Deer Browsing of Hardwoods in the Northeast

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A REVIEW AND ANALYSIS OF THE SITUATION AND THE RESEARCH NEEDED

Contents

	Page
INTRODUCTION	1
THE BROWSE SITUATION	3
SINGLE-USE MANAGEMENT	5
Cutting	6
Herbicides	10
Fire	12
Bulldozing	13
MULTIPLE-USE MANAGEMENT	13
BROWSE NUTRITION AND PALATABILITY, AND DEER PREFERENCES	17
BROWSE MEASUREMENT	20
Characteristics of browse twigs	21
Statistical considerations	21
Twig-length method	24
Twig-count methods	25
Density methods	26
Weight-estimation methods	26
Clip-and-weigh method	27
Descriptive methods	27
Comparison method	28
Pellet-conversion method	28
Exclosures	28
CONCLUSIONS	30
RESEARCH NEEDS	31
LITERATURE CITED	33

Introduction

THE white-tailed deer *(Odocoilens virginianus)* is by far the most important big-game animal in the Northeast, both in hunter interest and in its damaging effects to field and forest. In the absence of predators, deer have the potential to increase rapidly to greater numbers than the natural food supply will support. If hunting regulations are unduly restrictive, excessive populations build up. The animals decline in size and vigor, and both farm crops and forest reproduction suffer. Winter browse is the crucial item in the year-round food supply; when it fails during a severe winter, mass starvation may occur.

The most obvious and direct answer to this problem is to reduce the deer populations by more liberal hunting regulations. A second measure, which ideally should be coordinated with population control, is to manage non-agricultural land for greater browse production. However, the latter measure is easier said than done; it requires much technical knowledge, which forest and wildlife technicians are just in the process of acquiring. Such knowledge is particularly essential where management for browse is to be integrated into multiple-use systems of land management.

Deer research in the past has been concentrated on herd control, and information on this aspect of deer management is now nearly adequate although not yet applied in many places because of the public's overly protective attitude. Once deer are in balance with their natural food supply, the primary multiple-use objective on many areas will be to maintain a healthy herd at a population level that the range can continuously support without the tree reproduction that is essential for sustained timber production being destroyed.

To provide guides for accomplishing this, extensive research is needed in the timber-wildlife phase of multiple-use land management to determine, for specific timber types and regions, what constitutes a proper balance between timber and deer. Certain relationships between deer and forest management practices that apply to, or are adaptable to, sections of the Northeast have already been summarized in several studies (Little *et al.* 1958, Gill 1957c, Banasiak 1961, Jenkins and Bartlett 1959, Latham 1950).

This report deals with the production, utilization, and measurement of hardwood deer browse in the forests of the Northeast. It is basically a review of pertinent literature. To the extent that the cited literature has been selected and interpreted, that conclusions have been drawn, and that recommendations have been made, this report is also an analysis of the problems and research needs in managing forest land for deer. The purpose is to provide a reference tool for both administrators and researchers involved in the technical problems of timber-deer management in this region.

As indicated above this report is concerned primarily with hardwood browse — the twigs, buds, and leaves of woody plants of the hardwood category (as opposed to softwoods or conifers). However, information on other forms of vegetation or on non-indigenous species has been included when it seemed relevant to the discussion.

References are made in this report to certain concepts that lend themselves to precise definition only in the context of specified conditions and management objectives in particular situations. Among these concepts are "carrying capacity," "in balance with the food supply," and "multiple use."

The concept of carrying capacity has been discussed by Edwards and Fowle (1955), who state that "carrying capacity is determined by the whole environment, and with some reservations, the number of animals upon a unit of range is in itself a measure of the carrying capacity of that area." However, they say that the factors in the environment should be considered separately when determining carrying capacity. These factors usually follow Liebig's "Law of the Minimum," with the most critical factor having a major influence.

"Multiple use" is both a concept and a management system. In the context of this review, it involves planned maximum use of a given area for deer habitat and timber production; it means that the intensity and pattern of timber cutting should be guided, insofar as is feasible, by multiple-use rather than single-use criteria in order to meet the increasing demand for both timber and deer. And, although not further discussed here, it should be understood that habitat for other wildlife, and management for other purposes—such as watershed protection, recreation, and scenic values—may also be involved. Multiple use explicitly re-

quires management for various renewable resources "over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions."[1]

The Browse Situation

The present condition of browse in the Northeast is the result of past land-use (Leopold 1950, Bennett 1957, and Latham 1959). In the late 1800s much of the timber throughout the Northeast was cut heavily. As a result, vast areas of young sprout-growth in the early 1900s provided abundant deer food; and deer populations increased rapidly. When the sprout growth developed into even-aged sapling and pole stands (fig. 1), such as those that now occupy more than 52 percent of the commercial forest land in the Northeast (U. S. Forest Service 1958), the much reduced understory vegetation could not support the large deer herds and the following results, as listed by Latham (1950), occurred: (1) reduction of total carrying capacity; (2) reduced populations of certain small game; (3) decreased or complete loss of forest reproduction; (4) crop damage; (5) abnormalities of deer themselves caused by malnutrition; (6) reduced antler size; (7) reproductive abnormalities; (8) winter mortality; and (9) disease.

However, heavy browsing is not always detrimental. In deer-yards in northern Michigan, which contained many of the same tree species found in the Northeast, Davenport *et al.* (1953) observed that deterioration occurred almost as rapidly in areas that were not used by deer as in areas that were used. The deterioration comes about through self-pruning of the trees and suppression of the undergrowth by shading, and from damage to the undergrowth by snowshoe hares. The authors concluded that "Good management, therefore, should strive to prevent underutilization as well as overutilization of those yards having high browse production."

Webb (1957), in discussing overbrowsing in Northeastern forests, commented that, at some stages of a forest rotation,

[1]Multiple use as it relates to management for timber and deer is defined in the Multiple Use and Sustained Yield Act of June 12, 1960, passed by the 86th Congress (Public Law 86-517) as a directive for the administration of the National Forests.

Figure 1.—A typical even-aged (45 years) sprout-origin stand of northern hardwoods with practically no reproduction or browse in the understory.

". . . heavy browsing is allowable and perhaps even desirable . . . but . . . at other times in the rotation even light browsing may be detrimental to the forest . . ." In another study, Webb *et al.* (1956) stated that deer were not a significant factor in controlling the vegetation of a mature hardwood forest in the Adirondack Mountains of New York State. However, one of the most important facts brought out by these and other studies is that sustained-yield forestry and production of the maximum number of deer are incompatible (Little *et al.* 1958).

Thus a major problem of the multiple-use land manager in the Northeast has become: For a given area of forest land, to determine the best way to integrate sustained timber and deer-browse

production so that management of one as a key value will complement the other to the highest possible degree. The problem becomes even more complex when the manager must consider other products of the land such as water and other wildlife besides deer.

Several authors have stated or implied that deer herds should be reduced and held at or below the existing carrying capacity of the range for 3 to 6 years before attempting a management program for sustained integrated production of timber and deer (Wingard 1959, Dahlberg and Guettinger 1956, Robertson and Wingard 1959, and Stoeckeler *et al.* 1957).

Single-Use Management

Deer-browse management practices in the past have been concentrated largely on noncommercial browse production rather than on integrated timber and browse production. The primary, and sometimes only, objective of most methods has been to lower a maximum amount of what Webb *et al.* (1956) referred to as the "photosynthetic zone," so that energy stored by plants is within reach of the deer. Fortunately, single-use management for browse is gradually being replaced by multiple-use land management practices.

It has been suggested that land devoted to single-use management for deer-browse be low-quality sites incapable of pulpwood or timber production (Grange 1949). However, this practice seldom can be followed in the Northeast because most low-quality sites either cannot produce much browse, or the browse that is produced on them is unpalatable or unnutritious, and hence is not utilized. The scrub oak *(Quercus ilicifolia)* barrens in parts of eastern and central Pennsylvania are a case in point. Therefore, if deer-browse management were relegated to only the poor sites, only poor deer or few deer might logically be expected. That poor sites result in poor deer has not actually been demonstrated; and in view of deer mobility and our limited knowledge of deer nutrition, perhaps few deer is the more reasonable assumption.[2] The integration of deer and timber management on the better forest sites will be discussed in a later section.

[2]Personal correspondence with Dr. James Jordan, project leader, Forest Recreation and Wildlife Laboratory, U. S. Forest Service, Warren, Pa.

Noncommercial browse-production methods have included the cut-and-bend method (fig. 2), complete severance of trees, bulldozing, fire, and ground and aerial application of herbicides. These methods may be useful (1) to temporarily relieve deer pressure in areas of excessive damage to tree reproduction, and (2) to provide food for concentrated deer herds on winter range. Several of these methods also seem adaptable to multiple-use land management.

Cutting

The cut-and-bend method, as described by DeBoer (1952), Gill (1957c), Swift (1953), and Chase and Severinghaus (1949), and complete severance of stems, as noted by Krefting (1941) and Morriss (1954), are the two principal methods used in noncommercial browse cutting. The sprout growth of many hardwood species that results from these methods usually is available to deer for about 10 years (DeBoer 1952). However, as number of twigs per sprout clump increases with age, the twigs available to deer decrease in size (Krefting 1941).

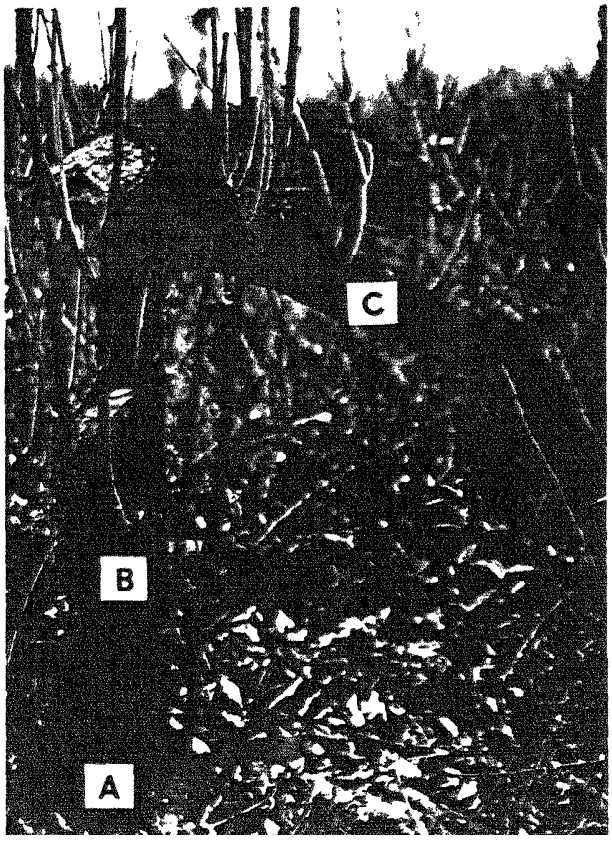

Figure 2. — The cut-and-bend method, showing the typical sprouting habit of many hardwood species: A, from the root collar; B, from the stump above the root collar; C, from the felled stem.

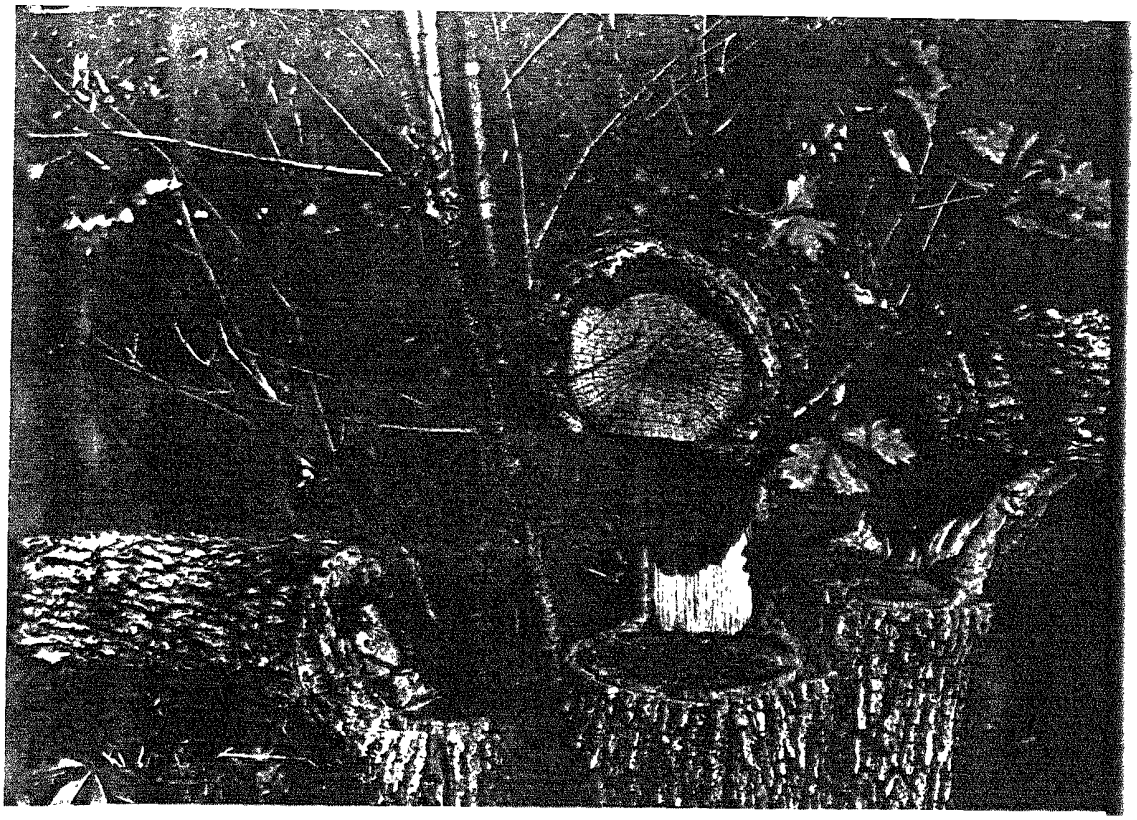

Figure 3.—With the cut-and-bend method, callus tissue often forms at the bend. This keeps the felled crown alive for a longer period of time.

In the cut-and-bend method, trees are felled by cutting the main stem about three quarters through, thus leaving the top connected to the root system. This keeps part of the crown alive for several years, and also stimulates sprouting from the stump. If callus tissue forms at the bend (fig. 3), the felled crown remains alive for a longer period. In pole and sawlog-size stands of the northern hardwood-hemlock type in northeastern Wisconsin, Stoeckeler *et al.* (1958) found that crowns of felled hardwood trees contained an average of 13 pounds of browse for each square foot of basal area.

The most vigorous sprout growth of many hardwood species is obtained when stems are cut to 12-inch or lower stumps (Krefting 1941, and Morton and Sedam 1938). Unlike most species, beech *(Fagus grandifolia)* when cut sprouts mostly from the tops of the stumps (fig. 4).

Figure 4.—Typical sprouting habit of beech.

The size and age of a tree affect its browse-production potential. In hardwoods, sprouting ability (and thus browse production) of stumps declines sharply with age (Hawley and Smith 1954) and with diameter increase (fig. 5) above 8-10 inches (MacKinney and Korstian 1932). Hawley and Smith (1954) have explained that, as bark thickness increases with age of a tree, the possibility decreases for dormant buds to break through and grow. Moreover, dormant buds will not sprout if, during growth, the connection is broken between the pith of the bud and the pith of the original stem.

Gill (1957a) recommended November through March as the best time to cut for hardwood browse in Maine: "This makes tops available when needed most and also produces as much stump growth as cutting at any other time."

Morriss (1954) proposed that, in commercial hardwood logging operations in North Carolina, the openings be shaped to

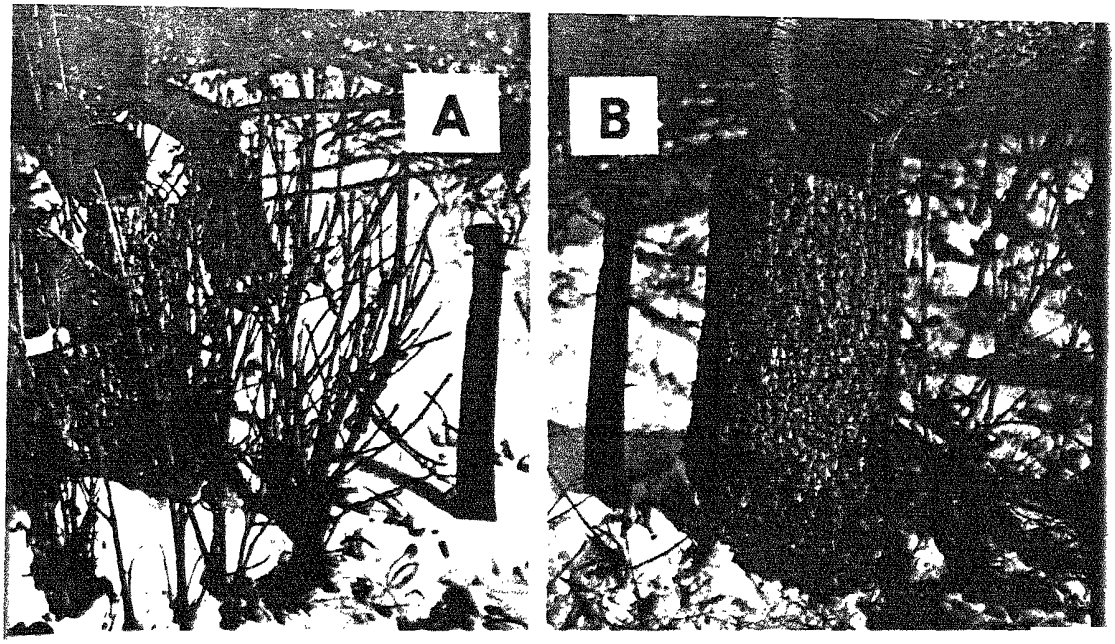

Figure 5.—Sprouting ability of stumps declines sharply with diameter increase. Here several white oaks (*Quercus alba*) of approximately the same age (34-38 years) were cut for browse production: A, sprouts from stumps of 2- to 3-inch d.b.h. trees produced abundant browse. B, sprout growth was insignificant from the stump of a typical 8-inch d.b.h. tree.

maximize the amount of border or edge so as to increase browse production and utilization. For young hardwood stands in Pennsylvania, Morton and Sedam (1938) suggested ". . . clear-cutting in zigzag strips 50 to 90 feet wide . . . The length of slashing can be anywhere from 300 to 600 feet, depending upon local conditions . . . The trees should be felled back into adjoining timber to provide more cover and additional sunlight for shrub production at the edges of the cut strip."

Morton and Sedam (1938) also recommended repeating cuttings at intervals of a few years on the same areas. However, Hawley and Smith (1954) stated that a progressive decline in vigor occurs in most tree species when repeated cuttings are made on the same root stocks at relatively short intervals of time; and further, that frequent clearcuttings result in a relatively thin canopy and exposure of the forest floor to erosion and desiccation.

In discussing several methods of regulating chamise brushlands in California, Biswell (1961) stated that deer like to feed

in areas that are partially open, and will spend more time feeding where shrubs are separate or at the edge of a patch than where the plants are growing densely. This principle also seems pertinent in the Northeast: browse within the dense thickets that often develop after clearcutting tends to be inaccessible and therefore of little benefit to deer, no matter how abundant or palatable it may be. Another disadvantage of clearcutting, explained by Gill (1957a), is that browse grows out of reach of deer more quickly than in other types of cutting (fig. 6).

Cuttings of mast-producing species such as oak and beech have been made specifically for browse in young stands in Pennsylvania. Where 50 to 75 percent of the overstory was removed, residual trees developed a more open crown with increased capacity to produce mast (Morton and Sedam 1938). Suggestions for this type of management also have been made by Reid and Goodrum (1957) for the longleaf pine type. Their recommendations, although pertaining to a different region, would seem to be generally applicable to the Northeast.

Herbicides

In addition to cutting, herbicides such as 2,4-D and 2,4,5-T have been used effectively for producing browse (Van Etten and Thomson 1959, Ruch 1957, Coulter 1958, and Jenkins and Bartlett 1959); and such browse is readily eaten by deer (Krefting *et al.* 1956, and Gysel 1957). Neither of these hormone-type herbicides nor ammate are toxic to wildlife. Haugen (1951) reported that, when experimental deer were fed ammate and ammate-treated foliage, the only effect it seemed to have was "to help them (the deer) gain weight."

With aerial application of herbicides, there are problems of drift, interception of spray by the overstory, lack of the desired selectivity, and the requirement that areas for treatment be fairly large. Some of these problems can be avoided by using mistblowers (MacConnell and Bond 1961).

Herbicides have been aerially sprayed in strips on large wildfire burns in California to retard development and maintain the brush cover in varying stages, but Biswell (1961) cautioned that this practice may also kill certain shrubs that are preferred by deer.

For hardwood areas in northern Michigan, Ruch (1957) recommended creating openings by aerial spraying of strips 30 to 50 feet wide and $\frac{1}{4}$ to $\frac{1}{2}$ mile long. Preliminary data gathered

Figure 6.—Three-year-old sprout growth of a red maple stump in a clearcut area. Note how much of the browse has grown up out of the reach of deer.

by Krefting *et al.* (1960), for upland forest types in Minnesota, indicated that areas of 100 acres or less may be sprayed from the air for less than $4 per acre.

Krefting *et al.* (1956) reported that in spray treatments of mountain maple *(Acer spicatum)* with ground equipment at early bud-burst time, 2,4,-D at concentrations of 4,8, and 12 pounds ahg was generally more effective than 2,4,5-T in inducing regrowth. As concentrations were increased, the number of stems and lineal feet of regrowth also increased. Breast-height applications generally resulted in greater stimulation of regrowth than basal treatments. Herbicide treatments were found to be signifi-

cantly superior to fire for stimulating sprout growth, and stands could be treated with herbicides in winter much faster than they could be cut with axes. However, the cost of the herbicide offset the saving in labor time. Cost by either method was about $5 per acre. Ax cutting resulted in the most regrowth.

Gysel (1957) recommended girdling, rather than frill treatment with herbicide, for maximum sprouting and browse production. He also suggested that some trees be left untreated to create diversity of food and cover.

Not only browse, but herbage also, has been successfully increased for deer by the use of herbicides (Ehrenreich 1959, and Bramble *et al.* 1956).

Fire

Fire is probably the least desirable method for producing browse (Latham 1950, and Pond and Cable 1960); but, if properly controlled and limited to forest growth of little commercial value, fire may be a useful tool. In Wisconsin, fire eliminated a stand of practically worthless aspen, prepared a good seedbed, and permitted 20,000 to 30,000 stems of aspen per acre to emerge for deer browse (DeBoer 1952). Prescribed burning for forest-management purposes in the Pine Region of southern New Jersey has been useful in increasing browse production (Little *et al.* 1958). However, successful control burns for browse are limited by available men and equipment and by the few days when weather conditions are suitable (Jenkins and Bartlett 1959).

Fire for creating browse has probably been used most successfully in the chaparral area of California—often in combination with bulldozing, disking, and herbicide treatments (Biswell 1961). In California, the protein content of browse was found to be higher in burned areas than in unburned areas (Shantz 1947, and Taber and Dasmann 1958). In Maryland, DeWitt and Derby (1955) found that a high-intensity fire produced significant increases in the protein content of red maple *(Acer rubrum)*, white oak *(Quercus alba)*, flowering dogwood *(Cornus florida)*, and roundleaf greenbrier *(Smilax rotundifolia)* browse; but the results suggested that repeated high-intensity fires are necessary to maintain this high-protein condition. The adverse effects of burning are that it may lower the fertility and productivity of the soil (Latham 1950), and it reduces or eliminates many browse species preferred by deer (Pond and Cable 1960).

Bulldozing

Bulldozers have been used to push down trees so the crowns are available to deer (DeBoer 1953). Part of the root system is left in place to keep the crown alive for several years. To lessen the damage to root systems, Forbes and Harney (1952) suggested that bulldozing be done in the spring when the ground is moist and soft. In pole-stage beech-birch-maple stands of Pennsylvania, large bulldozers (D-7s) "experienced little difficulty in pushing over trees" and then "moving ahead, always overrunning the trees"; smaller bulldozers (D-4s) "could not negotiate through many of larger tangles" and had to move around the bulkier down trees rather than over them (Forbes and Harney 1952). Tractors equipped with tree-cutter blades also have been used to increase available browse (Beale 1960).

In pole-size hardwoods of central Pennsylvania, Sharpe (1957) reported that browse utilization on bulldozed 5-acre openings was relatively small as compared to that on 1-acre openings.

Although a bulldozer can push down hundreds of pounds of browse a day, as noted by DeBoer (1952), bulldozing obviously entails many of the same disadvantages for browse utilization as clearcutting.

Multiple-Use Management

Very little research has been done on multiple-use management methods for integrated timber and browse production. Various procedures have been proposed, but few experiments have been made in the Northeast to test them. The following recommendations and observations seem relevant to multiple-use management under Northeastern conditions:

1. Lauckhart (1955), in reference to the West, pointed out that browse conditions in any large area will vary considerably—some localized parts of it may be overstocked and other parts may be understocked. He recommended, therefore, that the management of a large area be based on the average rather than the extreme conditions.

2. Dahlberg and Guettinger (1956) suggested that management in Wisconsin be directed mainly toward second- and third-choice browse species, rather than toward re-establishment of

first-choice species that have disappeared because of heavy deer pressure.

3. Graham (1954) emphasized that mixtures of softwoods with hardwoods are essential for good browse utilization in Michigan. He noted that, without hemlock in mixture, deciduous hardwood stands are open to winter winds and therefore become uninhabitable for deer during severe weather. This suggested that winter deer range perhaps could be expanded by underplanting browse-resistant conifers, such as white spruce *(Picea glauca)*, in areas where browse cuttings have been made.

4. In Adirondack forest types, Barick (1945) reported that transition zones between different types have the greatest potential for browse-habitat improvement because of the variety of cover that can be created.

5. Morriss (1954) has shown for hardwood types in North Carolina that improvement cuttings provided approximately the same amount of usable browse as clearcuttings or modified clearcuttings.

6. Grisez (1960) noted that, where deer are abundant in Northeastern Pennsylvania, slash from commercial hardwood cuttings should not be reduced because it provides some protection to desired tree seedlings. The planned placement and preservation of slash would seem to be especially worthwhile for reproduction and harvest cuts. However, slash less than 2 feet high seldom affects browse utilization (Gill 1957b).

In northern Michigan, the most practical method for producing browse has been "a continuous commercial timber cutting program covering the largest total area that the market will permit, well distributed in small blocks, and with the shortest possible period between cuts" (Jenkins and Bartlett 1959). This method seems especially appropriate to group selection and shelterwood cutting—silvicultural systems that often are recommended for northeastern hardwood forest management. Small forest openings created by this type of cutting may also increase groundwater supply, as suggested by Sharp (1957), and thus qualify as a good watershed-management practice. Cutting cycles would have to be short—probably every 10-15 years—to maintain desirable amounts of browse. Over an entire rotation, management of this kind should result in a wide variety of age classes, densities, and stand compositions. Such a variety of conditions is recommended as good deer habitat by Dahlberg and Guettinger (1956).

Figure 7.—Results immediately after thinning the same stand shown in figure 1. The multiple-use objective was to produce accessible browse for deer and to increase the timber quality and growth of the residual stand.

Intermediate silvicultural cuttings (Hawley and Smith 1954), in which suppressed or poor-quality trees in 40- to 50-year-old even-aged hardwood stands (fig. 7) are removed, seem especially appropriate for integrated timber-browse management for two reasons: (1) trees in these stands sprout more profusely than older trees and thus produce more browse; and (2) thinning in pole-size stands generally yields more return on the investment than other cultural operations (Webster 1960). Another probable advantage of intermediate cuttings would be that the residual overstory would reduce the rate of understory height growth; hence browse would remain accessible to deer for a longer period of time. Either cut-and-bend or complete severance of stems could be used to fell trees in this type of cutting; if maximum browse

production were the objective, the cut-and-bend method would seem to be indicated. Intensity and distribution of such multiple-use cutting would depend on overall management objectives.

In older stands, it may be necessary to restrict browse-production operations to cuttings that improve stand composition and quality; that is, to remove only trees of undesirable species, form, or condition. Primarily, these would be salvage or sanitation cuttings (Hawley and Smith 1954); and they would produce less browse, which would be more sensitive to browsing pressure, than earlier intermediate cuts. For example, Halls and Crawford (1960) found, for upland hardwood forests in Arkansas, that as stand size and density increased, browse was reduced considerably even when subjected to only light browsing.

In North Carolina, post-sale cultural work has been intensified so that areas treated for browse production are dispersed within the commercial sale area (Morriss 1954). Commercial thinning of ponderosa pine *(Pinus ponderosa)* stands in the Black Hills of South Dakota (Pase and Hurd 1957) and of loblolly pine *(Pinus taeda)* plantations in Louisiana (Blair 1960) have also resulted in increased production of hardwood browse.

Grange (1949) emphasized the point that, regardless of the objectives in any timber-browse management program, no high-quality timber tree should be felled for browse unless it is to be utilized for wood products. Presumably, the browse created by felling a high-quality tree is not sufficient to offset its timber value. However, comparisons of values between the timber in a tree and the browse it is capable of producing are extremely difficult to make because of the intangible values associated with the recreational aspects of a healthy deer population.

Browse Nutrition and Palatability, and Deer Preferences

The nutrition and palatability of browse, and the preferences of deer, are complex and important biological factors that must be given careful consideration in wildland management procedures. The following discussion involves only a few of the more important items in this phase of timber-deer management and research.

French and McEwen (1955) reported that "Experimental feeding studies with deer have been rather few in number because of the great difficulty and expense as well as the long period of time required in conducting them." Magruder *et al.* (1957) referred to "a complete review of literature on deer nutrition" by French *et al.* (1956), which included only 11 references. French's list indicated the limited amount of nutrition research that had been done at that time. And not much has been done since.

An average daily nutritional requirement for deer is difficult to determine because deer exhibit "extreme seasonal changes in body weight and feed consumption" (Magruder *et al.* 1957). French and McEwen (1955) found, in a study of measured nutritive requirements of 22 penned white-tailed deer in Pennsylvania, that the daily food requirement of a 150-pound deer was "at least 10 to 12 pounds of good deer browse, of usual moisture content," and that the protein content of this browse should be 13 to 16 percent for optimal growth and antler development. In a continuation of the same experiment, Magruder *et al.* (1957) reported that: "Calcium and phosphorus requirements were closely interrelated. A deficiency of one was better tolerated if the other was present in adequate amounts . . . Best antler growth was obtained when deer were fed a high dietary level of 0.64 percent calcium and 0.56 percent phosphorus."

Protein content of browse is a critical factor in deer nutrition; Einarsen (1946) noted that black-tailed deer *(Odocoileus hemionus columbianus)* in Oregon could not survive long on a ration containing less than 5 percent protein. In discussing nutrient requirements of deer in California, Leopold *et al.* (1951) observed

that the available twigs of choice, high-protein browse are nipped first; the deer are forced to eat species containing less protein as winter progresses and the supply of preferred browse decreases. They state further that "The mechanism by which a deer recognizes superior forage is unknown."

Protein content of various species of deciduous browse is greatest during the growing season and declines gradually to a low in winter (Dietz *et al.* 1958, Smith *et al.* 1956, and Hellmers 1941). C. M. Aldous (1945) found that protein was concentrated in the terminal buds of bitterbrush *(Purshia tridentata)*, with decreasing amounts in the lower portions of the twigs. The same may be true of hardwood species in general. Several researchers (Cook and Harris 1950, Einarsen 1946, Gordon and Sampson 1939, and Swank 1956a) have reported that the protein content of twigs decreases as a plant matures; and Taber and Dasmann (1958) found that regrowth of moderately browsed sprouts in California was higher in protein content than the original browsed portion.

Dahlberg and Guettinger (1956) and Trippensee (1948) concluded that browse plants of high palatability do not necessarily have high nutritional value. On the other hand, Leopold *et al.* (1951) found that the crude protein content of browse approximately followed the "gradient of palatability" among six shrubs on winter range in California. Obviously the interrelationship between nutritional quality and palatability of browse does not lend itself to simple generalization.

Deer in southwest Colorado were observed to choose browse containing the highest nutrients during each season, and this led Dietz *et al.* (1958) to conclude that two or three browse species cannot supply deer with an adequate diet. This suggests that browse-management practices should be designed to favor a number of species rather than just one or two.

Seasonal fluctuations in rainfall may influence a plant's nutrient content and its tolerance to browsing (Sharp 1958); plants can withstand heavier browsing during a wet summer than during a dry one.

Variations in nutrient content and species preference may often be related to soil types and site conditions (Gaines *et al.* 1954, Denny 1944, Cronemiller 1955, Hundley 1959, and Swank 1956b). Forbes (1959) observed that deer overbrowsed the understory of the beech-birch-maple type in south central Pennsylvania, but

available browse in a surrounding oak-hickory type was only lightly utilized. Tarr (1953) found that deer in central Pennsylvania browsed more selectively on north slopes than on south slopes; however, the animals spent more time on the south slopes even though more browse was available on the north slopes.

Sharp (1958) stated that deer are very adaptable and can alter their food preferences to coincide with differences in habitat. Aldous (1938) reported that trembling aspen *(Populus tremuloides)* was not eaten extensively by deer in Minnesota, but Julander (1937) considered aspen a key species on the summer range in the Southwest. This comparison involves two different species of deer; but local deer stocks also may have different preferences (Leopold *et al.* 1951), and even individual deer in the same locality appear to vary in this respect (Deen 1938).

There have been many studies in which browse species were listed by degrees of deer preference (Bramble and Goddard 1953, Dahlberg and Guettinger 1956, Dalke 1941, Deen 1938, Gill 1957c, Little *et al.* 1958, and Stegeman 1937). However, on much of the overbrowsed range in the Northeast, browse preferences are difficult to demonstrate except for a few notably unpalatable species such as beech *(Fagus grandifolia)* and striped maple *(Acer pensylvanicum)*. And even the least palatable species may not always be rejected. For instance, deer in Pennsylvania have been observed to feed extensively on beech sprouts in the spring while the shoots are young and succulent. Generally, the native conifers are less nutritious than most hardwood species, and serve mostly as "fillers" or "stuffing" during winter browse shortages (Latham 1950).

Browsing intensity does not have a uniform effect on all species. For example, sugar maple *(Acer saccharum)* and red maple *(A. rubrum)* are considered tolerant to heavy browsing, while black oak *(Quercus velutina)* and red oak *(Q. rubra)* are extremely intolerant (Stoeckeler *et al.* 1957, Webb *et al.* 1956, and Sharp 1957). However, where browsing has been severe, even the most tolerant species recover very slowly and often become stunted and malformed (Stoeckeler *et al.* 1957). Obviously this is not conducive to sustained timber production.

The true nature and quality of deer browse may be seriously underestimated. In studying the rumen contents of deer, Bissel (1959) concluded that "deer either select vegetation which is approximately 2 to 3 times higher in protein than is generally

supposed," or "the protein content of the rumen is enhanced to a very high degree by some factors not now apparent." The inference here is that considerable research is needed before management specifications can be formulated regarding browse nutrition, palatability, and preference. Dahlberg and Guettinger (1956) summarized the problem when they stated: "Both the habitat and the deer are a lot tougher than we sometimes dare to believe." This fact seems to be substantiated in nutritional studies by Severinghaus (1951) in the Northeast and Goodrum and Reid (1958) in the South, who have shown that a relatively large number of deer (1 deer per 9.5 acres) can sustain themselves for several years on heavily browsed range. However, fawn production declines in advance of any appreciable browsing on low-choice plants.

Browse Measurement

Since one of the major limiting factors in deer management is the extent to which winter range can support deer, one of the basic problems of management is to determine the carrying capacity of the winter range. The purpose of any range inventory is to determine the welfare of existing vegetation in relation to deer-browse production (Dahlbert and Guettinger 1956).

Dasmann (1948) reviewed western range-survey methods and their application to deer-range management. Most of the methods were concerned chiefly with browse or forage species for domestic livestock. The growth pattern of these species generally is different from that of hardwood deer-browse plants. Nevertheless certain principles hold true for all range surveys. Dasmann pointed out that "The range manager needs to be concerned not so much with the fraction that range animals take as with the fraction of vegetative growth that range animals leave." This axiom seems equally appropriate to hardwood deer-browse management. Dasmann called the fraction that animals leave "the range management reserve."

For most management and experimental purposes the ideal browse measurement method should be economically feasible, not too time-consuming, should require a minimum amount of training of personnel, and should yield data that can be tested statistically.

Characteristics of Browsed Twigs

Browse utilization and its effects are not always limited to current annual growth (Aldous, S. E., 1952; Aldous, C. M., 1945). When a twig is browsed, it dies back to a lateral bud or to the previous year's terminal-bud scar (fig. 8). Resprouting will often occur from a lateral bud during the growing season if browsing was not too severe (fig. 9). Repeated browsing of the same twigs during a growing season causes them to become bushy (fig. 10); the mass effect of such severe browsing on a sprout clump is to cause it to "hedge" (fig. 11).

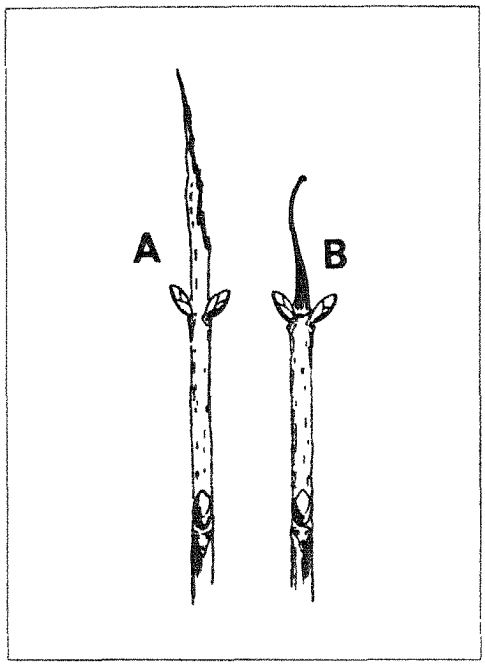

Figure 8.—Effect of deer browsing on twig dieback: *A*, a freshly browsed twig. *B*, a succulent twig that has withered back to a lateral bud after browsing. Hardened twigs browsed in late fall or winter do not wither, but also die back to a bud.

Statistical Considerations

In sampling browse, a limited number of species that are common in the area and preferred by deer are usually designated as the key browse species. This singling out of a few species for intensive study is a matter of practical necessity, and is a standard technique of browse investigators (Julander 1937, Leopold *et al.* 1951, and Cole 1959).

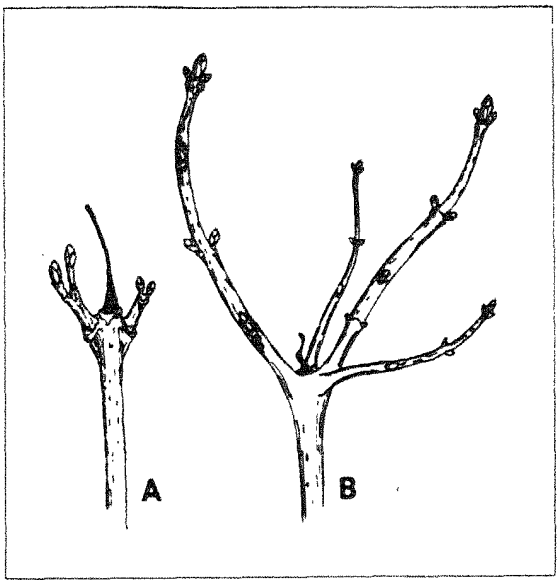

Figure 9. — Re-sprouting from lateral buds after terminal bud has been browsed: *A*, browsed late in the growing season. *B*, browsed early in the growing season.

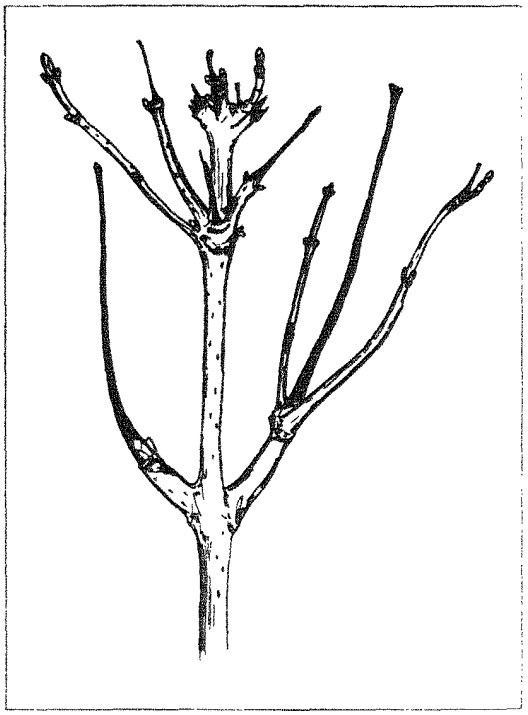

Figure 10. — Heavily browsed twig that has sprouted after each of several browsings during the growing season.

Carrying capacity may vary widely from year to year, which makes it difficult to determine overutilization of large and highly variable ranges. Lauckhart (1955) therefore suggested that browse plots be examined every 4 or 5 years rather than every year.

Snedecor (1957) has pointed out the difficulties involved when a perennial crop (such as browse) is investigated in a statistically-designed experiment that is continued several years on the same plots. He stated that "The yields from a plot in successive years are probably correlated; the experimental error one season is not independent of that in another season." For these reasons, any primary analysis of browse-measurement data from such plots should be based on the sum of plot yields over all the years of the experiment. Cochran (1937) has provided an example for analyzing this type of data.

The shape and size of plot used to sample browse will be influenced by browse density. For example, smaller sample plots would be required in a dense understory than in an open area with sparse vegetation. Two kinds of circular plots are commonly used for browse investigations: the milacre (radius 3.72 feet), and the 100-square-foot plot (radius 5.64 feet). "With the 100-square-foot plot, multiplying grams of browse per plot by 0.96 converts grams per plot to pounds per acre" (Schwan and Swift 1941).

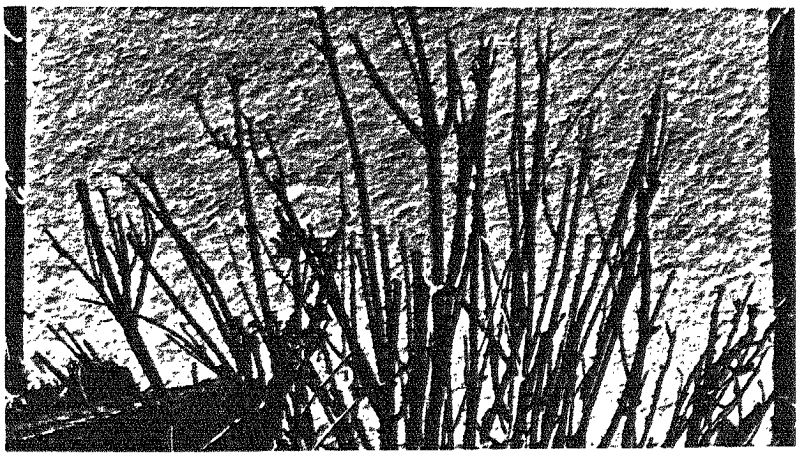

Figure 11.—Severe deer browsing of sprout growth causes it to "hedge".

The number of plots needed to obtain a reliable sample from any area is not primarily a function of the size of the area, but rather of the variation from place to place within it. Bormann (1953) described a method whereby statistical variance can be used to determine the most effective size and shape of plot for sampling a natural plant population. He explained that "Variance (among plots) decreases as plots are increased in length provided that the longest axes of the rectangular plots cross observed contours and vegetational or soil bandings."

Great variation is typical of browse vegetation (Shafer 1961), and the manner in which a particular sampling unit is defined can either simplify or reduce this variation. To determine the total number of plots needed, it is necessary first to establish and measure about 30 plots on the area to be sampled (State of California 1957) to obtain an estimate of the population variance. The resulting data should be analyzed statistically (Snedecor 1957) to learn the degree of reliability attained. The State of California (1957) recommended that browse sampling on deer-management areas should be intensive enough to provide confidence limits of ± 10 percent at the 95-percent probability level. It is questionable that this degree of accuracy is necessary in measuring browse production in the Northeast. Size of the deer herd cannot be regulated accurately enough for a change of ± 10 percent in browse production to be detected. An accuracy of ± 20 percent seems more realistic for Northeastern conditions. A complete randomized design (Shafer 1961) or a mechanical design (Swift 1948) can be used to locate plots.

Other statistical considerations and problems involved in sampling browse have been discussed by Ehrenreich (1958) Evans (1958), and Morriss (1958).

Twig-Length Method

Some wildlife managers determine or estimate the average normal length of twigs or leaders and the average length left after browsing, and then express deer use as a percentage of normal twig length.

Using this method to estimate amount of current twig growth grazed on bitterbrush, Hormay (1943) established plots 20 inches wide and 2 or 3 chains long, which included 20 to 25 average-size plants per plot. Twenty to 25 such plots were recommended in stands of 20-percent density. Hubbard and Dunaway (1958)

found that an unrestricted random sample of 19 to 39 leaders from each of five bitterbrush plants studied were required for estimating the true mean leader length within 10 percent of the actual value. This twig-length method can probably be applied to the dormant twigs of other browse species on which current twig growth is easily recognized (Aldous, C. M., 1945; and Aldous, S. E. 1952).

In Montana, Cole (1959) used a "closest-plant" sampling technique to obtain yearly condition and use data from key browse plants. Plant condition was estimated according to browse availability and age classes. Leader-use estimates were expressed as an average based on the percent of total available leaders showing use. Cole recommended sampling about 25 browse plants within each sampling unit.

Julander (1937) measured all current shoot growth before and after browsing on an unspecified number of plots to determine annual utilization of browse in northern Arizona.

In northern and central Wisconsin, 5 million acres were surveyed to determine deer damage to forest reproduction. Eighteen mechanically placed 1/50-acre plots were used to sample each 23,000 acres of managed forest land. Percent browsing was calculated for individual species; damage was rated according to the following categories: unbrowsed, lightly browsed, or heavily browsed. A specimen that had its terminal bud removed or one-third or more of its crown clipped was classified as heavily browsed (Swift 1948).

Twig-Count Methods

In studying seasonal browse preferences, Bramble and Goddard (1953) established 242 plots (1 or 2 milacres in size) in the oak-chestnut forest region of central Pennsylvania, and counted the number of twigs browsed per plot during each month. Each browsed twig was cut with a knife to avoid recounting it the following month. Results were expressed in percentage of total number of twigs utilized by deer.

Eighty milacre plots were sampled by the twig-count method on 238 acres of the Pisgah National Forest in North Carolina to estimate numbers of seedling and sprout stems per acre 2 years after three cutting treatments had been made (Morriss 1954). The topography of the three cutting areas ranged from high cove to ridge top.

When evaluating browse production in clearcuttings of non-merchantable hardwoods in Michigan, Beale (1960) found that stump sprouts were so small and numerous that complete counts of all twigs on 1/100-acre plots were impractical. Total numbers of twigs per plot therefore were estimated by counting a small subsample in each plot.

Shafer (1961) described a twig-count method for measuring dormant hardwood browse in northeastern Pennsylvania. The method utilized average twig weights to convert twig-count data to pounds of browse per acre.

Density Methods

Density measurements are useful for describing the horizontal aspect of plants and for comparisons of relative spread of vegetation on ranges of similar sites and types. However, Dasmann (1948) has pointed out many weaknesses in density methods, and has recommended that density not be used as a sole measure of browse yield.

In southern Arizona, Cooper (1957) used the variable-plot method, first described by Bitterlich (1948) and Grosenbaugh (1952), to estimate an index of dispersion for shrub cover. This method can be used to estimate densities of shrubs ranging from 6 inches to 30 feet in crown diameter, but is most reliable in open shrub stands of low density. Kinsinger *et al.* (1960) have shown that cover estimates by the variable-plot method are higher than true cover, and they suggest that the method be modified to exclude dead crowns from cover estimates.

Weight-Estimation Methods

Smith (1944) found that weight estimates of browse in three vegetation types (sagebrush, winterfat, and a grass type) in Utah differed significantly among observers on different days and even on the same day. However, Shafer (1961) has shown that the weight-estimation method is almost as accurate as the clip-and-weigh method for measuring browse weight of 2-year-old hardwood sprout growth of various species in the Northeast. The estimation method is not recommended for experimental purposes except by highly trained personnel. Some experienced individuals probably can estimate the weight of browse production almost as accurately as it can be determined by cut-and-weight procedures.

In such cases, estimates can be analyzed statistically and used for experimental purposes, but confidence in these estimates is usually based on some prior knowledge of the correlation between the estimated and actual values—usually as a result of double sampling. For example, Pase and Hurd (1957) used the weight-estimation method, described by Pechanec and Pickford (1937), on twenty 9.6-square-foot plots (for each of 31 sample areas) to estimate herbage production under various basal-area conditions of the ponderosa pine type in South Dakota and Wyoming. But to relate estimates to actual weights, they measured the herbage quantitatively on a square-foot subplot in the center of alternate 9.6-square-foot plots.

Clip-and-Weigh Method

The clip-and-weigh method used in many western range surveys (Schwan and Swift 1941) has not been used so extensively for measuring hardwood browse.

Following aspen logging in lower Michigan, Casey (1954) used 10 milacre plots to measure browse production by weighing twigs clipped at the 1/4- and 1/2-inch diameter points; these two clipping dimensions represented use by deer during normal and high population pressures. Dalke (1941), in an exclosure study in the Ozark plateau of Missouri, and Blair (1960), in a loblolly pine *(Pinus taeda)* thinning study in Louisiana, clipped and weighed all current annual growth (leaves and stems) of herbaceous and woody forage to a height of 5 feet on milacre plots.

Goebel *et al.* (1958) described a "25-square-foot method" used in surveys of desert shrub vegetation on relatively small areas. Forage production by each species was derived by determining the average air-dry weight per 1/16-square-foot unit of the species, and multiplying by the number of such units that the species occupied. The average weights were determined by clipping, drying, and weighing samples of the current year's growth of each species.

Descriptive Methods

McConnell and Dalke (1960) used a qualitative approach for range evaluation in Idaho by noting the general relationship of vegetation to the browsing habits of deer. Dahlberg and Guettinger (1956) also used this technique in a random walking cruise (or appraisal) of a large number of deeryards in Wisconsin.

Observers made notes on species distribution, composition, and density, availability of various deer-browse plants, evidence of current browsing pressure, and the degree of yarding. Although reports of this type are somewhat subject to human error, they were considered to be sufficiently accurate for use in formulating deer-management recommendations in Wisconsin.

Comparison Method

Roy (1960) studied set-back caused by deer browsing on Douglas-fir seedlings *(Pseudotsuga menziesii)* in northwestern California. Two curves were compared: one curve showed average heights by years through the first 6 years after planting for seedlings that were not browsed or were browsed only once; the other curve showed average 6-year heights of seedlings under different frequencies of browsing. The range in average 6-year heights was 16 to 41 inches. Thus trees that were browsed every year were set back 25 inches.

Pellet-Conversion Method

Leopold *et al.* (1951) used a pellet conversion method in estimating forage use on the Jawbone range in California. They made no actual weight determinations of forage produced or utilized, but on the basis of figures worked out by Nichol (1938), Smith (1950), and others, they computed from pellet counts the approximate amount of forage removed per acre. These computed estimates corresponded fairly well with Leopold's impression of changing forage density in the study area.

Exclosures

Exclosures with check plots immediately adjacent have been used in many places to study the effects of browsing on the vegetation (Grisez 1959, Stoeckeler *et al.* 1957, Krefting and Arend 1960, and Graham 1958). By measuring the amount and types of reproduction that develop when an area is completely protected from deer, in comparison with the growth on an unprotected but otherwise similar area, data are obtained from which evaluations of range condition and browsing pressure can be made.

The following studies were conducted to show the types and amounts of damage and the problems encountered in establishing forest reproduction in areas of excessive deer populations:

1. In oak-maple stands in northeastern Pennsylvania, Shafer *et al.* (1961) enumerated and measured the height of all vegetation in six 1/40-acre exclosures and associated check plots.

2. In the Adirondacks, Webb *et al.* (1956) studied the results of protection in two 2.1-acre fenced areas in a mature northern hardwood stand. Their data were based on 24 3-foot-square sample plots in each exclosure and in each adjacent check area.

3. Livestock and deer were excluded for 10 years from a series of three 0.1-acre plots in each of three major timber types in the Arkansas Ozarks (Halls and Crawford 1960). The estimation method was used on ten 3.1-foot square plots inside and outside each exclosure to determine the weight of browse and herbage produced up to a height of 5 feet.

Two experiments by Dahlberg and Guettinger (1956) in Wisconsin provided demonstrations of range-carrying capacity, which have been used to help laymen understand the relationship between deer and their habitat. In the first experiment fenced exclosures were established to compare shrub and tree growth in protected and unprotected areas. In the second experiment, fenced enclosures were used to confine a known number of deer to specific units of range. The number of deer-browse days in different enclosures was varied to show the effects of different degrees of browsing pressure on the range.

The effects of cattle grazing upon sprout growth of tamarisk *(Tamarix pentandra)* were computed in Arizona by using three fenced plots and three unfenced plots (Gray 1960). Within each plot 75 tamarisk plants were cut about 6 inches above ground. Then, at monthly intervals, the sprout growth was clipped from 10 randomly selected cut plants in each plot. New plants were selected for each monthly sampling.

In Minnesota, Aldous (1952) conducted a clipping study on northern white-cedar *(Thuja occidentalis)* and several hardwood species in exclosures to obtain information about how much deer browsing these species could withstand and still continue to grow.

Cooley (1961) has shown that the fence need be only 4 feet high for exclosures of 1 milacre. For larger exclosures, 10-foot fencing is recommended. Exclosures of 1 acre or more involve excessive maintenance costs (Dahlberg and Guettinger 1956).

Conclusions

Although results of the studies that have been reported are somewhat variable because of different research procedures and the wide range of browse conditions, several generalizations concerning the production, utilization, and measurement of hardwood browse can be made:

- Management of forest land for browse production usually should be integrated into multiple-use land management in which sustained timber production is one of the other uses, except possibly on submarginal forest lands.
- Commercial timber cutting according to either group selection or shelterwood silvicultural systems, with 10- to 20-year cutting cycles, is adaptable to sustained timber-browse production in the Northeast.
- Silvicultural thinnings in pole-size hardwood stands provide maximum available browse, increase timber production, and yield a higher return on the investment than other cultural operations.
- Deer herds should be balanced with or reduced below the existing carrying capacity of the range before browse management is attempted.
- Browse cuttings should be aimed at creating a wide variety of age classes, densities, and species mixtures in the woody vegetation.
- Since, within any large area, some localized portions are likely to be relatively overstocked or understocked, browse management on the area as a whole should be based on average conditions.
- Browse production on winter deer range should be in balance with use of the range by the animals.
- Noncommercial browse-production methods include the cut-and-bend method, aerial and ground applications of herbicides, fire, and bulldozing. The cut-and-bend method is appropriate for commercial thinning operations if maximum browse production is desired.
- Sprouting ability of hardwood stumps declines sharply with tree age and with size after a stem d.b.h. of 8 to 10 inches is attained.

- Browse grows more slowly under partial canopy or under slash than in the open.
- Deer tend to select the available twigs of certain species that are highest in nutrient content. How they are able to select nutritionally superior browse is not known.
- Protein content of deciduous browse is greatest during the growing period and declines gradually as the tissues mature and become dormant, reaching a minimum in winter.
- Some species are more tolerant to browsing than others, but even the most tolerant species recover very slowly after repeated severe browsing.
- Deer are very adaptable and can alter their food preferences according to the browse species that are available.
- Great variation in the woody browse vegetation within areas and between areas is typical, and consequently measurement is difficult. Many methods have been used to measure browse production and utilization. Those that express quantities of browse in pounds per acre seem most realistic for management purposes.

The final conclusions from this review are that browse production, utilization, and measurement are subjects that (1) offer unlimited research possibilities, and (2) merit intensive research because of the increasing emphasis on multiple-use of forest lands.

Research Needs

Following is a list of studies, which are comprehensive in scope and will require major research to obtain adequate answers to the problems involved. These studies, arranged in a tentative order of priority, are considered to be of primary importance.

- Develop browse-measurement techniques that are quick and easy to use and that are sufficiently accurate for both research and management purposes.
- Determine the kind and size of experimental designs necessary for sound results in multiple-use research on deer browse and timber production.
- Determine the effects of various timber-stand-improvement practices, commercial cutting intensities, and silvicultural sys-

tems (including coppice management) on browse production and utilization, and on timber growth and quality, in the major forest types and conditions of the Northeast.

- Determine how best to integrate noncommercial browse-production techniques such as fire and bulldozing with sustained timber production.

In conjunction with or paralleling these last two items:

- Investigate the minimum daily and seasonal nutritional requirements of deer.
- Determine the basis of palatability and preference in browse, and how variations in nutrient content associated with species, origin, age, and condition of browse affect palatability and preference.
- Explore the effects of various browsing intensities on nutrient content and future growth potential of both sprouts and seedlings of important timber species of the Northeast.
- Investigate fertilization treatments for increasing the nutrient content and palatability of those species in the understory that are both low-preference deer food and of low value for timber.
- Study the nutrient content, palatability, and preference (1) of twigs growing in various sections of the crowns of felled trees, and (2) of twigs growing from the root collars and stumps of various species under different overstory density and site conditions.
- Determine the amount of woody browse consumed in relation to amounts and availability of other foods such as mast and herbaceous plants.
- Study the net effect on other wildlife of maintaining a deer population in balance with the carrying capacity of the range.

■

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