\ = 1\text{ if surface}\\ \text{vegetation}\\ \text{remains in place}\\ \text{throughout year.}\\ \text{Calculate value}\\ \text{if potential}\\ \text{surface vegetation}\\ \text{is deciduous or}\\ \text{ephemeral.}\end{array}\right]}$$

Figure 5. Form of the habitat gradient model when used as an index of wildlife habitat quality. The numerator represents measured values in a current vegetation type, and the denominator represents optimal values that are measurable in a potential natural vegetation type.

percentage, can be used to compare quality between different habitats within the PNVT.

Use of the Habitat Gradient Model in Land Use Planning

The five variables (guild blocks, percentage of total cover, equitability of cover, block size, and persistence of cover) in the habitat gradient model represent vegetative characteristics that are affected by land use changes. Values for these variables can be manipulated to reflect anticipated habitat changes, and the habitat gradient model used to predict the impact of the potential change on habitat quality.

Impacts of proposed management alternatives on a wildlife community or a particular wildlife species can be predicted with the habitat gradient model. Predicting impacts for a single species requires the development of the bell-shaped distribution curve that describes favorable habitat conditions for that species. If the position of the vegetative community on the habitat gradient, following management, represents the habitat structure required by the species, then the species would not be expected to be adversely affected by the habitat channge. If, however, the predicted new position of the vegetative community on the habitat gradient does not describe the habitat requirements of the species, the species will probably be adversely affected by the proposed change in habitat conditions.

When the model is used to predict the impacts of management on the total wildlife community, wildlife species are assigned a relative value. In the following example, all species have been assigned the same value and the conversion of native grassland to grazing or intensive agriculture are the land use changes that are considered. Management objectives for this example are to: (1) retain some native habitat and fauna; and (2) provide a more complex vegetative structure on

the remaining area so that the remaining area × wildlife species richness value equals the former total habitat area × wildlife species richness value.

The maximum wildlife habitat value for 100 units of grassland with abundant cover is calculated according to the formula in Figure 5:

Original wildlife habitat value = 100 units area × 9 guild blocks × log (100 percent cover × 0.1 equitability) × 1 habitat block size × 1 persistence
= 900

The wildlife habitat value would be about 30 percent less if the cover value of the grassland was reduced 50 percent by some new land use, such as grazing.

New wildlife habitat value = 100 × 9 × log (50 × 0.1) × 1 × 1
= 629

Proportion of original wildlife habitat value = 629/900
= 70%

The position of the 100-unit area of grassland on the habitat gradient for the PNVT would shift to the left, and fewer wildlife species would be expected to occur. Species whose distribution curves indicate a perference for 50 percent grassland cover should respond favorably to the change in habitat conditions, while species that require more than 50 percent cover probably would be adversely affected.

Habitat quality value for the grassland would also change if the entire area was converted to cropland. Subsurface and surface strata would be unsuitable as breeding habitat for wildlife if agricultural operations included spring discing, summer cultivation, autumn plowing, and fallow field conditions during winter. The number of guild blocks available as habitat would be reduced to three. The only wildlife that would remain are those species that bred elsewhere and fed in the subsurface (rarely), on the surface, or in the air. Crop cover at maturity might be as high as 100 percent but cover persistence might be, for example, only 33 percent.

The wildlife habitat value of the cropland would be only about 11 percent of the value of the original grassland.

Cropland wildlife habitat value = 100 × 3 × log (100 × 0.1) × 1 × 0.33
= 100

Proportion of original wildlife habitat value = 100/900
= 11%

The vegetative structure on the remaining grassland could be modified to help compensate for wildlife habitat loss if only part of the area is converted to cropland. For example, the development of shrub dominated fence rows or shelterbelts could

increase the value of wildlife habitat because these areas contain 16 guild blocks. Converting 27 percent of the grassland to a shelterbelt of multiflora rose would retain the original area × wildlife habitat value of the total grassland (900), provided the shrub midstory and the underlying native grassland surface cover each provided 60 percent cover.

Shelterbelt habitat cover $= 27 \times 16 \times \log(120 \times 0.68) \times 1 \times 1$
$= 826$

Cropland wildlife habitat value $= 73 \times 3 \times \log(100 \times 0.1) \times 1 \times 0.33$
$= 73$

Total wildlife habitat value $= 899$

It must be emphasized that this example is more an exercise in arithmetic than biology because each species has been considered of equal value in the analysis. The example is justified, however, because it illustrates that land use change in native grassland need not result in the complete destruction of native prairie as wildlife habitat.

Converting 27 percent of the grassland to a shrub-dominated grassland association (shelterbelt), scattered throughout the 100 unit area, would result in both agricultural and wildlife benefits. Shelterbelts help reduce loss of cropland to wind and water erosion and provide protection from adverse climatic conditions for homes and livestock. Wildlife benefits because the loss of habitat carrying capacity over much of the area is compensated for by the development of more complex habitat over the remaining area, even though different wildlife species may be favored. Martin (1980) recommended that shelterbelts be as close together as feasible and as large as possible, because larger shelterbelts are used by more species.

Use of Data from Aerial Photographs in the Habitat Gradient Model

Data from aerial photographs can be used to locate a vegetative community on a habitat gradient, although some initial ground truthing is needed. Ground truthing is done in the major current vegetation types in order to develop a predictive relationship between percentage of cover in the highest stratum and percentage of cover in the lower strata.

The relationship between overstory crown cover and shrub cover has been described for mixed coniferous forests in Oregon by Young et al. (1967). Percentage of crown cover has been correlated with forage production, which is a function of surface cover, in ponderosa pine habitats in the Black Hills (Pase 1958), pine-hardwood forests in Texas (Halls and Schuster 1965), and ponderosa pine and pinyon-juniper habitats in northern Arizona (Jameson 1967). Predictive relationships, like those in Figure 6, can be developed for percentage of overstory cover and percentage of cover in the understory and midstory. Estimates of percentage of crown closure can be determined from aerial photographs. The estimates are occular and are usually done with printed density scales or with comparative stereograms (Avery 1978).

Tree crown diameter, which can be determined from 1:20,000 aerial photographs

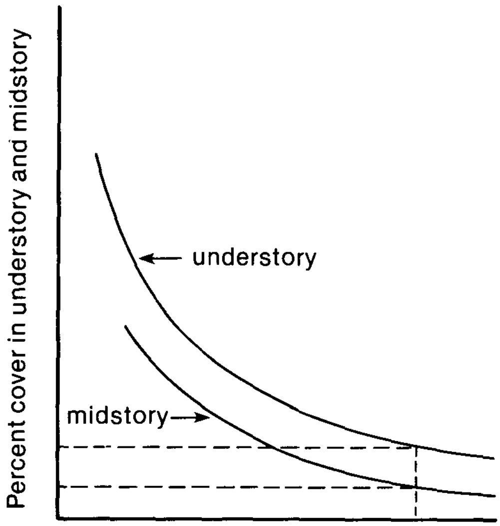
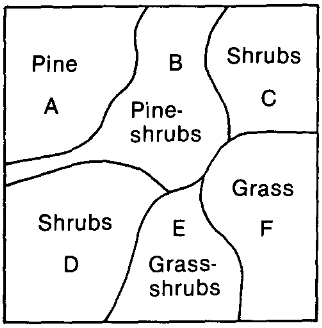


Figure 6. Form of prediction curves to estimate midstory and understory cover from values of cover measured in the overstory.

(Avery 1978), is related to trunk diameter for most conifers and many hardwoods. Individual crown diameters are most accurately measured in open growth stands, although average diameters of dominant trees in dense stands can be determined. The relationship between crown diameter and trunk diameter can be used to determine whether or not a tree bole is large enough to be used by wildlife. This distinction determines if the tree stand provides 25 or 36 guild blocks.

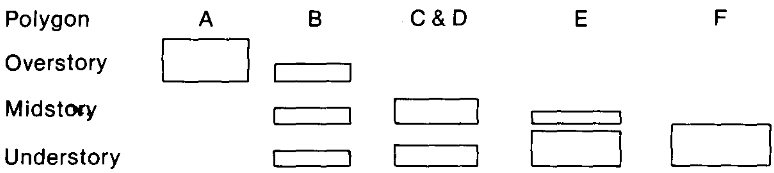
Current vegetative types that can be identified on an aerial photograph are separated into polygons on the basis of the number of strata and guild blocks present. The area of each polygon and the percentage of canopy cover in the highest stratum of each polygon are determined. The prediction equations developed to relate percentage of canopy cover in the highest stratum with percentage of canopy cover in the lower strata are used to estimate cover values for the lower strata that are present. Percentage of canopy cover values for all of the strata are assumed to provide a measure of percentage of total cover. The percentage of the total cover that is present in each stratum is used to calculate the equitability of cover using the Shannon formula (Shannon and Weaver 1963). The block size multiplier is applied when information is available on how fragmentation of habitat affects species use. The vegetation persistence multiplier is applied for agricultural areas.

Figure 7 illustrates how the wildlife habitat value is determined from aerial photographs for a hypothetical 100-unit area of mixed cover types. The polygons of different vegetation cover types (A–F) are demarcated and the area and cover profile of each polygon determined. Polygon A, a pine woodland, has a dense tree canopy and an average tree canopy size that indicates the presence of suitable



Photointerpretation of land area 100 units in size

Apparent vertical profile of polygons as determined from the canopy form observed from aerial photos and from ground truthing data.



Calculation of wildlife habitat value for 100 unit area

Polygon	Area	No. guild blocks	Density of canopy in highest stratum	Estimated mid-story if treeland polygon (Fig. 6)	Estimated under-story if treeland polygon (Fig. 6)	Estimated under-story if shrubland polygon	Total estimated per-cent cover	Estimated equi-tability of cover	Block size multiplier	Cover persis-tence value	Area x guild block x log (cover x equitability) x block size x persistence	
A	15	36	100	0	0		100	0.1	1	1	540	
B	30	36	40	40	40		120	1.1	1	1	2290	
C	10	16	60			60	120	0.65	1	1	303	4052
D	15	16	60			60	120	0.65	1	1	454	
E	10	16	30			90	120	0.5	1	1	285	
F	20	9	100				100	0.1	1	1	180	
Ideal	100	36	50	50	50		150	1.1	1	1	7983	

$$\frac{\text{Wildlife value x Area}}{\text{Ideal wildlife value x Area}} = \frac{4052}{7983} = 51\%$$

Figure 7. Procedure for characterizing the wildlife habitat value of lands from interpreted aerial photographs. The process involves predicting the structure of a vegetative community from the aerial photographs and suitable prediction equations, calculating wildlife habitat values for the land area, and comparing these values to the wildlife habitat values potentially obtainable on that land unit.

boles for wildlife use. Polygon B, a pine-shrub association, contains several strata and is essentially a large unit of "edge" between polygons of treeland habitat and areas with only midstory or understory strata. Polygons C, D, and E are shrub

and shrub-grass habitats, while polygon F is a grassland. The vegetative structural conditions that would be optimal for this PNVT, represented by the upper limit of the habitat diversity gradient, are also listed in Figure 7.

The wildlife habitat value of each polygon is determined and the values summed for the entire area being evaluated (Figure 7). The wildlife habitat value for optimal conditions is also determined for the total area. Ideal habitat would consist of large blocks of habitat, at least several square miles in area, with cover conditions similar to those in polygon B. The index obtained by comparing the current wildlife habitat value with the optimal habitat value is 51, about two-thirds of the way along the habitat gradient in Figure 4.

Habitat quality values, estimated from aerial photographs, can be directly compared between areas of the same size within a PNVT. In addition, estimates of the number of expected wildlife species, extrapolated from the habitat gradient, can be compared between areas within the PNVT if the species richness curve for that PNVT has been determined.

Optimal habitat for this example is the most heterogeneous habitat possible in this PNVT. Specifically, it is that habitat where all forest strata exist and where both the greatest possible total cover and the most equitable distribution of cover among strata occur, i.e., where an edge situation occurs around each tree in the overstory. This optimal habitat, represented by the denominator of the wildlife habitat value equation in Figure 7, is essentially a 100-unit block of edge.

Conclusions

The variety of habitats that exist within a PNVT can be described in terms of a habitat gradient. The variation in the vegetative structure of these habitats, will be accompanied by a corresponding variation in the structure of the wildlife communities that are present.

Comparing the structure of the vegetation on individual habitat sites with the maximum vegetative diversity that can occur in a PNVT provides a measure of habitat quality. Data about the structure of vegetative communmities, needed to estimate habitat quality, can be determined from field inventory data or from interpreted aerial photography, supplemented with ground truth information.

Regional or national assessments of habitat quality for wildlife can be accomplished by measuring the structural diversity of habitats within a PNVT and summing these measurements across all PNV types. Assessments done at two or more different times would describe changes that have occurred in habitat quantity and quality.

The vegetative variables that describe habitat diversity are measureable. They can be simulated in planning efforts in order to predict the effect of land use change on wildlife habitat and manipulated in actual wildlife management procedures in order to alter the habitat quality of land units.

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