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Gambel Oak Growth Forms: Management Opportunities for Increasing Ecosystem Diversity

Scott R. Abella

Abstract—Gambel oak (*Quercus gambelii*) clones have several different growth forms in southwestern ponderosa pine (*Pinus ponderosa*) forests, and these growth forms each provide unique wildlife habitat and resource values. The purposes of this note are to review published growth-form classifications for Gambel oak, provide examples of ecological effects of different growth forms, and summarize management strategies for promoting desired growth forms. Four different growth-form classifications have been published, which generally recognize variants of three basic forms: shrubby thickets of small-diameter stems, pole-sized clumps, and large trees. These growth forms exemplify ecological and management tradeoffs. For example, shrubby forms provide browse and cover yet produce few acorns, while larger oaks supply more acorns but offer little accessible browse or cover near the ground. Large oaks can be encouraged by thinning competing trees and protecting existing large stems from damage by prescribed fire or unauthorized fuelwood harvest. Pole-sized clumps may develop from thickets through time by self-thinning. Mechanically thinning within clumps may accelerate growth of remaining stems, depending on resource allocation within clones. Burning or cutting to stimulate sprouting sustains shrub-thicket forms.

Introduction

Gambel oak (*Quercus gambelii*) is one of only a few deciduous trees in southwestern ponderosa pine (*Pinus ponderosa*) forests. Oak is important for wildlife (Reynolds and others 1970), plant habitat (Brown 1958), soil fertility (Klemmedson 1987), and human values including aesthetics and fuelwood (Harper and others 1985). Recent reports reviewing Gambel oak literature have highlighted several principles of oak ecology in ponderosa pine forests. First, densities of small-diameter oaks have sharply increased in the past 140 years during a period of fire exclusion following Euro-American settlement (Abella and Fulé 2008b). For example, Fulé and others (1997) found that Gambel oak densities on a northern Arizona landscape increased from 32/acre (80/ha) in 1883, to 191/acre (471/ha) in 1994. Second, fires burned presettlement pine-oak forests on average at least once every 10 years, which is similar to pure ponderosa pine forests (Abella and Fulé 2008a). Fire is part of Gambel oak's evolutionary environment, and multiple growth forms of the species persisted in frequently burned

forests. Third, there is no general ecological basis for not actively managing pine-oak sites (Abella and Fulé 2008b), although passive management (in other words, no management) may be the most practical or appropriate depending on specific management objectives.

Gambel oak's biological characteristics, including its clonal habit and resprouting ability, result in the species having several different growth forms (Tiedemann and others 1987). These growth forms range from large, individual trees to multi-stemmed, shrubby thickets. Each form provides unique wildlife habitat and resource values (Kruse 1992). By managing the proportions and characteristics of these growth forms, great opportunities exist to enhance multiple resource values in pine-oak forests (Clary and Tiedemann 1992).

The purposes of this note are to: (1) review existing classifications of Gambel oak growth forms, (2) provide examples of the influences of different growth forms on ecosystem components, and (3) summarize management strategies for promoting specific growth forms. This note focuses on ponderosa pine forests where oak's tree form occurs, but a growth-form classification (Brown 1958) potentially applicable to ponderosa pine forests is included from the northern part of Gambel oak's range in Utah and Colorado where the species forms shrublands.

Growth Form Classifications

Four classifications of Gambel oak growth forms have been published (table 1). Each classification distinguishes growth forms based on different tree and clump characteristics. It should be recognized that some oaks

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Scott R. Abella is Research Specialist, Sr., Ecological Restoration Institute, Northern Arizona University, Flagstaff, AZ. Present address: Assistant Research Professor, Public Lands Institute and School of Life Sciences, University of Nevada Las Vegas, Las Vegas, NV.

Table 1—Comparison of Gambel oak growth form classifications.

Brown 1958 ^a	Kruse 1992	Rosenstock 1998	Abella and Springer 2008
Area occupied by oak	Successional stage	Stem diameter (inches)	Stem density, spacing
1. Clump (< 100 ft across)	1. Brushy (youngest)	1. Shrub like (< 1)	1. Single stem
2. Intermediate	2. Young pole stand	2. Small tree (1 to 8)	2. Dispersed clump (low-high, wide)
3. Thicket (stand > 5 acres)	3. Mature	3. Mature tree (8 to 15)	3. Thicket (high, close)
	4. Post mature (oldest)	4. Large, old tree (> 15)	

^a This classification was developed in west-central Colorado for Gambel oak shrublands. The other classifications were developed for ponderosa pine-oak forests.

encountered in the field may not readily fit into categories, as the classifications are an attempt to categorize continuous variability. These classifications are useful for site inventories, monitoring oak condition, understanding oak ecology, and developing management prescriptions and evaluating their effects. The four classifications are reviewed in the following sections.

Brown (1958) Clump Area

Brown (1958) developed the earliest Gambel oak classification, which he based on the ground area occupied by oak (table 1). He developed this classification for west-central Colorado where Gambel oak forms shrublands. The classification probably has limited utility in most ponderosa pine forests because oak develops smaller clumps in these forests than in shrublands. However, Brown’s (1958) classification could be useful in pine forests as a canopy-area classification if it was modified to include smaller areas of oak canopy cover.

Kruse (1992) Successional Status

Kruse (1992) classified Gambel oak growth forms based on their anticipated ages and successional status. Growth forms ranged from young, brushy forms to old, post-mature forms (table 1). He defined poles as stems > 15 ft (4.5 m) tall and > 3 inches [8 cm] in diameter at breast height. Kruse’s (1992) interpretation was that oak clumps begin in the young, brushy form, then self thin and develop into pole stands and mature trees through time. Age-diameter relationships do show that the largest oaks tend to be the oldest (Brotherson and others 1983). There also is evidence that oak clumps self thin through time (Clary and Tiedemann 1992). A limitation of Kruse’s (1992) classification, however, is that a given oak clump may contain stems of widely different ages. For example, the same clump could contain both young, re-sprout stems and older, pole-sized stems, making it unclear where this mixed-age clump fits in Kruse’s (1992) classification. This

classification was designed to categorize oak’s utility as wildlife habitat.

Rosenstock (1998) Stem Diameter

Rosenstock (1998) differentiated growth forms based on stem diameters, ranging from shrub-like forms (diameters < 1 inch) to large, old trees (> 15 inches; table 1). While not explicitly noted, Rosenstock (1998) also assumes that larger stems are the oldest. His classification focuses on individual stems and is less useful for classifying clumps that often contain stems of varying diameters. However, this classification could be used to categorize stem diameters primarily characterizing Kruse (1992) and Abella and Springer’s (2008) classifications of whole clumps. Rosenstock (1998) constructed this classification to measure avian habitat. For example, large-diameter stems may contain more cavities than smaller stems.

Abella and Springer (2008) Patch Structure

Abella and Springer (2008) used stem density and spacing to distinguish oak growth forms in a structural classification making no assumptions about successional status (table 1). Single stems can be of any size or age in this classification. Thickets have high densities of three or more closely spaced stems, which are usually smaller in diameter than stems in dispersed clumps (fig. 1). Dispersed clumps are intermediate between single stems and thickets and contain two or more widely spaced stems. Each growth form can contain stems of various sizes and ages since the growth forms are distinguished based only on stem density and spacing. Therefore, this classification has little utility for users desiring information on stem size or age because stems of different size and age can be classified into the same growth form. Another limitation is that any stem-stem distance or density cutoff between dispersed clumps and thickets would be arbitrary. The classification was made to support research of oak influences on soils and understory vegetation.

a**b****c**

Figure 1—Examples of Gambel oak growth forms on a basalt site north of Mormon Lake, Coconino National Forest, northern Arizona (35°11'48"N, 111°33'23"W). Following Abella and Springer's (2008) growth form classification, (a) is a single stem, (b) is a dispersed clump, and (c) is a thicket. Photos by S.R. Abella, 9 October 2005.

Ecological Effects of Oak Growth Forms: Examples

Bird Habitat

Lesh (1999) measured Gambel oak characteristics of foraging areas for seven breeding bird species in northern Arizona pine-oak forests. At a 0.1-acre (0.04-ha) plot scale, she found that Virginia's warblers (*Vermivora virginiae*) preferentially foraged in areas containing two to three times greater oak densities than were preferred by the other six bird species (fig. 2). Virginia's warblers also preferred oak clumps, on average, exceeding 1,500 ft² (139 m²) in area. Brushy growth forms containing high densities of small-diameter stems, such as Rosenstock's (1998) shrub-like form, appear critical as foraging habitat for Virginia's warblers. In another example, May and others (2004) reported that 40 percent of all Mexican spotted owl (*Strix occidentalis lucida*) nests in northern Arizona pine-oak forests were in Gambel oak trees (which contained cavities) greater than 17 inches (44 cm) in diameter. Different oak growth forms may provide different benefits (for example, foraging versus nest sites) to different species.

Understory Vegetation

Plant species richness and composition differed among oak growth forms following Abella and Springer's (2008) growth form classification in a study of northern Arizona pine-oak forests (fig. 3). Richness was greatest below single stems, intermediate below dispersed clumps, and least below thickets. Light-demanding, warm-season (C_4) pine dropseed (*Blepharoneuron tricholepis*) was most frequent below single stems, whereas aspen pea (*Lathyrus laetivirens*) was most frequent below thickets. Growth forms presumably created unique environments below their canopies that were favorable for different species (Schuhardt 1991).

Acorn Production

McCulloch and others (1965) found that 10- to 15-inch (25- to 38-cm) diameter Gambel oaks with 80 to 100 percent live crown produced the most plentiful acorn crops in northern Arizona (fig. 4). Oaks less than 5 inches (13 cm) or greater than 18 inches (46 cm) in diameter yielded few acorns. This study illustrates several tradeoffs with oak ecology and management. Small, shrubby oaks provide browse but few acorns for wildlife; larger oaks provide little accessible browse but copious acorns. In size/density tradeoffs, three times as many 6-inch (15-cm) diameter trees are needed to generate as many acorns as one 12-inch (30-cm) tree.

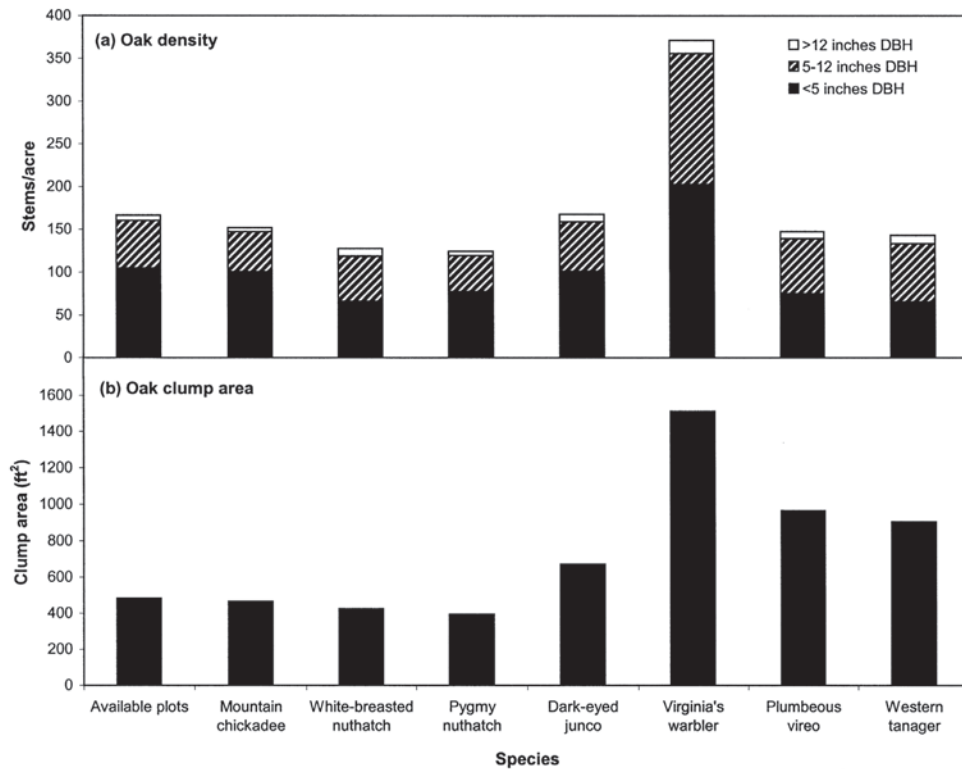


Figure 2—Gambel oak characteristics of foraging areas at a 0.01-acre (0.04-ha) plot scale for seven breeding bird species in ponderosa pine-Gambel oak forests at Camp Navajo, northern Arizona. Available plots represent average conditions in the study area. Virginia's warblers selected foraging areas containing greater oak densities and clump areas than other bird species and as compared to available plots. Data from Lesh (1999).

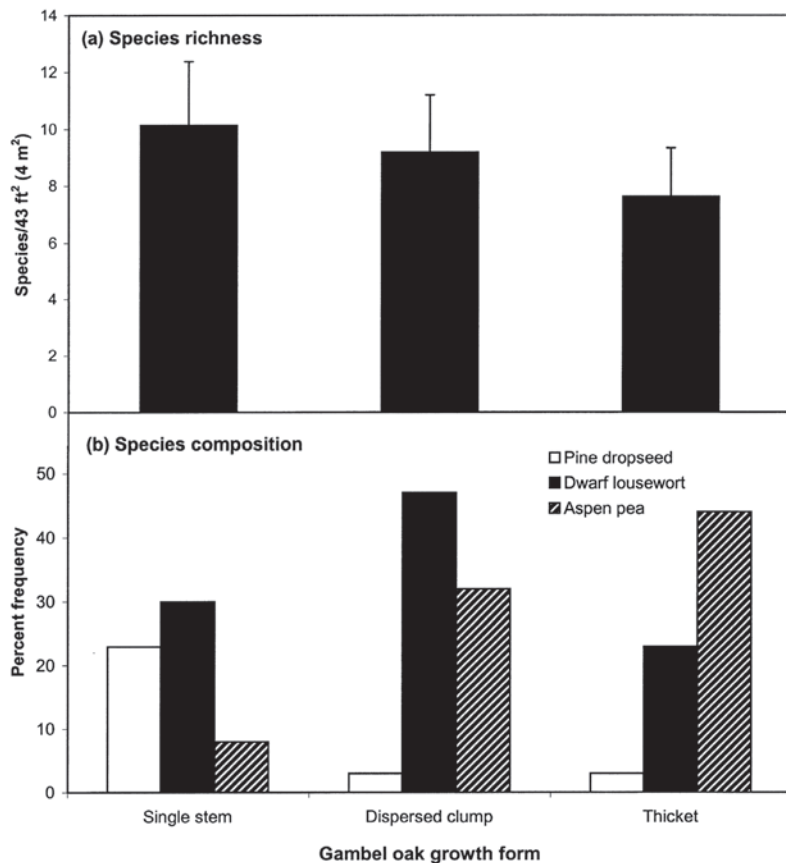


Figure 3—Understory plant (a) species richness and (b) composition among three Gambel oak growth forms following Abella and Springer's (2008) growth form classification. Error bars in (a) are 1 standard deviation, and percent frequencies in (b) are based on 43-ft² (4-m²) plots. Scientific names for species: aspen pea = *Lathyrus laetivirens*, dwarf lousewort = *Pedicularis centranthera*, and pine dropseed = *Blepharoneuron tricholepis*. Data from Abella and Springer (2008) averaged from 10 sites in ponderosa pine-Gambel oak forests within the Coconino National Forest, northern Arizona.

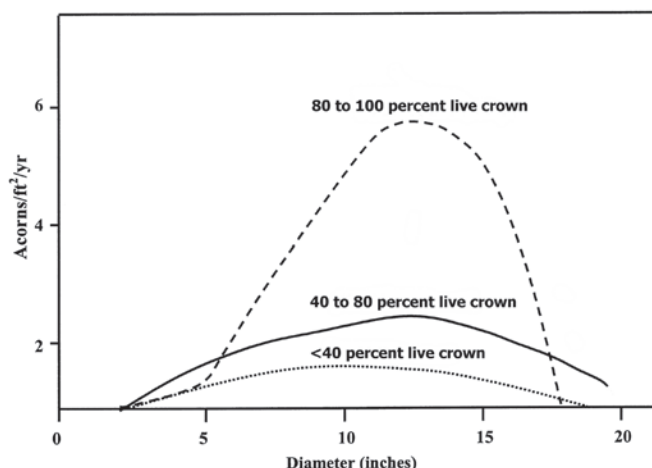


Figure 4—Gambel oak acorn production as a function of stem diameter and crown vigor, measured for six years on the Coconino National Forest, northern Arizona. Oaks 10 to 15 inches (25 to 38 cm) in diameter and possessing 80 to 100 percent live crown yielded the most acorns. Data from McCulloch and others (1965).

Managing Oak Growth Forms

Management prescriptions for maintaining different proportions of Gambel oak's growth forms can potentially enhance diversity of wildlife habitat, plant communities, and human resource values. Existing research suggests that large oaks can be promoted by thinning ponderosa pine or other competing trees to accelerate growth of smaller oaks (table 2; Onkonburi 1999). During prescribed burning, keeping pine slash and fuels away from oak boles may help protect existing large trees from damage (Abella and Fulé 2008a). Pole-sized clumps can possibly develop with time by natural self-thinning of brushy thickets (Clary and Tiedemann 1992). Mechanically thinning oak within clumps may hasten this process, but effects of thinning Gambel oak are not well known (Onkonburi 1999). Growth rates of residual stems may depend on

how much energy clones allocate to resprouting of the cut stems (Harrington 1989).

Following the logic underlying Kruse's (1992) growth-form classification, young, brushy thickets can be promoted by reversing succession in older, pole-sized clumps. Stems could be cut or burned within pole-sized clumps to stimulate resprouting to form brushy thickets (table 2). Pole-sized clumps may be particularly amenable to management for fuelwood by thinning stems to potentially encourage large-tree growth forms or sprouting to maintain brushy thicket forms. Cutting live oak stems would represent a policy shift in some areas (Brischler 2002). However, cutting should not be overlooked as a possibility for manipulating growth forms and increasing diameter increment. A landscape-scale perspective is useful for identifying areas where active oak management would be appropriate or inappropriate and has few or no conflicts with other management priorities or mandates (Prather and others 2008). Because of their value to wildlife (Kruse 1992, Reynolds and others 1970), protection of existing large oaks from fire damage, unauthorized cutting, and intense competition from other trees (even possibly from smaller oaks themselves, within a clone or from other clones) should be a priority. Ensuring that sufficient pole-sized stems survive to grow into new cohorts of large trees (Brischler 2002) is also an important consideration, although forest reconstruction data suggest that pole-sized stems are more abundant in current than historical forests (Abella and Fulé 2008b).

Summary

- In southwestern ponderosa pine forests, Gambel oak has several growth forms distinguished by stem sizes and the density and spacing of stems within clumps.
- Four Gambel oak growth-form classifications have been published, each with different focuses that classify growth forms using different criteria.

Table 2—Summary of potential management prescriptions to promote three basic growth forms of Gambel oak in southwestern ponderosa pine-oak forests.

Growth form	Prescriptions ^a
Large tree	Thin ponderosa pine; thin within oak clumps ^b ; protect large stems from damage
Pole/dispersed clump	Allow natural self-thinning; thin dense clumps then possibly burn; fuelwood management ^c
Brushy thicket	Burn and cut stems to facilitate sprouting; fuelwood management

^a Prescriptions summarized primarily from Abella and Fulé (2008b), Brischler (2002), Clary and Tiedemann (1992), Harrington (1989), and Onkonburi (1999). The magnitudes of the effects of the suggested prescriptions may vary with site conditions and prescription-implementation. Additional research is needed to quantify effects of these variables.

^b A particularly important area for future research is to more clearly elucidate effects of oak thinning on the growth of remaining stems.

^c Fuelwood harvests should be carefully planned or regulated to ensure that only prescribed stem diameters and densities are cut.

- Oak's growth forms afford flexibility in managing oak for different wildlife habitat and resource values. For example, large-tree growth forms often contain cavities for wildlife, while smaller, shrubby forms supply accessible browse and ground cover.
- Thinning competing trees (pine, but also possibly oak itself) likely encourages growth of large oaks. Preventing pine slash and fuels from accumulating near oak boles might help protect existing large oaks during prescribed fire.
- Pole-sized growth forms can develop through time, possibly by self-thinning in younger clumps. Mechanically thinning within clumps may accelerate this process, but effects of thinning on the growth of remaining stems are poorly understood.
- Cutting or burning to stimulate sprouting maintains brushy thicket forms.
- Existing research suggests that actively managing Gambel oak and pine-oak sites through prescribed burning, thinning of small- or medium-sized oaks, or thinning of competing trees (for example, ponderosa pine) can sustain desired proportions of oak growth forms. Maintaining an assortment of oak growth forms, within or across sites, will likely enhance ecological diversity and human resource values.

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