Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Pacific Northwest Research Station | General Technical Report PNW-GTR-1016 | October 2023

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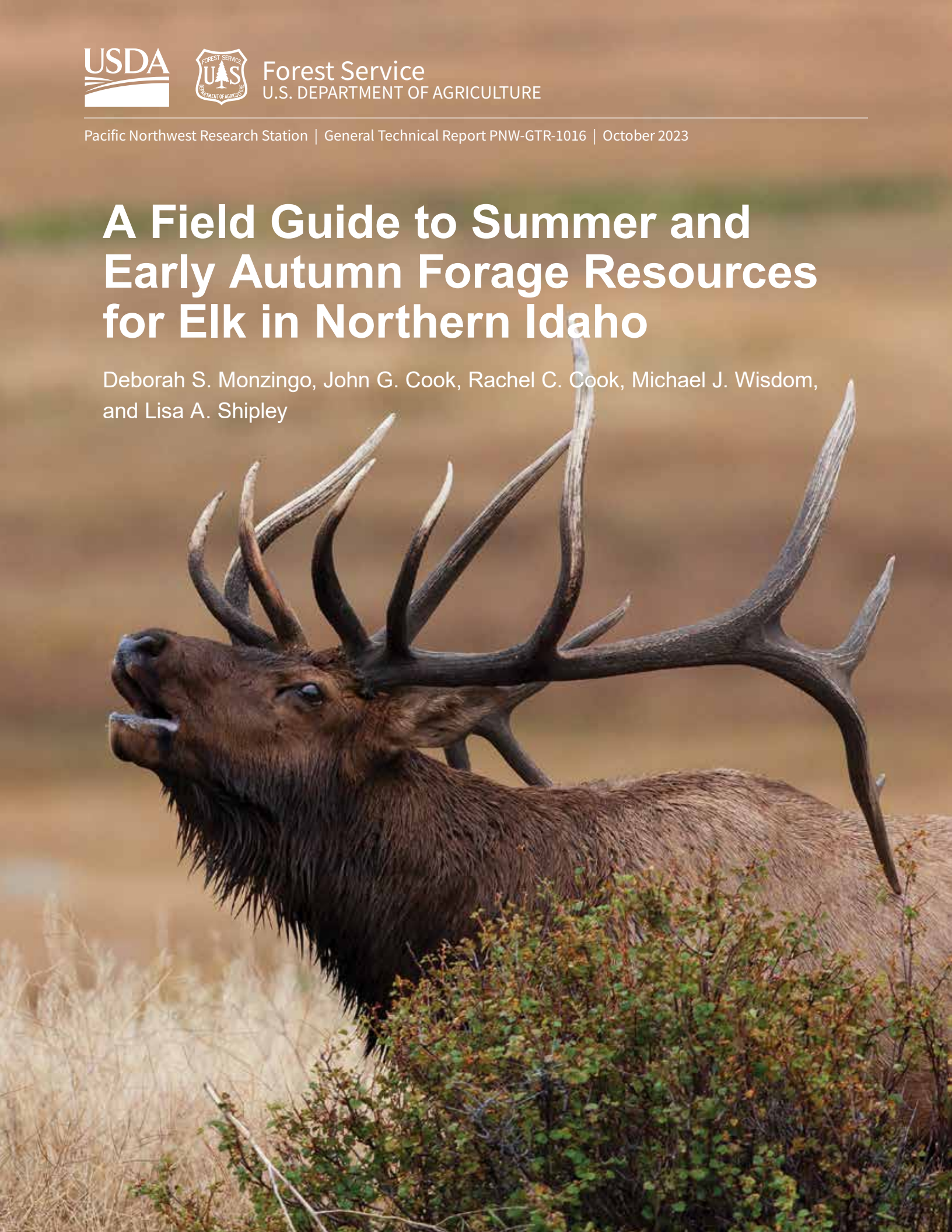

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U.S. Department of Agriculture, Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-1016
October 2023

Published in cooperation with:
National Council for Air and Stream Improvement
Washington State University
Clearwater Basin Collaborative
Idaho Department of Fish and Game

Abstract

Monzingo, Deborah S.; Cook, John G.; Cook, Rachel C.; Wisdom, Michael J.; Shipley, Lisa A. 2023. A field guide to summer and early autumn forage resources for elk in northern Idaho. Gen. Tech. Rep. PNW-GTR-1016. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 88 p. https://doi.org/10.2737/PNW-GTR-1016.

Forage quality and quantity are nutritional attributes that influence ungulate populations through bottom-up processes. In northern Idaho, harsh winters occasionally cause substantial mortality of elk (*Cervus canadensis*) and deer (*Odocoileus hemionus*) populations; however, recent studies in the Western United States show that nutritional deficiencies on summer range also affect populations by reducing reproduction and survival. In fact, in many settings, nutritional deficiencies in summer may have a more limiting effect on elk populations than deficiencies in winter. Large tracts of mid- and late-succession forests, a product of fire suppression and declines in timber harvest in many areas of the West, often support forage resources of relatively low quantity and quality. Natural disturbance events and forest management can greatly increase forage quantity and quality to improve forage resources across landscapes. We sampled plant communities in northern Idaho during the summers of 2016 and 2017 to describe patterns of forage quantity and quality among seral stages and potential vegetation communities from late spring through early autumn. In this report, we summarized these patterns and provided insights for managing forests to improve forage for elk. For all potential vegetation (PV) series ranging from Douglas-fir to subalpine fir, early-seral communities (<25 years old) provided greater forage abundance and often forage of higher quality. But forage response to disturbance varied among PV series. Forage quality was higher in PV series at higher elevations (e.g., the spruce-fir, western redcedar, and western hemlock series), particularly in late summer. Early-seral communities created by stand-replacing disturbance produced the best forage (high quantity and high quality) for elk in the western redcedar, western hemlock, and wetter extents of the grand fir and spruce-fir series, providing the greatest benefit to elk relative to the cost of increasing forage through forest management. In PV series where climate is especially conducive to conifer growth (e.g., western redcedar, western hemlock, and wetter extents of the grand fir series), forest overstory development after disturbance was rapid, and duration of abundant, nutritious forage in the early-seral communities was short. Successional development of the overstory in drier PV series at lower elevations (Douglas-fir series) and at the highest elevations (spruce-fir series) was slower, and forage readily consumed by elk persisted into older stands to a greater degree than in series where climate supports rapid conifer development. Dense mid- and late-seral forests greatly dominated across central and eastern portions of our study area, suggesting that restoring early-seral communities, well-distributed across the region, will benefit elk and other wildlife that depend on these productive, diverse community types.

Keywords: *Cervus canadensis*, disturbance forage, nutrition, plant biomass, Rocky Mountain elk, succession.

Contents

Chapter 1: Introduction and Background

Many environmental factors influence the dynamics of large ungulate populations, but nutrition, particularly during summer, has received increasing emphasis over the past two decades, particularly in the Western United States. Despite increases in forage quality and abundance during the growing season, forage resources might not fully satisfy nutritional requirements of adult females and their offspring, particularly as the forage that elk (*Cervus canadensis*) readily eat wanes in late summer and early autumn. Daily digestible energy (DE) and digestible protein (DP) requirements of adult females with juveniles (calves) in summer are two- to threefold greater than in winter (Cook et al. 2004, National Research Council 2007, Oftedal 1985). Controlled studies demonstrated strong, direct correlations between nutritional deficiencies and stunted performance of females and juveniles, including reduced rates of body fat accrual during summer and autumn; timing of ovulation and probability of breeding; body condition at the beginning of winter; neonatal vigor and size; juvenile growth, development, and survival; growth and development of subadults; and age at which females first breed (Cook et al. 1996, 2004; Crête et al. 1993; Tollefson et al. 2010). Findings from captive ungulate studies have been corroborated in wild settings for a variety of large ungulate species throughout the Northern Hemisphere (Cook et al. 2013, 2021; Crête and Huot 1993; Dale et al. 2008; Hjeljord and Histol 1999; Monteith et al. 2015; Peek et al. 2002; Proffitt et al. 2016; Rolandsen et al. 2017; Schrempp et al. 2019).

Limiting effects of deficient summer nutrition on ungulate populations also have been well demonstrated in the Pacific and Inland Northwest. In western Oregon and Washington, Cook et al. (2016) showed that dietary DE levels and forage intake rates of elk were routinely inadequate to satisfy nutritional requirements of females and their calves, and Cook et al. (2018) showed that variation in body condition and pregnancy rates of lactating females was well correlated to estimates of DE available to elk among nine elk populations in the region. Ulappa et al. (2020) also reported that DE, DP, and forage intake rates typically were insufficient in most vegetation communities to satisfy summer nutritional needs of black-tailed deer (*Odocoileus hemionus columbianus*) in western Washington. In northeastern Oregon, Cook et al. (2014) found that nutrient levels in forage consumed by elk in rangelands and *Pinus ponderosa* savannahs, relatively mesic forest communities, and wet meadows declined below nutritional requirements in mid-June, late July, and mid-August, respectively. In Idaho, nutritional limitations during summer were linked to survival rates of elk calves (Horne et al. 2019) and growth rates of moose (*Alces alces*) populations (Schrempp et al. 2019). Also, in Idaho, nutritional limitations during the growing season influenced recruitment rates of mule deer (*O. hemionus*) fawns (Hurley et al. 2014). In northeastern Washington, Cook et al. (2021) found substantial evidence that summer nutritional limitations in moose

affected pregnancy rates and survival, particularly of moose that were successful in raising a calf. In western Montana, Proffitt et al. (2016) reported that forage quantity and quality in summer contributed significantly to differences in pregnancy rates and body condition of female elk in two adjacent elk populations. In south-central Oregon, Peek et al. (2002) correlated long-term trends in mule deer populations with forage abundance and weather.

In general, these studies documented that variation in plant composition, abundance, phenology, and forage nutrient content at fine scales influences individual animal performance and population dynamics at broad scales (Cook et al. 2018, Shipley 2007). However, data are lacking that quantify how forage attributes (i.e., quality and quantity) that affect animal performance vary spatially and seasonally in response to disturbance, succession, and biogeoclimatic characteristics. Also lacking are data that demonstrate the extent to which habitat management through stand-replacing disturbance can be used to improve forage resources for large ungulates. In the summers of 2016 and 2017, we conducted extensive field sampling in the Clearwater and St. Joe River basins in northern Idaho to evaluate influences of disturbance, succession, and biogeoclimatic characteristics on forage resources for summering elk. Monzingo (2020) and Monzingo et al. (2023) summarized methods and results of this work. Herein, we provide field photos, graphs, forage resource descriptions, and management priorities and management options for each of the common vegetation communities in the study region in a field guide format. We emphasized responses of forage resources to disturbance and succession because these responses provide insights of how forage will likely respond to habitat management through stand-replacing disturbance. We also drew upon our past work of conducting foraging trials using captive elk (Cook et al. 2014, 2016, 2018; Rowland et al. 2018) and captive black-tailed and mule deer (Ulappa et al. 2020, Wagoner et al. 2013) in the Inland and Pacific Northwest. Our objective was to make available to land managers, wildlife biologists, and interested public insights from our past work that were specific to the vegetation communities of northern Idaho.

Chapter 2: Methods

Study Area

The study area was located in the Clearwater (33 000 km^2) and St. Joe River basins (3512 km^2) in northern Idaho (Ecovista et al. 2003, Haugo and Welch 2013) (fig. 2.1). Topography across the study area ranged from western rolling prairie at 230-m elevation to eastern mountain peaks at 2590-m elevation near the Continental Divide in the Rocky Mountains (USDC EDA 2014). Temperatures strongly varied along the west-to-east elevation gradient, with average highs ranging from 30 to 40 °C and lows ranging from −18 to −7 °C (USDC EDA 2014). Precipitation ranged from 30 to 230 cm/year across the study area (Clark and Harris 2011, Ecovista

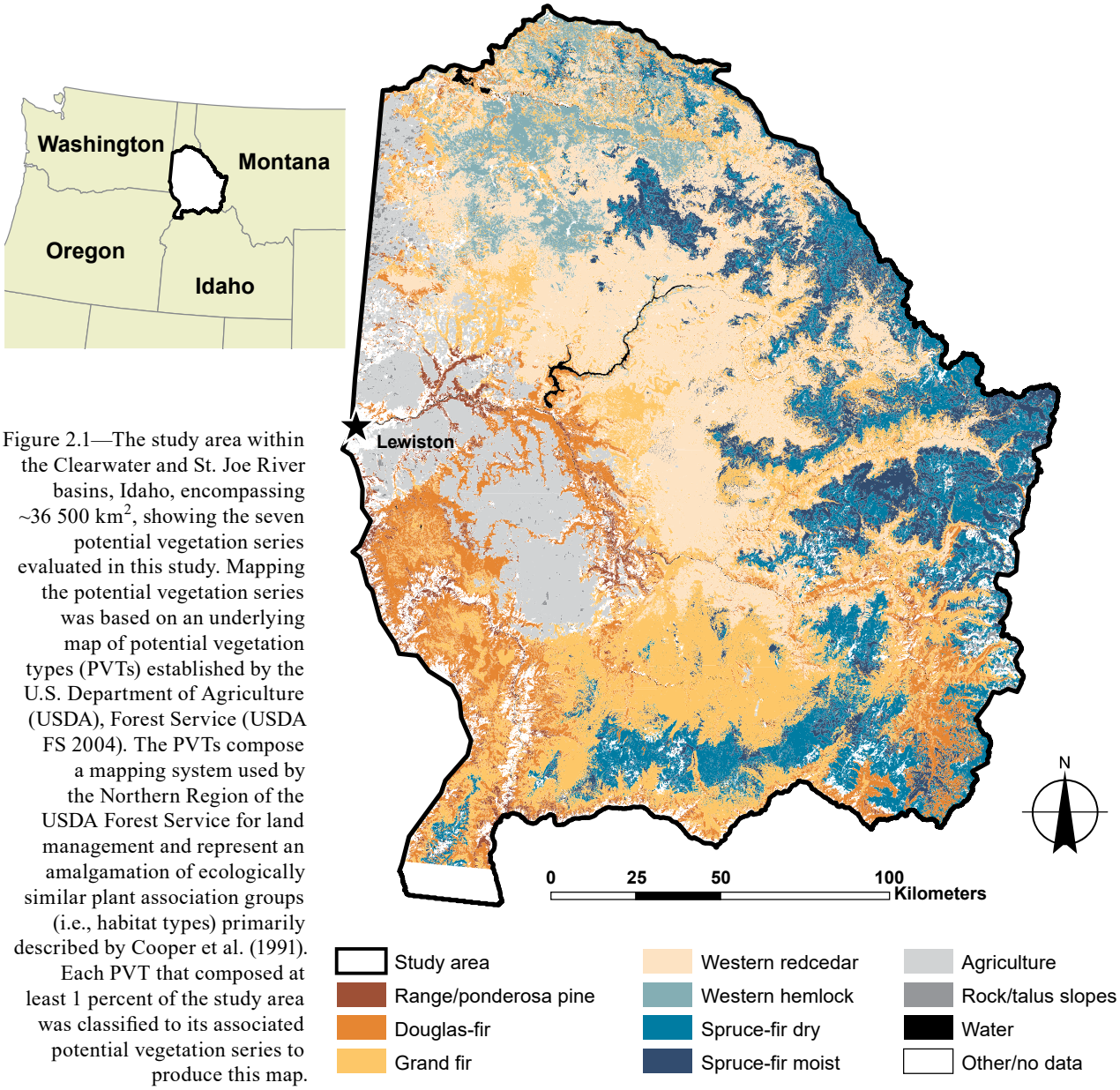

Figure 2.1—The study area within the Clearwater and St. Joe River basins, Idaho, encompassing ~36 500 km^2, showing the seven potential vegetation series evaluated in this study. Mapping the potential vegetation series was based on an underlying map of potential vegetation types (PVTs) established by the U.S. Department of Agriculture (USDA), Forest Service (USDA FS 2004). The PVTs compose a mapping system used by the Northern Region of the USDA Forest Service for land management and represent an amalgamation of ecologically similar plant association groups (i.e., habitat types) primarily described by Cooper et al. (1991). Each PVT that composed at least 1 percent of the study area was classified to its associated potential vegetation series to produce this map.

et al. 2003). We focused on five elk management zones established by the Idaho Department of Fish and Game for managing elk and other wildlife: the Dworshak, Elk City, Selway, Hells Canyon, and Lolo zones in the Clearwater River basin and the southeastern portion of the Panhandle zone in the St. Joe River basin.

Vegetation in the region was strongly influenced by precipitation, temperature, and soil types that varied greatly along elevational and latitudinal gradients. Cooper et al. (1991) provided detailed descriptions of potential natural vegetation communities arraying from low to high elevations as follows: bunchgrass rangelands and savannahs of ponderosa pine and Douglas-fir at the lowest and driest portions; grand fir, western redcedar, and western hemlock at mid-elevations; and the subalpine forests supporting mountain hemlock and subalpine fir at the highest elevations. Range/ponderosa pine and Douglas-fir series largely occurred in southwestern areas; western hemlock, in particular, and the western redcedar and grand fir series largely occurred in central and northern areas; and the subalpine series at higher elevations occurred in eastern areas of our study region (for species common names refer to app. 1). Cooper et al. (1991) described vegetation characteristics of the region.

Fires ranged from low-severity wildfires occurring on average in 10- to 50-year intervals to high-severity wildfires occurring on average in intervals of 60 to 250+ years, depending on vegetation community type (Smith and Fischer 1997). Historical fire occurrence, seral-stage distribution, and stand structure and composition (Arno et al. 2000) have been manipulated by more than a century of fire suppression and timber harvest (Ecosystem Research Group 2013, Haugo and Welch 2013). In general, timber harvest in the study area was extensive during the 20th century and has been drastically reduced over the past two to three decades, resulting in large tracts of dense forests with sparse forage resources (Haugo and Welch 2013, Monzingo et al. 2023).

In 2014, the elk population in the Clearwater River basin was estimated to be ~19,500 (IDFG 2014), with an additional ~3,500 elk in the St. Joe River basin (Moore 2021), levels that were substantially lower than in the past, at least in some areas of the region (Peek et al. 2020, Wright and Groen 2010). Considerable speculation and debate exist about the causes of declines, but loss of vast areas of early-seral vegetation on elk winter and summer ranges and increasing predation, or combinations of both, typically have been considered to be the most likely causes (Peek et al. 2020). In addition to elk, other large wild ungulates (i.e., white-tailed deer [*O. virginianus*], mule deer, and moose) and predators (i.e., gray wolves [*Canis lupus*], mountain lions [*Puma concolor*], and American black bears [*Ursus americanus*]) occupied the study area (Amadon et al. 2010[1], IDFG 2014).

[1] Amadon, J.; Boal, J.; Callister, D.; Herrera, E.; Holt, J.; Keithly, M.; Lemmel, G.; Sandars, B.; Shumake, M.; Beinert, R.; Brown, K.; Cummings, C.; Hopkins, G.; Jahir, J.; Ledford, B.; Mankoff, K.; Shrestha, S.; Weller, N. 2010. The Clearwater Basin bioregion atlas. Moscow, ID: University of Idaho. On file with: Tamara Laninga, associate professor, Department of Urban and Environmental Planning and Policy, Western Washington University, 516 High Street, Bellingham, WA 98225.

Study Design

The scope and focus of the findings in this report reflect attributes of field sampling we conducted in 2016 and 2017. Our original objectives for the field sampling were to describe forage resources at medium and broad scales across the two basins of our study region and to develop models that reflected how variation in forage resources at these scales affect habitat use and productivity of the region's elk herds. Because of time and logistical constraints during the field work, we emphasized sampling forage resources in the common vegetation types and the extant disturbance types of our study region. Thus, our datasets generally do not reflect rare vegetation types in the region, though these might be unusually valuable to elk from a nutrition perspective (e.g., mountain meadows, riparian habitat, perched water tables). In addition, clearcut logging and wildfires of sufficient intensity to eliminate most trees were the disturbance types that shaped current vegetation communities, and thus, our data primarily reflect these disturbance types. Our study's scope was too limited to provide reliable information about how forage resources differ as a function of commercial timber harvest options (e.g., clearcutting, shelterwood, seed tree), site preparation (e.g., slash control, chemical weed control), and a variety of other forest management options, under which forage resources would undoubtedly vary. This report presents guidelines on the vegetation types and forest management options for which we have data. Future research and the experience and insights of land managers will be required to augment gaps in our information for managing forage resources on behalf of elk in northern Idaho.

Vegetation Classification

We used a potential natural vegetation classification system at the series level as described for our study region by Cooper et al. (1991), with several minor alterations. First, at lower elevations and vegetation communities on the driest sites sampled, we combined bunchgrass-dominated rangelands with the *Pinus ponderosa* series as described by Cooper at al. (1991) into a potential vegetation (PV) series that we hereafter refer to as the range/ponderosa pine series. In practice, the *P. ponderosa* plant association groups that we sampled were largely restricted to the drier extreme of this series, mainly pine savannahs with overstory conifer cover usually <20 percent. We combined these two types because species composition (undergrowth plant species) and plant phenology were similar, as were elk nutrition and foraging dynamics, based on captive elk studies in northeastern Oregon (Cook et al. 2014). Second, Cooper et al. (1991) recognized two subalpine series at the highest elevations of our study region, the *Tsuga mertensiana* series and *Abies lasiocarpa* series. Both had similar composition of undergrowth vegetation under similar temperature and precipitation regimes, and thus, we combined them into a spruce-fir series. We subdivided this series into wet and dry series, reflecting markedly different undergrowth species composition and site productivity. The spruce-fir dry series occurred in frost pockets often with coarse-textured soils with low water retention or along ridgelines with shallow soils, and was among the coldest, most

unproductive series in our study region. Vegetation characteristics of the *T. mertensiana-Xerophyllum tenax*, *T. mertensiana-Menziesia ferruginea*, *Abies lasiocarpa-X. tenax*, and *A. lasicarpa-M. ferruginea* plant association groups described by Cooper et al. (1991) best reflect those that we sampled in the spruce-fir dry series. In contrast, the spruce-fir moist series occupied sites with deeper, fine-textured soils that supported considerably more productive and diverse vegetation communities. For elk nutrition, the need to divide these high-elevation forested plant communities into two series reflected the markedly different levels of available selected versus avoided forage (described below). With these changes, our sampling and analysis of forage resources were conducted in the following seven series: range/ponderosa pine, Douglas-fir, grand fir, western redcedar, western hemlock, spruce-fir dry, and spruce-fir moist (fig. 2.1). For field identification of these series, we primarily relied on the series key presented by Cooper et al. (1991: 13), which we adapted for our purposes (app. 2).

Sampling Forage Resources

We sampled vegetation during two field seasons (2016 and 2017) in the seven PV series and across multiple seral stages (see Monzingo et al. 2023). Field seasons occurred between May and October, but sampling in high-elevation series was limited to late-June–early-September because of snow cover. We sampled vegetation in 359 macroplots, the primary sampling unit. Macroplots were rectangular (0.18 ha, 60 by 30 m) and were located >50 m from edges (i.e., edge of PV series, seral stage, or road) (fig. 2.2). Overstory and undergrowth vegetation characteristics were measured on three parallel, 30-m transects and 15 vegetation plots (0.85 m^2) per macroplot (5 plots per transect). The number of macroplots was generally evenly distributed among PV series, across seasons, and two stand-age categories (<15 years after disturbance and >15 years after disturbance). The method of disturbance for macroplots sampled in early-seral communities was visually described as either logged (n = 101) or wildfire (n = 26). We did not directly measure any biogeoclimatic characteristics (e.g., soil type, moisture, and climate) because we assumed these to be inherently reflected in the PV series (Cooper et al. 1991).

Along the three parallel transects in each macroplot (fig. 2.2), we measured percentage of overstory canopy cover using a densitometer (an ocular sighting tube that provides an unbiased estimate of overstory cover) (Cook et al. 1995). We also measured basal area (square meters per hectare) with a Cruz-All (JIM-GEM®, Forestry Suppliers, Inc., Jackson, MS[2]) and tree density (trees per hectare) based on stem counts in three, 3- by 15-m belt transects per macroplot. Average stand age was estimated by taking a core sample from a tree representing the mean age and size of trees in the overstory of the stand. For this, trees that occurred in the upper strata of the canopy (i.e., part of the cohort of trees that established after the last stand-replacing disturbance event)

[2] The use of trade or firm names mentioned in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

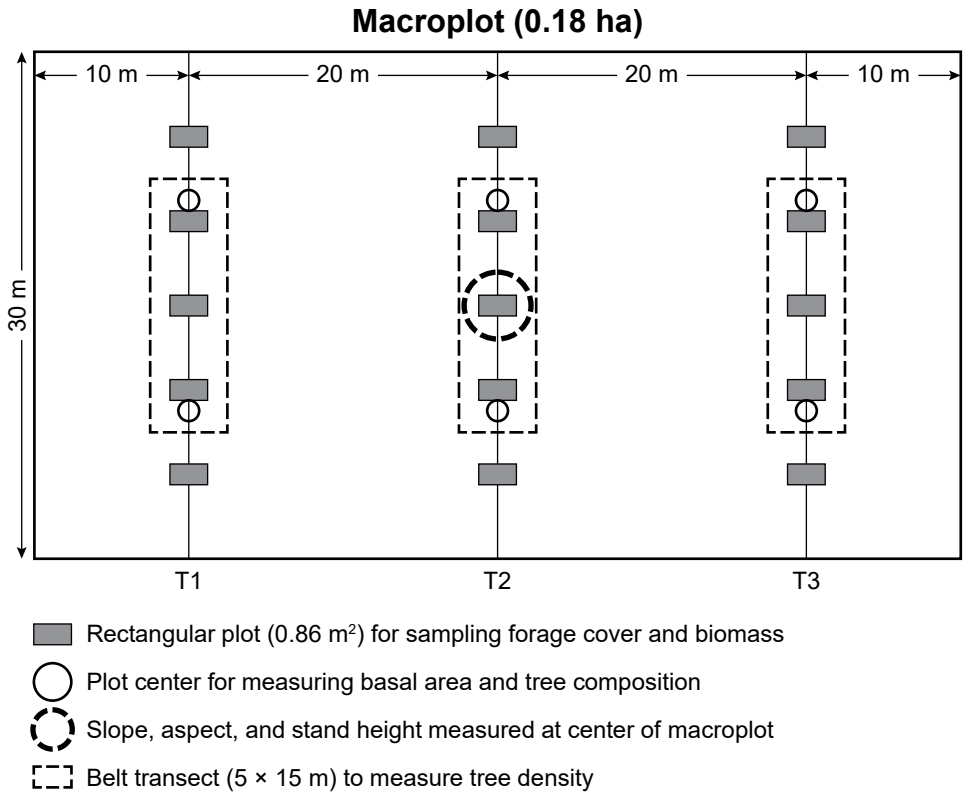

Figure 2.2—Macroplot design for sampling overstory characteristics, vegetation abundance in the undergrowth layer, topography, and stand age along three transects within the Clearwater and St. Joe River basins, Idaho, during summer, 2016 and 2017.

were selected for sampling, and trees in middle or lower strata of the canopy or trees that substantially exceeded the upper strata (i.e., survived the last stand-replacing disturbance event) were excluded for tree-ring sampling.

We used a plot-based double sampling technique to estimate biomass of vegetation (Monzingo et al. 2022). We estimated horizontal cover in 15 plots per macroplot and clipped, dried, and weighed (grams) by plant species within one of 15 plots per macroplot. Only current annual growth of deciduous shrubs and herbs was clipped and included in biomass estimates, although we also clipped previous year's growth of evergreen shrubs because elk will occasionally eat those portions (Cook et al. 2016). We included biomass of previous year's growth only in estimates of total undergrowth biomass (kilograms) but excluded it from all other categories of biomass (these categories are described below). We created conversion equations using the cover-biomass pairs to estimate biomass from the horizontal cover estimates for each plant taxa sampled (Monzingo et al. 2022). We created 93 models using a Gamma distribution generalized linear model; 77 percent of these models had pseudo R^2 values >0.60 (Monzingo et al. 2022).

During field sampling, we further separated forage within taxa into high- and low-quality portions because nutrient content of the two differed markedly (Monzingo et al. 2022). In general, high-quality biomass was composed only of foliage, whereas low-quality biomass was composed of stems and flowering stalks. We then predicted the amount of high-quality biomass from its associated total biomass, by plant species, using the same modeling method described above

(i.e., Gamma distributed generalized linear models). For this, we created 48 models to predict high-quality biomass (response variable) from total biomass (independent variable), all with pseudo R^2 >0.65 (Monzingo et al. 2022).

For field sampling and subsequent analyses, we divided plants into three selection classes reflecting their relative palatability to elk: selected, neutral, and avoided species. These categories were based on eight years of foraging studies conducted between 1999 and 2012 with captive elk in rangeland and forested ecosystems of western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016). Selected species were those proportionally more abundant in elk diets than available to elk in the plant communities in which they foraged; neutral species were those consumed in roughly the same proportion in diets as was available to them in the plant communities in which they foraged; and avoided species were proportionally less abundant in elk diets than available to elk in the plant communities in which they foraged (Cook et al. 2014, 2016, 2018) (app. 1). For presentation of results, we calculated a fourth category, "accepted" species, which included both selected and neutral plant species. We generally classified perennial forbs and deciduous shrubs with no existing data of elk preference from past captive animal studies as accepted species. Of these species with no pre-existing data, we classified evergreen shrubs, annual forbs, annual grasses, ferns, and large thistle (*Cirsium* spp.) species with prominent spines as avoided species (Cook et al. 2014, 2016). Although annual forbs may be eaten to some extent in some seasons, they are typically of low quality and are avoided during summer, particularly late summer. Several older food habit studies exist for elk in northern Idaho (Asherin 1976, Bohne 1974, Irwin and Peek 1983) that used a variety of methods across multiple seasons, including winter. Previous studies did not provide rigorous estimates of forage selection (which requires estimates of forage availability). Thus, we excluded results from these older studies from our analysis of summer forage.

We also collected fresh plant samples during the 2016 and 2017 field seasons to estimate digestible energy (DE [kilojoules per gram]) and digestible protein (DP [grams of protein per 100 grams of forage]) content of vegetation in the macroplots. We placed these samples on ice and froze them for future nutritional analysis (Monzingo et al. 2023). Freeze-dried and ground forage samples were analyzed by the Wildlife Habitat and Nutrition Laboratory and the Soil, Plant, and Waste Analytical Laboratory at Washington State University. Samples were analyzed for sequential fiber (Goering and Van Soest 1970) (applying a correction to fiber results as recommended by Cook et al. 2022), gross energy (kilojoules per gram) using bomb calorimetry (C5000, IKA Works, Inc., Wilmington, North Carolina), nitrogen content (percentage) with a Carbon-Nitrogen TruSpec analyzer (LECO, St. Joseph, Michigan), and protein-binding capacity of tannins (milligrams bovine serum albumin precipitate per milligram of forage) (Martin and Martin 1982). With these assays, we estimated dry matter digestibility (percentage) and DP from the summative equations of Robbins et al. (1987a, 1987b). We calculated DE (kilojoules per gram) from the product of the gross energy content and dry matter digestibility. See Monzingo et al. (2023) for additional details.

Chapter 3: Elk Forage Field Guide

Forage Resource Metrics

Forage resources affect the ability of large ungulates to acquire daily nutritional needs in two primary ways. The first involves the rate at which an ungulate can "harvest" forage (i.e., how fast they can eat). Nutritional ecologists typically consider two temporal scales of interest: (1) harvest rate (grams consumed per minute of foraging), often referred to as instantaneous intake rate; and (2) daily intake rate, which is the amount of forage the animals consume per 24-hour period. Harvest rate is a function of abundance, composition, and structure of vegetation in the various plant communities available to these animals. Ungulates will select forage plants and plant parts of higher quality; thus, the greater the proportion in the plant community of plants with high levels of digestible energy (DE) and digestible protein (DP) and low levels of toxic compounds, the less time they spend searching for good food and the faster they can eat. Harvest rate is greatly influenced by the mass (weight) of the bites they take (Cook et al. 2016, Shipley et al. 1999). Shrubs, mushrooms, and some forbs offer a relatively large bite size; small forbs, forest land grasses with sparse foliage, and many lichens offer a relatively small bite size. Thus, if plants offering good nutrition are abundant and also provide large bite sizes, harvest rates tend to be high. Total forage consumed over the day is a function of harvest rate and the vegetation factors that influence it, but it is also the amount of time spent feeding each day. Foraging time is generally behaviorally and physiologically restricted to less than 15 hours per day because ruminant herbivores must allocate time for ruminating, resting, being vigilant for predators, caring for young, and traveling.

The second primary way forage resources affect the ability of ungulates to satisfy nutritional requirements relates to the concentration of DE, DP, and other nutrients in the forage that they eat (i.e., forage quality). Both DE, in particular, and DP have long been recognized as essential to production, growth, and development of juveniles as well as milk production, accumulation of fat reserves in summer, and high pregnancy rates and early breeding in adults (Cook et al. 2004). Energy and protein are also well recognized as being essential to high production of livestock (National Research Council 1984, 1985, 2007). For any given amount of forage consumed, the greater the concentration of energy and nutrients in their food, the more protein, energy, and other nutrients herbivores consume each day. However, the effects of forage quality on nutrition of ruminant herbivores are substantially more complicated. For example, forages with low DE and DP have high levels of plant fiber (i.e., cellulose and lignin), which slows digestion rates. Slow digestion rates, in turn, reduce the amount of food ruminants can consume each day (Cook et al. 2004, Hobbs 2003, Owen-Smith 2002, Robbins 1983). In many plant communities, low-quality forage is typically abundant, whereas high-quality forage

usually is not (Illius 1997). Consequently, ruminant herbivores such as elk often must carefully select which plants and plant parts they consume and which cover types they choose for foraging if they are to meet their daily energy and nutrient requirements (Cook et al. 2016, 2018). By foraging on plants that provide superior quality and relatively large bite sizes, elk can maintain high levels of food intake each day in the hours available to them for foraging and have a better chance of satisfying their nutritional requirements.

To evaluate and describe nutritional adequacy of individual plant community types for elk across our study region, we calculated three pairs of metrics that varied in how forage quality and quantity were incorporated. Two of these metrics, community-wide-weighted means of DE and DP, represented forage quality only. These were calculated as the weighted mean based on proportion of each accepted plant species (species elk consume in equal proportion to available or in greater proportion than available and excludes species elk avoid) in the plant community (hereafter "community DE," kilojoules per gram forage and "community DP," grams of protein per 100 grams of forage). We used only the high-quality portions to calculate community DE and community DP because (1) DE and DP levels of low-quality portions were 11 to 91 percent below the summer requirement threshold for lactating elk and their calves (Monzingo et al. 2023), and thus we assumed that these portions were too nutritionally poor to be biologically significant contributors to the nutritional well-being of lactating elk and their calves in summer; and (2) ungulates usually forage mainly on foliage on upper portions of plants and avoid the more fibrous stems and stalks (Cook et al. 2014, 2016; Denryter et al. 2017; Ulappa et al. 2020). Also, for these reasons, we assumed that community DE and DP were well correlated to DE and DP levels elk are likely to acquire in their diets when foraging. Past studies have shown dietary DP and, particularly, dietary DE to be strong indicators of the nutritional value of plant communities to elk in summer (Cook et al. 2014, 2016).

We calculated a second pair of forage metrics representing forage quantity only: biomass (kilograms per hectare) of accepted (plant species elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid) and selected (species proportionally more abundant in elk diets than available to elk in the plant communities in which they foraged) plant species. Forage intake rates (grams per minute or grams per day) in elk decline at accelerating rates at accepted forage levels below 900 to 1000 kg/ha in grassland communities (Hudson and Watkins 1986, Wickstrom et al. 1984) and below 250 to 500 kg/ha in forest land communities (Cook et al. 2016, Wickstrom et al. 1984) (summarized in fig. 3.1). These patterns have important implications to elk in northern Idaho ecosystems.

Most mid- and late-seral forest communities support accepted biomass levels of <150 kg/ha, and in these communities, female elk with calves generally will be unable to eat fast enough to satisfy daily nutritional needs in summer. Other studies have shown that as accepted biomass levels decline to low levels, elk may switch to foods of lower DE and DP content to compensate, resulting in a decline

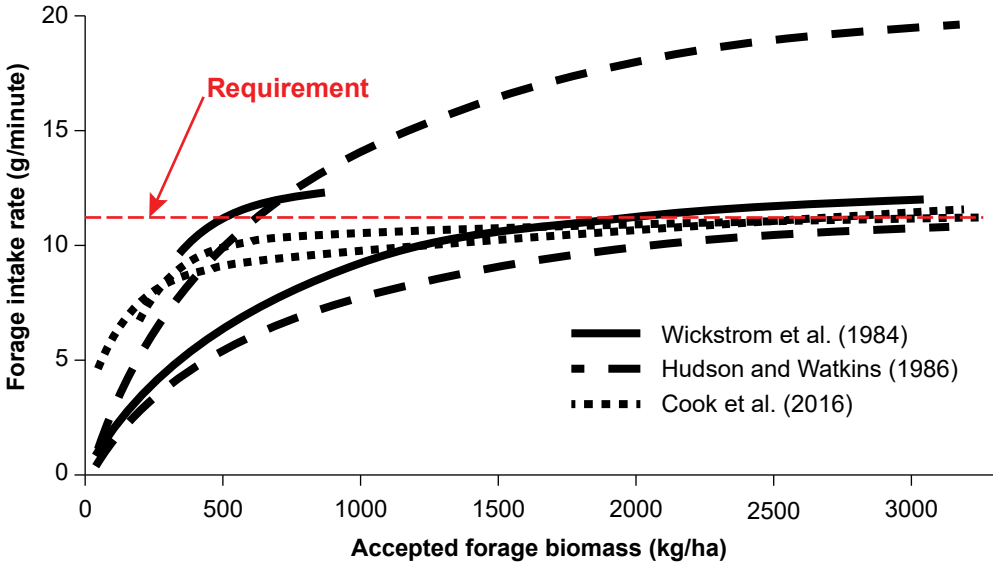

Figure 3.1—Relationships between forage biomass and forage intake rate reported for elk in western North America. The forage intake requirement line indicates the approximate grams of forage on a dry-matter basis that adult lactating elk need to consume per minute to satisfy their daily forage requirements, assuming they spend 15 hours a day feeding (a level often reported as an upper limit of daily feeding time for elk [Cook et al. 2016]). These results illustrate strong declines in forage intake rate when levels of forage biomass fall below 300 to 500 kg/ha.

in the quality of their diet (Cook et al. 2016), a second way overall nutrition can be reduced (Cook et al. 2004, Hobbs 2003, Owen-Smith 2002). Thus, accepted species may be disproportionately valuable to elk even in areas where their biomass is relatively low.

We calculated a final category of forage metrics that integrated both forage quality and quantity to account for nutritional requirements of elk: suitable biomass. This method was first presented by Hobbs and Swift (1985) and later formalized in a linear programming model, Forage Resource Evaluation System for Habitat for Deer (FRESH-Deer), by Hanley et al. (2012). The model uses linear programming to calculate the maximum quantity of vegetation (kilograms per hectare) that satisfies the minimum nutritional requirements of DE and DP needed by elk (Hanley and McKendrick 1985, Hanley et al. 2012). It optimizes the quantity of suitable biomass based on three forage metrics: abundance (kilograms per hectare), DE content, and DP content of each plant species in the plant community. For our calculations, we included only accepted plant species in the model and allowed either high-quality or low-quality plant portions to be included (Monzingo et al. 2023). We excluded avoided vegetation in these calculations because avoided plants contribute little to the nutritional well-being of elk in summer as a result of either low nutrient levels or toxic compounds (Cook et al. 2016).

Using the FRESH-Deer model required setting nutritional requirement thresholds for DE and DP. Monzingo et al. (2023) modeled two levels of nutritional requirements, the first termed “basic” suitable biomass and the second termed “optimal” suitable biomass. We defined basic suitable biomass as the amount of

forage (kilograms per hectare) that will support constant body fat levels of adult lactating elk over summer and high herd-level pregnancy rates based on estimates provided by Cook et al. (2004) for DE (DE > 11.09 kJ/g of food [2.65 kcal/g of food]) and by Cook (2002) for DP (DP > 4.9 g protein/100 g forage [4.9 percent of forage]). However, these levels of DE and DP will not support high levels of fat development over summer and early autumn, nor high rates of over-summer calf and yearling growth, attainment of sexual maturity at young ages, and early breeding, and thus early birthing, of adult female elk (Cook et al. 2004). Therefore, we also calculated optimal suitable biomass (kilograms per hectare) that reflected nutritional requirements to support levels of adult female and juvenile performance that are, by and large, not limited by nutrition (DE > 11.72 kJ/g [2.8 kcal/g] and DP > 6.7 g protein/100 g forage [6.7 percent DP]) (Cook 2002, Cook et al. 2004).

Summer forage quality and quantity varied widely among potential vegetation (PV) series and seral stages. Thus, we summarize these summer forage resource metrics for elk in relation to each PV series and associated seral stage as the foundation for our field guide.

Forage Resource Description by Potential Vegetation Series

Range/Ponderosa Pine Series

General description—

The range/ponderosa pine series occurred at the lowest elevations (300 to 1220 m) of our study region. This series included bunchgrass rangelands where trees were completely absent to *Pinus ponderosa* savannahs that generally supported sparse trees at <20 percent canopy cover (fig. 3.2). Undergrowth in these savannahs predominantly included species that commonly occur in nonforested rangeland communities, and we presumed that the forage layer in both types offered similar value to elk in summer based on foraging trials conducted with captive elk in eastern Oregon (Cook et al. 2014). The range/ponderosa pine series composed minor amounts of our overall study region (10 percent of the entire study region) but was a dominant series primarily on southerly exposures in river canyons in the southwestern areas (fig. 2.1).

Overstory development after disturbance—

Overstory canopy cover and basal area in the range/ponderosa pine series occurred at levels too low to appreciably affect forage resources. Thus, we present no data of overstory-undergrowth relationships for this series.

Forage resources—

More than other PV series, exotic and invasive annual grasses and forbs dominated in the range/ponderosa pine series, averaging 209.0 ± 38.3 kg/ha (table 3.1, app. 4). These plants were of little value to elk in summer, particularly after early summer

Figure 3.2—Range/ponderosa pine series ~11 km east of White Bird, Idaho, showing a bunchgrass-dominated grassland community in the foreground and *Pinus ponderosa* savannah in the background. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 67 kg/ha and primarily included *Achillea millefolium* and *Potentilla gracilis*. Forage in this photo was dormant in mid-August, and thus, forage quality from this site was too low to satisfy protein and energy needs of lactating elk in late summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

(<August 10). Perennial grasses, including *Pseudoroegneria spicata*, *Poa secunda*, *Festuca idahoensis*, and *Danthonia unispicata*, were the prominent selected and neutral species (i.e., accepted species) (table 3.1; see app. 1 for common names of plant species) (*Poa* spp. can compose a significant portion of elk diets in spring and autumn but was typically too desiccated for use in summer and thus was rated as avoided for summer in this study). Relatively abundant accepted forbs included *Achillea millefolium*, *Eriogonum heracleoides,* and *Potentilla gracilis.* Accepted shrubs generally were a minor component of this PV series (table 3.1), but *Physocarpus malvaceus, Symphoricarpos albus,* and *Rosa* spp. were occasionally encountered.

Total biomass averaged 650 and 520 kg/ha in early and late summer, respectively (Monzingo et al. 2023), and accepted and selected species averaged ~200 and ~170 kg/ha, respectively (fig. 3.3). These levels exceeded those in mid- and late-seral stages in forested series and averaged about half of those in early-seral

Table 3.1—Biomass of the 15 most abundant plant species in the range/ponderosa pine potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Annual herbs	Graminoid/forb	Avoided	209.0 ± 38.3
Pseudoroegneria spicata	Graminoid	Selected	65.0 ± 11.5
Poa secunda	Graminoid	Avoided	31.3 ± 6.4
Festuca idahoensis	Graminoid	Selected	23.9 ± 12.0
Achillea millefolium	Forb	Neutral	22.3 ± 4.7
Eriogonum heracleoides	Forb	Selected	17.5 ± 6.1
Lupinus spp.	Forb	Avoided	12.7 ± 5.7
Danthonia unispicata	Graminoid	Selected	12.6 ± 4.4
Potentilla gracilis	Forb	Selected	12.0 ± 15.8
Poa spp.	Graminoid	Avoided	9.8 ± 20.1
Elymus elymoides	Graminoid	Avoided	9.7 ± 29.0
Lomatium ambiguum	Forb	Avoided	9.6 ± 3.8
Carex geyeri	Graminoid	Neutral	9.2 ± 7.0
Sedum spp.	Forb	Avoided	9.0 ± 3.7
Elymus spp.	Graminoid	Neutral	7.7 ± 22.2

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

forested stands (Monzingo et al. 2023). Based on accepted biomass levels, forage abundance levels would at best only marginally support forage intake rates that would satisfy daily forage requirements of lactating elk in summer (fig. 3.3).

Community DE levels averaged 10.9 and 10.7 kJ/g in early and late summer, respectively; both estimates were at least marginally below requirements and overall were the lowest levels among all series in our analysis (Monzingo et al. 2023) (fig. 3.3). Community DP levels averaged 6.2 and 3.8 percent in early and late summer, respectively, which was sufficient to satisfy DP requirements in early summer but was deficient in late summer (fig. 3.3). At 240 and 150 kg/ha in early summer, basic and optimal suitable biomass averaged about half of that in early-seral forest stands and exceeded that in mid- and late-seral stands in most forested series (fig. 3.3). At 150 and 80 kg/ha in late summer, basic and optimal suitable biomass was similar to that in early-seral stands in PV series in late summer and tended to exceed that in mid- and late-seral stands in most PV series (Monzingo et al. 2023).

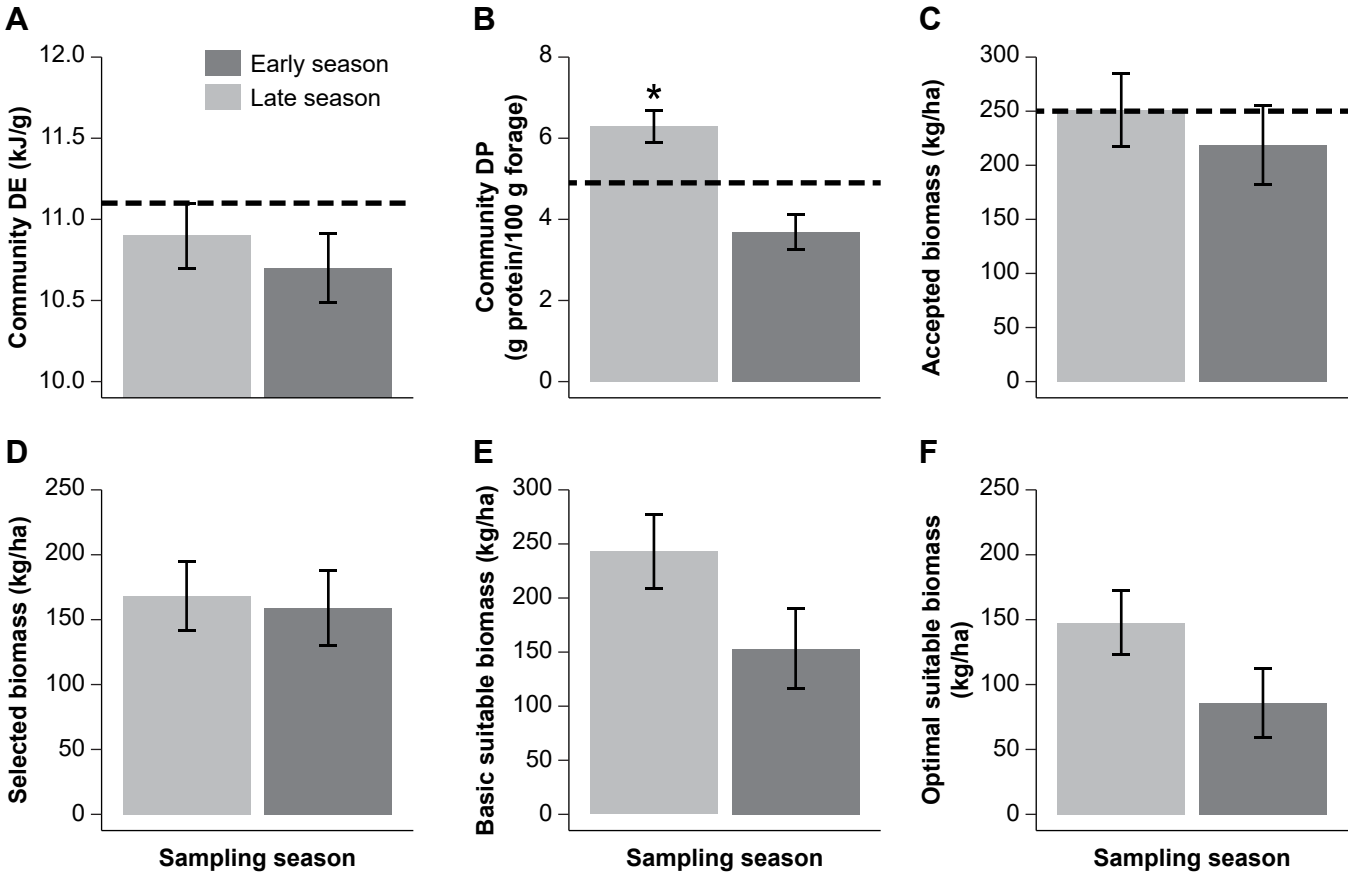

Figure 3.3—Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the range/ponderosa pine series by season (early = May 31–August 10, late = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating female elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisk denotes significant differences between season within a seral stage, and dashed lines denote levels needed to satisfy basic nutritional requirements in summer.

Management considerations—

Community DE and accepted biomass in the range/ponderosa pine series occurred at levels at which lactating elk would not likely satisfy daily nutritional requirements. This finding was consistent with research on foraging trials with captive elk in similar vegetation communities in northeastern Oregon (Cook et al. 2014), where DE content of diets fell below requirement after mid-June each year of the 3-year study. Although this PV series is important for elk in autumn, winter, and spring, and may figure prominently in livestock grazing and prescribed burning programs, we consider it to be a low priority for habitat management to benefit elk during most of summer.

Douglas-Fir Series

General description—

The Douglas-fir series primarily occurred in the central and southern portions of our study region (13 percent of the entire study region) (fig. 2.1). It existed on a variety of landforms, slopes, and aspects, with a tendency to occur mid-slope on moderately steep, south-southwest aspects between the range/ponderosa pine and grand fir series. Seral tree species primarily included *Pinus ponderosa*, but *Larix occidentalis* or *P. contorta* were common on moister sites (Cooper et al. 1991). Across the range of this series, undergrowth vegetation varied markedly, from bunchgrass types under open forest canopies to stands of dense, tall shrubs and relatively dense overstories (figs. 3.4 through 3.6). Rehfeldt (1978, as cited in Cooper et al. 1991) reported two broad ecological settings for the Douglas-fir series, one in cool settings at higher elevations (>1500 m) and the other at lower elevations in warmer settings. Our data were collected in the warmer settings, largely at elevations ranging from 760 to 1130 m.

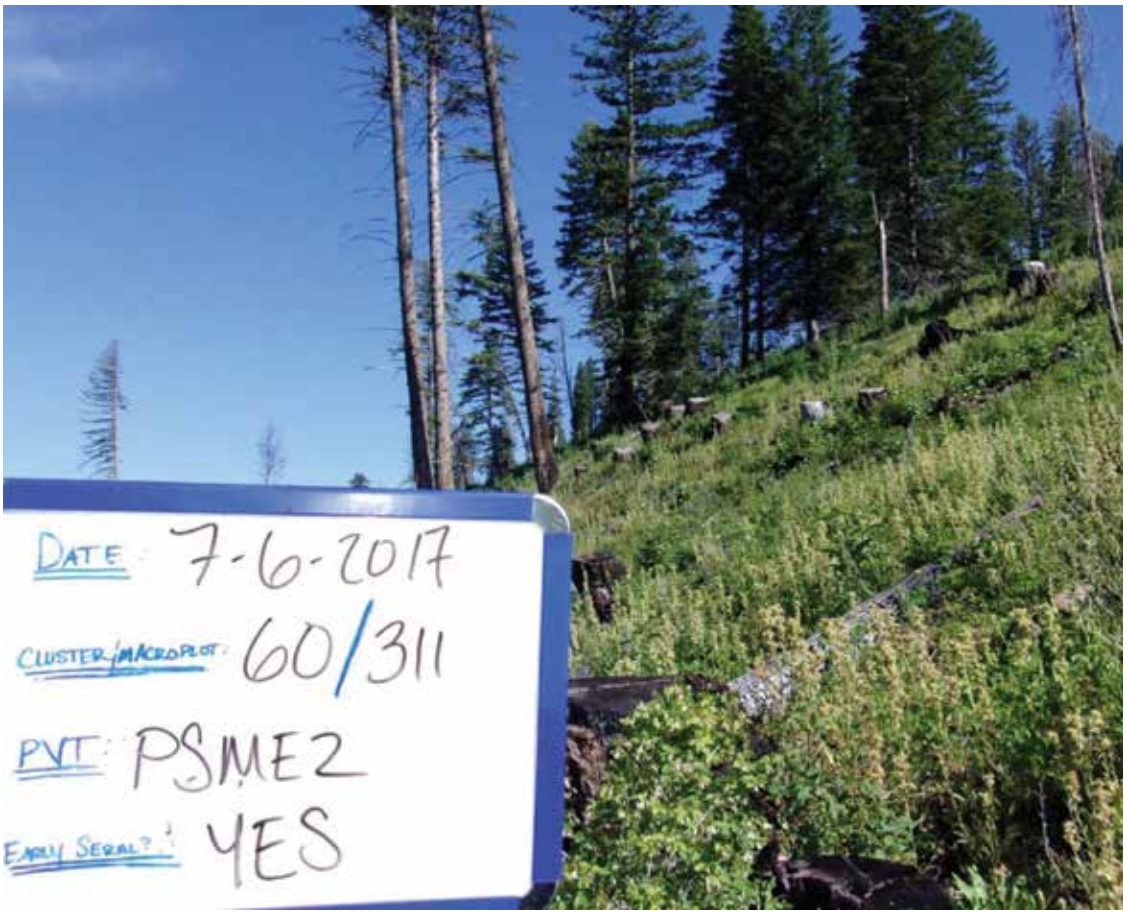

Figure 3.4—Early-seral Douglas-fir series ~3 years old, ~16 km southeast of White Bird, Idaho. This logged stand retained a sparse overstory of *Pseudotsuga menziesii*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 320 kg/ha and primarily included *Mahonia repens*, *Spiraea betulifolia*, and *Vaccinium membranaceum*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.5—Mid-seral Douglas-fir series ~53 years old, ~8 km west of White Bird, Idaho. The overstory consisted of *Pseudostuga menziesii* and *Pinus ponderosa.* Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 74 kg/ha and primarily included *Arnica cordifolia*, *Symphoricarpos albus*, and *Holodiscus discolor.* Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.6—Late-seral Douglas-fir series ~90 years old, ~10 km east of White Bird, Idaho. The overstory was dominated by *Pseudotsuga menziesii* and *Pinus ponderosa*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 162 kg/ha and primarily included *Physocarpus malvaceus*, *Holodiscus discolor*, and *Spiraea betulifolia.* The open forest canopy typical of Douglas-fir series often allows relatively abundant understory vegetation even in older stands such as this one. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

In our dataset, stand age accounted for 22 to 63 percent of the variation in overstory canopy cover, basal area, and tree density in the Douglas-fir series (fig. 3.7). Overstory canopy cover reached an asymptote at ~40 years of age and stabilized at 50 percent canopy cover (fig. 3.7). Rate of increase in basal area was rapid through the first 50 years after disturbance and declined thereafter (fig. 3.7). Tree density peaked by 50 years of age and declined rapidly thereafter (fig. 3.7). Rate of development of the overstory canopy was moderately slower in the Douglas-fir series and averaged, in older stands, about half of that in mid-elevation PV series (e.g., western redcedar, western hemlock series) probably reflecting lower precipitation and drier soil moisture levels in the Douglas-fir series.

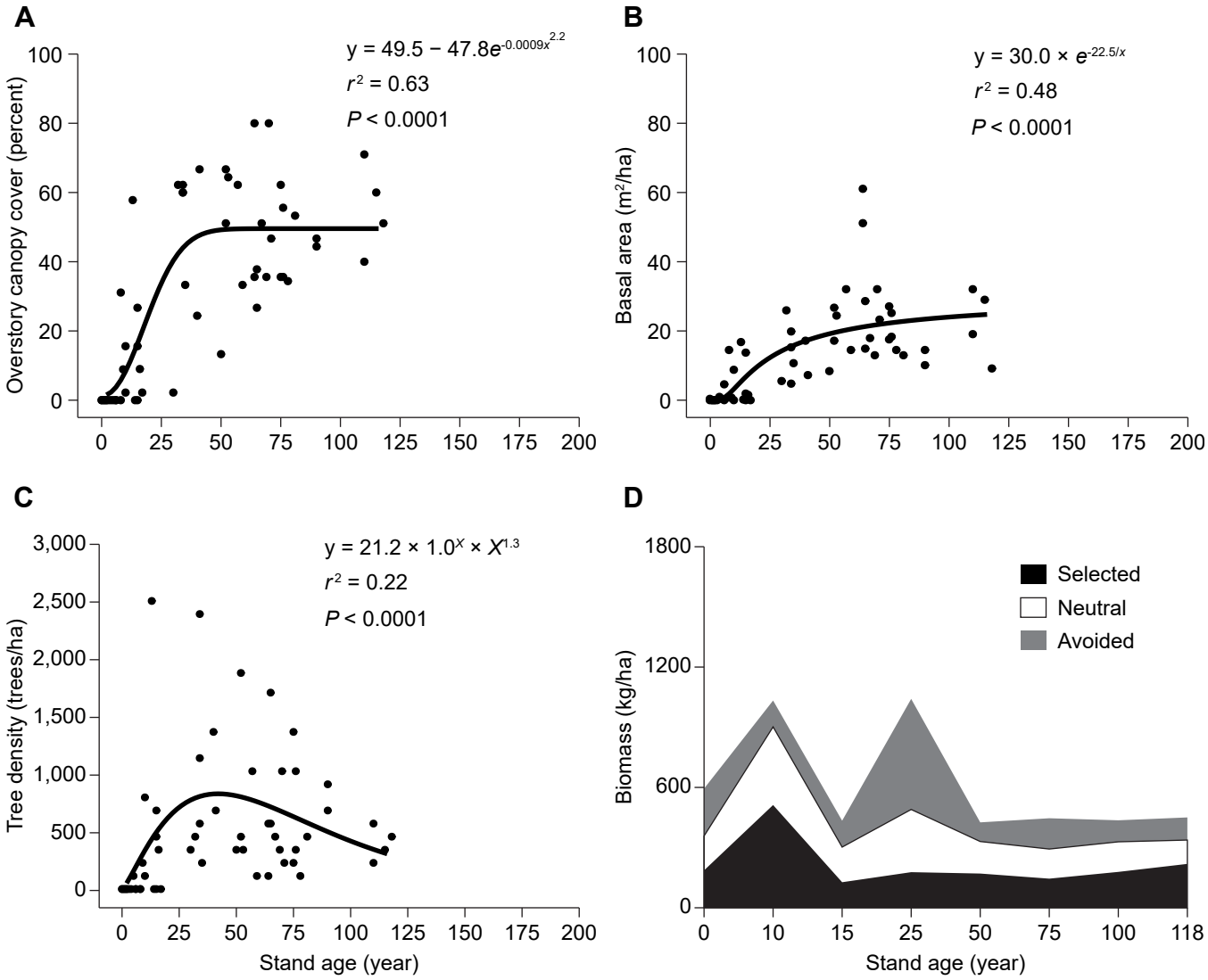

Figure 3.7—Relationships in the Douglas-fir series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

Forage resources—

Prominent neutral and selected (i.e., accepted) graminoid species (table 3.2) included *Dactylis glomerata*, *Carex geyeri*, and *Elymus* spp.; accepted forbs included *Achillea millefolium*, *Cirsium* spp., and *Trifolium* spp.; and accepted shrubs included *Physocarpus malvaceus*, *Symphoricarpos albus*, *Spiraea betulifolia*, *Holodiscus discolor*, and *Amelanchier alnifolia*, with all basic life-form groups well represented in most of the sites we sampled (table 3.2; app. 3). Avoided species that were well represented included annual herbs, *Calamagrostis rubescens*, and *Poa* spp.

Table 3.2—Biomass of the 15 most abundant plant species in the Douglas-fir potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Physocarpus malvaceus	Deciduous shrub	Neutral	92.9 ± 22.3
Symphoricarpos albus	Deciduous shrub	Selected	43.8 ± 8.6
Dactylis glomerata	Graminoid	Selected	34.9 ± 18.9
Annual herbs	Graminoid/forb	Avoided	30.6 ± 7.9
Calamagrostis rubescens	Graminoid	Avoided	23.8 ± 8.8
Spiraea betulifolia	Deciduous shrub	Selected	16.0 ± 3.0
Holodiscus discolor	Deciduous shrub	Selected	14.5 ± 4.9
Carex geyeri	Graminoid	Neutral	13.2 ± 13.7
Achillea millefolium	Forb	Neutral	13.1 ± 2.53
Poa spp.	Graminoid	Avoided	12.8 ± 5.7
Carex spp.	Graminoid	Avoided	12.6 ± 4.0
Elymus spp.	Graminoid	Neutral	11.8 ± 4.1
Cirsium spp.[a]	Forb	Neutral	10.3 ± 13.0
Amelanchier alnifolia	Deciduous shrub	Selected	9.8 ± 4.1
Trifolium spp.	Forb	Selected	9.8 ± 7.5

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] This includes those species of *Cirsium* that elk consume and excludes those species which elk avoid evidently because of heavy spines.

As in other forested series, total undergrowth biomass trended highest in early-seral communities and declined thereafter (fig. 3.7) (Monzingo et al. 2023). Correlations of accepted biomass with overstory canopy cover and basal area were low (fig. 3.8); as stands aged, the strong trend of increasing dominance of avoided species in most PV series was less apparent in the Douglas-fir series, and accepted species remained reasonably well represented even in older stands. In fact, accepted (368 ± 29 kg/ha), selected (178 ± 17 kg/ha), and suitable (293 ± 28 kg/ha) biomass

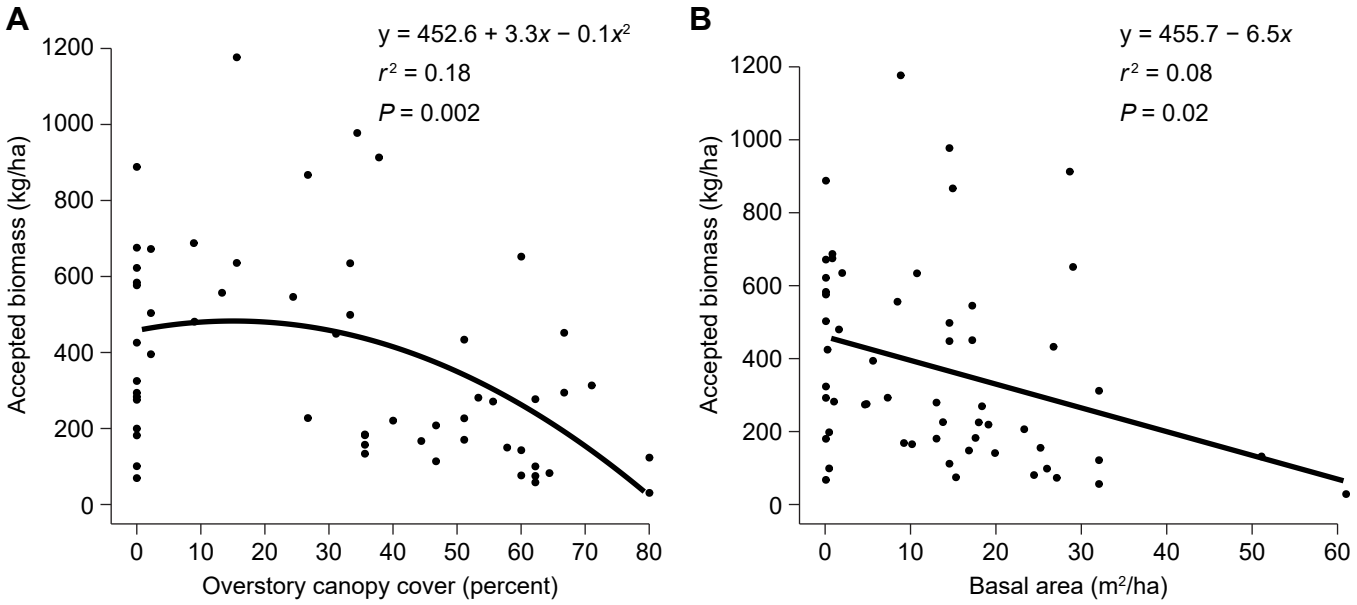

Figure 3.8—Relationships in the Douglas-fir series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

levels all averaged the highest in the Douglas-fir series of any PV series (Monzingo et al. 2023), and most season-seral stage combinations produced levels of accepted biomass needed by elk to maintain adequate forage intake rates (fig. 3.9).

Forage quality levels, in contrast, were moderate compared to those in the other PV series (Monzingo et al. 2023). Community DE and DP trended lower with advancing succession in early summer, but trended higher with succession in late summer, although not significantly so (Monzingo et al. 2023). Community DE levels in most season-seral stage combinations averaged at levels that satisfied requirements, but community DP levels typically were below requirements in late summer in all seral stages (fig. 3.9). Biomass of basic and optimal suitable vegetation was relatively high in early summer but declined sharply in late summer and early autumn, particularly that of optimal suitable vegetation (fig. 3.9).

Management considerations—

Undergrowth of the Douglas-fir series was highly heterogeneous, ranging from dryland bunchgrass-dominated understories (e.g., *P. menziesii-Agropyron spicatum-Festuca idahoensis* plant associations) (Cooper et al. 1991) to substantially more productive, shrub-dominated types with favorable soil moisture regimes. The drier bunchgrass-dominated plant associations were infrequent in northern Idaho and were more common across southwestern extents of our study region (Cooper et al. 1991); our data were more representative of the more productive plant associations. Understories of the drier communities were similar to those in the range/ponderosa pine series that we sampled, and we assume that nutritional value in these types is relatively low in comparison to requirements of lactating elk in summer. These

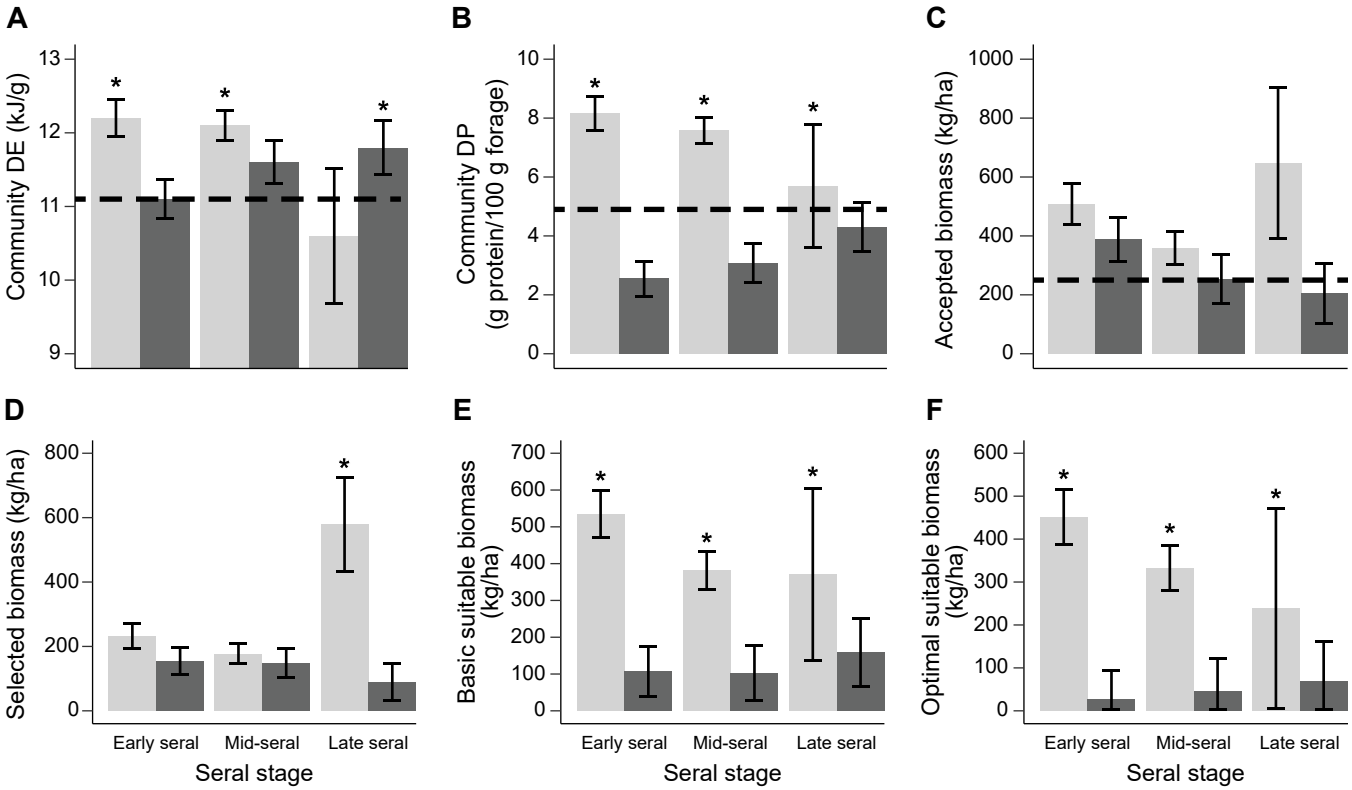

Figure 3.9—Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the Douglas-fir series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, late = >81 years) and season (light gray = May 31–August 10, dark gray = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within seral stage, and dashed lines denote nutritional requirements for lactating elk in summer.

drier types are probably of greatest value to elk during spring and autumn, the latter if sufficient precipitation falls to initiate autumn growth of bunchgrasses and other herbaceous vegetation. We consider them to be of low priority for management to enhance summer nutrition of elk.

The productive plant associations in this series supported a more diverse array of shrubs and forbs and probably provided forage resources of greater value to elk in summer than do the drier associations in this series. Foraging trials with captive elk in the Douglas-fir series in eastern Oregon indicated that elk could acquire significantly better nutrition than in the range/ponderosa pine series and levels of nutrition equivalent to that in the moister grand fir series (Cook et al. 2014). Based on suitable biomass that reflected the combination of quality and quantity of forage, (1) the Douglas-fir series provided some of the best forage resources of all PV series but only during early summer (Monzingo et al. 2023); (2) early-seral communities tended to offer better forage than mid- and late-seral stages but again only during early summer, whereas forage value was roughly equivalent among seral stages during late summer and early autumn; and (3) forage value during late summer

and early autumn was moderate compared to that in other series (Monzingo et al. 2023). Cooper et al. (1991) indicated that selection or shelterwood harvests often may be the most appropriate silviculture strategy in drier areas of this series, in part because partial shade may be required for natural regeneration of desired tree species "on these relatively harsh sites." In addition, Hull et al. (2020) found a positive relationship between thinning and undergrowth abundance, which peaked at 12 years posttreatment. We speculate that retaining some overstory canopy (e.g., 20 to 40 percent overstory canopy cover) (Cook et al. 2014) through selective harvests may provide similar benefits as stand-replacing treatments in the context of forage resources, particularly during late summer because (1) accepted species retained their dominance across all seral stages in this series suggesting that complete overstory removal may have less positive overall effect on accepted forage abundance than in wetter forest PV series, and (2) forage quality during late-summer tended to be at least as high or higher in stands with some overstory than in stands without. More work is required to evaluate these expectations, but we offer the following recommendation in the Douglas-fir series: (1) for habitat management priorities that focus on improving forage resources for elk, greater benefit relative to costs is more probable in the wetter, more productive plant association groups in this series; and (2) the greatest benefit of overstory removal with logging is likely to occur on the most productive sites that support relatively dense overstory canopies (>50 percent overstory canopy cover).

Grand Fir Series

General description—

The grand fir series was the most common PV series and thus was an important series for elk across the southern portion of our region (26 percent of the entire study region) (fig. 2.1). It was located at elevations (460 to 1920 m) between the Douglas-fir and spruce-fir series and was bounded by the western redcedar and western hemlock series at similar elevations on wetter sites. Cooper et al. (1991) noted that it is the most floristically diverse series in the region, with undergrowth species from all adjacent series well represented. Seral tree species primarily included *Pinus ponderosa*, *Larix occidentalis*, *P. contorta*, and *Pseudotsuga menziesii* (figs. 3.10 through 3.12).

Figure 3.10—Early-seral grand fir series ~12 years old, ~28 km northeast of Riggins, Idaho. The emerging overstory in this logged stand was dominated by *Larix occidentalis*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 676 kg/ha and primarily included *Ribes viscosissimum*, *Achillea millefolium*, and *Fragaria vesca*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.11—Mid-seral grand fir series ~56 years old, ~15 km southwest of Winchester, Idaho. This stand's overstory was dominated by *Abies grandis*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 141 kg/ha and primarily included *Vaccinium membranaceum, Symphoricarpos albus*, and *Frasera fastigiata*. At 141 kg/ha of accepted forage biomass, this site would probably support forage intake rates too low to satisfy daily forage needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.12—Late-seral grand fir series ~150 years old, ~15 km northeast of Orofino, Idaho. Overstory plant species consisted of *Pseudotsuga menziesii* and *Abies grandis*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 135 kg/ha and primarily included *Symphoricarpos albus* and *Smilacina stellata*. At 135 kg/ha of accepted forage biomass, this site would probably support forage intake rates too low to satisfy daily forage needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

Stand age accounted for 15 to 67 percent of the variation in overstory canopy cover, basal area, and tree density in the grand fir series (fig. 3.13). Overstory canopy cover achieved an asymptote of ~75 percent by 50 to 60 years of age, basal area increased rapidly until ~75 years of age and then slowed as the stand aged, and tree density peaked at 40 to 50 years of age and declined thereafter (fig. 3.13). Overall, rate of establishment and asymptotic overstory canopy cover tended to be slower and lower than in the western redcedar and western hemlock series but more rapid and higher than in the drier Douglas-fir and colder spruce-fir series (Monzingo et al. 2023).

Forage resources—

Prominent neutral and selected (i.e., accepted) graminoid species in the grand fir series (table 3.3) included *Phleum pratense* and *Elymus* spp.; accepted forbs and ferns included *Fragaria vesca*, *Pteridium aquilinum* (see footnote a regarding this species in table 3.3), and *Achillea millefolium*; and accepted shrubs included *Symphoricarpos albus*, *Physocarpus malvaceus*, *Vaccinium membranaceum*, *Rubus parviflorus*, and *Holodiscus discolor.* Avoided species that were well represented included *Xerophyllum tenax*, *Calamagrostis rubescens*, *Thermopsis montana*, and *Carex* spp. (table 3.3; app. 3). By far, the most common species in this series was the avoided *X. tenax*, with four times the biomass as the second most common (but accepted) species, *S. albus* (table 3.3).

Total undergrowth biomass peaked at ~1200 kg/ha by 25 years after stand-replacing disturbance and declined significantly thereafter. Avoided biomass

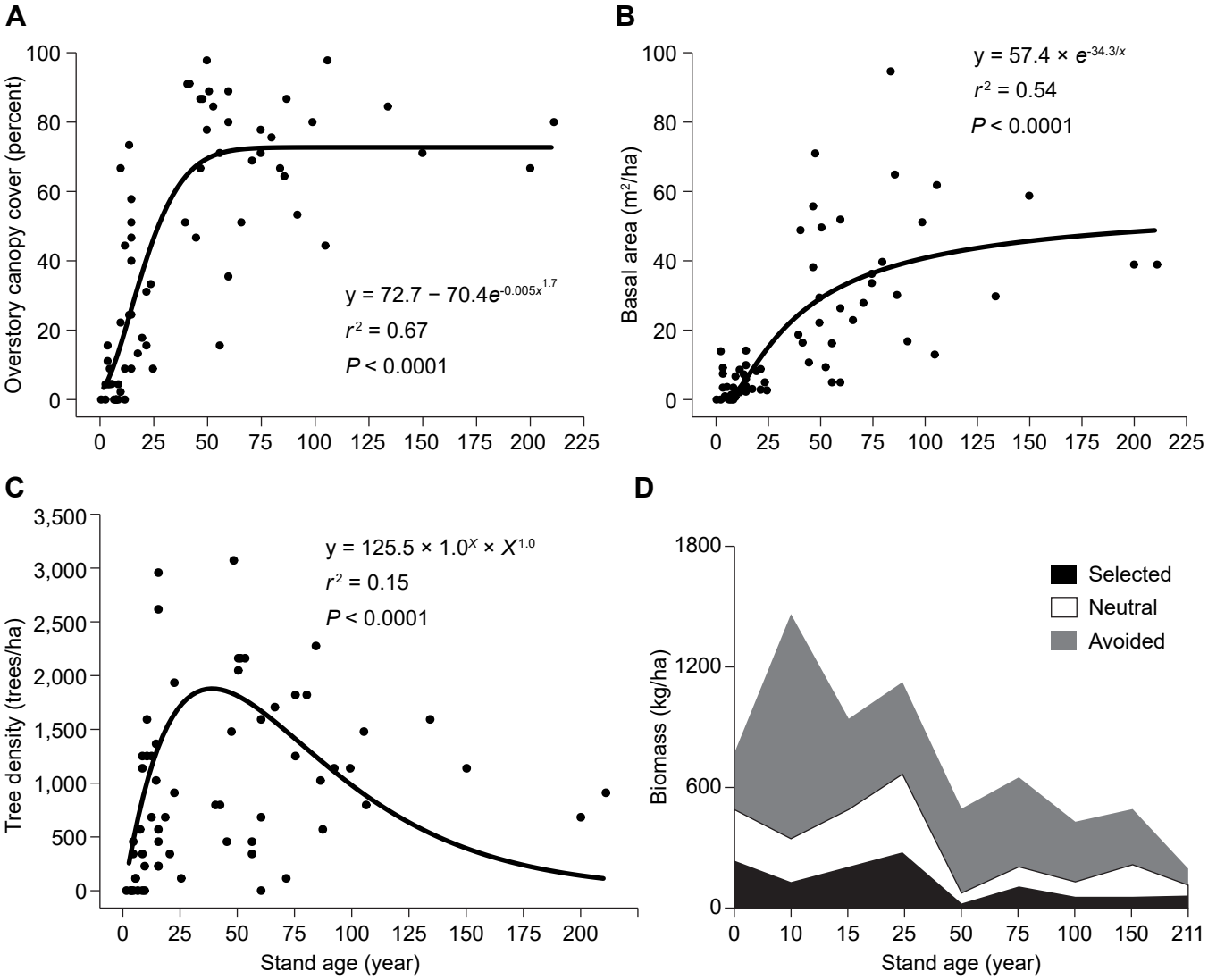

Figure 3.13—Relationships in the grand fir series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

composed 40 to 60 percent of total biomass, substantially greater proportions than in the Douglas-fir series (fig. 3.13). Correlations of accepted biomass with overstory canopy cover and basal area were moderate (fig. 3.14) but stronger than in the Douglas-fir series, likely reflecting the greater level of overstory canopy cover, and concomitant suppressing effects on undergrowth development, in older stands. Accepted and selected biomass averaged ~400 and 180 kg/ha, respectively, in early-seral communities, roughly three times greater than in mid- and late-seral stands (fig. 3.15). However, biomass of accepted species in early-seral communities was highly variable, ranging from 100 to 850 kg/ha. Cooper et al. (1991) indicated that early-seral communities in the grand fir series can be variable depending on seed source, type of disturbance, and site potential. Drier extents or cold pockets may

Table 3.3—Biomass of the 15 most abundant plant species in the grand fir potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Xerophyllum tenax	Forb	Avoided	191.1 ± 66.8
Symphoricarpos albus	Deciduous shrub	Selected	47.1 ± 9.5
Physocarpus malvaceus	Deciduous shrub	Neutral	33.6 ± 10.0
Calamagrostis rubescens	Graminoid	Avoided	21.4 ± 8.1
Vaccinium membranaceum	Deciduous shrub	Neutral	21.0 ± 4.9
Thermopsis montana	Forb	Avoided	17.6 ± 7.4
Carex spp.	Graminoid	Avoided	16.7 ± 5.7
Cirsium spp.[a]	Forb	Avoided	14.9 ± 14.5
Fragaria vesca	Forb	Neutral	14.7 ± 4.0
Pteridium aquilinum[b]	Fern	Neutral	11.6 ± 9.5
Rubus parviflorus	Deciduous shrub	Selected	10.7 ± 4.5
Phleum pratense	Graminoid	Neutral	10.4 ± 8.6
Achillea millefolium	Forb	Neutral	9.0 ± 4.5
Elymus spp.	Graminoid	Neutral	8.1 ± 4.8
Holodiscus discolor	Deciduous shrub	Selected	8.1 ± 2.9

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] This includes thistles that are heavily defended by spines in the genera of *Cirsium*, *Carduus*, and *Onopordum*.

[b] We listed *P. aquilinum* as neutral because elk eat this plant in limited amounts, but as it is toxic to livestock (USDA ARS 2022), we assumed that the amount of this species that elk can eat is limited.

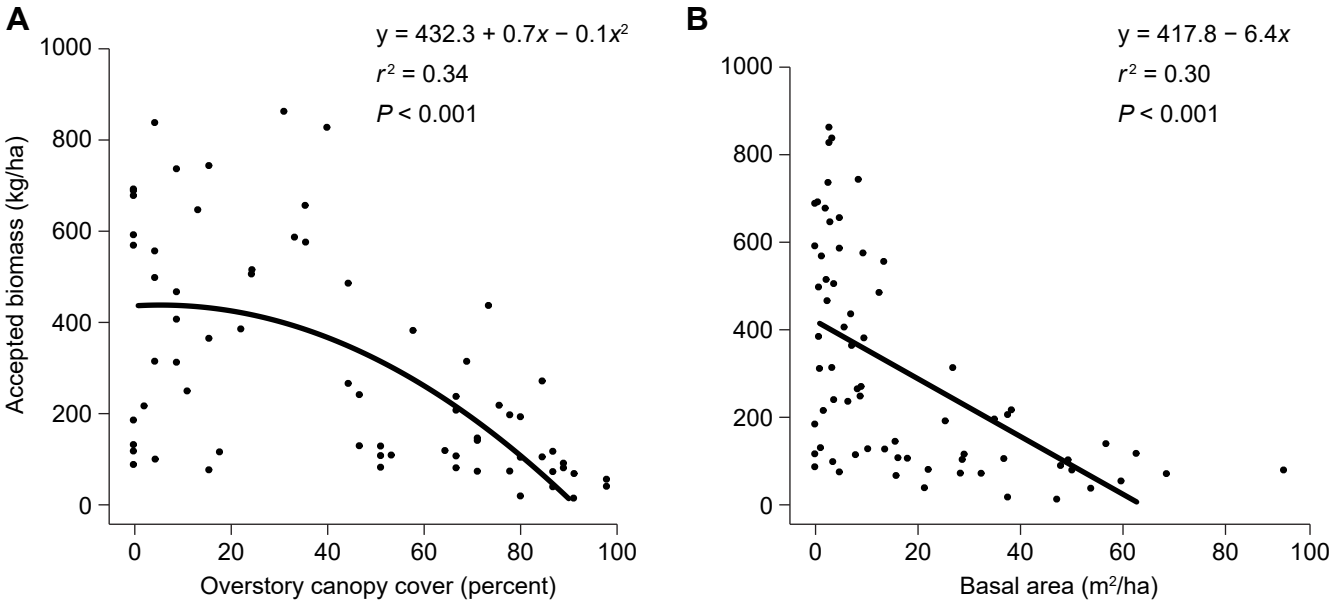

Figure 3.14—Relationships in the grand fir series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

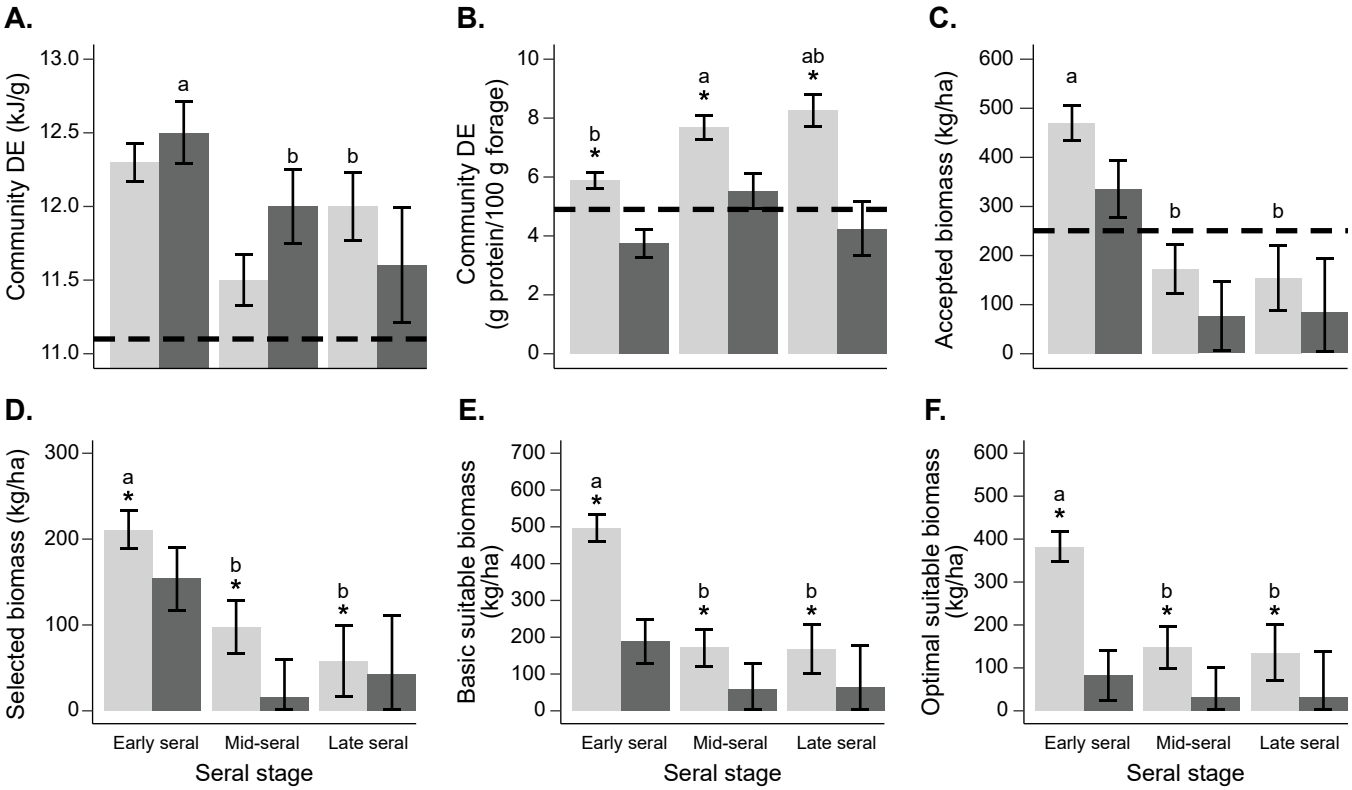

Figure 3.15— Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the grand fir series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, and late = >81 years) and season (light gray = May 31–August 10, dark gray = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within seral stage, different letters denote significant differences among seral stages, and dashed lines denote requirements for lactating elk in summer.

support poor forage across all seral stages. Localized, heavy foraging by wild and domestic ungulates also may have contributed to variation in accepted biomass in early-seral communities (Cook et al. 2014). In mid- and late-seral stages, accepted biomass averaged 175 and 75 kg/ha during early and late summer–early autumn, respectively. These forage levels in mid- and late-seral stages were indicative of plant communities in which elk are unable to eat rapidly enough to satisfy daily dry matter intake and nutrient requirements.

Overall forage quality levels were similar to those in the other PV series but lower than those in the spruce-fir moist series (Monzingo et al. 2023). Community DE declined significantly with advancing succession but averaged modestly higher than basic requirements even in late-seral stands during the late summer-autumn period (fig. 3.15). In eastern Oregon grand fir series, foraging studies showed captive elk acquired dietary DE levels through most of July that satisfied requirements, but on average, failed to do so during late summer and early autumn (Cook et al. 2014). Community DP averaged above requirement during early summer in all seral stages but tended to average lower than requirement

in all seral stages during late summer (fig. 3.15). Biomass of basic and optimal suitable vegetation averaged about 500 and 475 kg/ha, respectively, in early-seral communities during early summer but averaged <200 kg/ha in all other seral stages and seasonal periods, indicating a sharp decline in nutritional value of mid- and late-seral stands to elk in late summer (fig. 3.15).

Management considerations—
In contrast with the Douglas-fir series, most mid- and late-seral stands in the grand fir series provide poor foraging habitat for lactating elk in summer. However, early-seral stands resulting from stand-replacing disturbance in the grand fir series normally should provide good nutritional benefits to elk through late summer and autumn. Increasing the extent of early-seral communities would help meet elk nutrition objectives in the grand fir series, particularly in southern areas of our study region where it may represent the most common, nutritionally productive PV series.

In the context of conifer regeneration after stand-replacing disturbance, Cooper et al. (1991) noted that some sites in the grand fir series may produce swards of *Rudbeckia occidentalis*, *Pteridium aquilinum,* or *Calamagrostis rubescens* that greatly hinder reforestation, all of which are of poor value to elk in summer. We listed *P. aquilinum* as neutral (table 3.3) because elk do eat this plant in limited amounts, but it is toxic to livestock (USDA ARS 2022), and we assumed that the amount elk can eat of this species is limited. Thus, these early-seral communities may sometimes provide relatively low-value forage to elk in summer. In addition, of our 70 macroplots in the grand fir series, 16 supported biomass levels ≥200 kg/ha (up to 1500 kg/ha) of *Xerophyllum tenax*, a strongly avoided forb (although flower stalks may be well eaten in early summer before they desiccate later in summer). Cooper et al. (1991) identified two phases of the *Abies grandis-X. tenax* plant association group that they indicated occupied sites similar to the cool, dry sites where the spruce-fir dry series occurs. Considering how poorly forage resources respond to disturbance in the spruce-fir dry series (described below), we caution that stand-replacing disturbance in the grand fir series may provide relatively small nutritional benefit if implemented where *X. tenax* dominates, usually on drier, coarse-textured soils in areas where cold air accumulates (Cooper et al. 1991). Hence, some early-seral communities in the grand fir series may be of marginal value to elk if located on sites that support vegetation strongly dominated by these low-value or avoided species (i.e., *R. occidentalis*, *P. aquilinum*, *C. rubescens, X. tenax*, *Thermopsis montana*). Our data are inadequate to predict where these plant communities are likely to occur. Ground surveys after treatments to monitor general vegetation responses to disturbance may be useful to determine if and where these concerns are valid. Additional research may be needed to clarify the extent of variation in development of forage resources after disturbance among site potentials within the grand fir series.

In eastern Oregon, foraging trials with captive elk in the grand fir series indicated marginally higher levels of dietary DE in stands averaging 10 to 30 percent overstory canopy cover that were created, in many cases, through selective harvests than in stands with virtually no overstory cover or those with greater levels of cover (Cook et al. 2014). This finding suggested that some type of partial harvests that reduce overstory to <40 percent may be sufficient to provide high-quality forage resources. In our study region, however, the strong dominance of shade-tolerant, avoided species, particularly in older stands, suggests disturbance must be sufficient to strongly promote shade-intolerant accepted species in young stands to fully develop forage resources.

Western Redcedar Series

General description—

The western redcedar series was the most common PV series at mid-elevations (455 to 1675 m) in the central portions of our study region (23 percent of the study region) (fig. 2.1). This series existed in a restricted range of environmental conditions—wetter than the grand fir series, warmer than the spruce-fir series, and *Thuja plicata* was more tolerant of drought, excessive soil moisture, and cold compared to *Tsuga heterophylla*. *T. heterophylla* often occurred with *T. plicata* in mixed stands, generally north of the North Fork of the Clearwater River, in the western redcedar series, along with *Pseudotsuga menziesii*, *Abies grandis*, *Pinus monticola*, *Picea engelmannii*, and *Larix occidentalis*. This series occurred across a variety of landforms, including bottomlands with relatively moist soils, and was correlated with the ash cap layer (Cooper et al. 1991) (figs. 3.16 through 3.18).

Figure 3.16—Early-seral western redcedar series ~15 years old, ~22 km northeast of Headquarters, Idaho. This stand was logged, then treated with herbicides, and the regenerating conifer layer was dominated by *Pseudotsuga menziesii* and *Larix occidentalis*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was 543 kg/ha and primarily included *Disporum hookeri* and *Vaccinium membranaceum*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.17—Mid-seral western redcedar series ~80 years old, ~22 km southeast of Glenwood, Idaho, on Highway 12. The overstory in this stand was dominated by *Thuja plicata* and *Abies grandis*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was 145 kg/ha and primarily included *Adiantum aleuticum*, *Gymnocarpium dryopteris*, and *Adenocaulon bicolor*. Accepted forage biomass was probably too low to support lactating elk in summer. The fern in the foreground was *Polystichum munitum*, a highly unpalatable species that can dominate understory vegetation in moist forests in northern Idaho. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.18—Late-seral western redcedar series ~92 years old, ~13 km southeast of Glenwood, Idaho, on Highway 12. This old-forest stand was dominated by *Thuja plicata*. Under a dense overstory layer, biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was just 23 kg/ha and primarily included *Adiantum aleuticum*, *Chimaphila umbellata*, and *Disporum hookeri*. Such stands are unsuitable as foraging habitat for lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

Stand age explained 23 to 88 percent of the variation in overstory canopy cover, basal area, and tree density in the western redcedar series. Overstories achieved an asymptote of 83 percent canopy cover by 30 years of age, basal area increased rapidly until ~75 years of age and then slowed as the stand aged, and tree density increased throughout at least the first 100 years of age (fig. 3.19), showing little evidence of the decline in tree density >50 years of age that was apparent in most of the other PV series. Overstory development after stand-replacing disturbance was among the fastest of the PV series in our study (Monzingo et al. 2023).

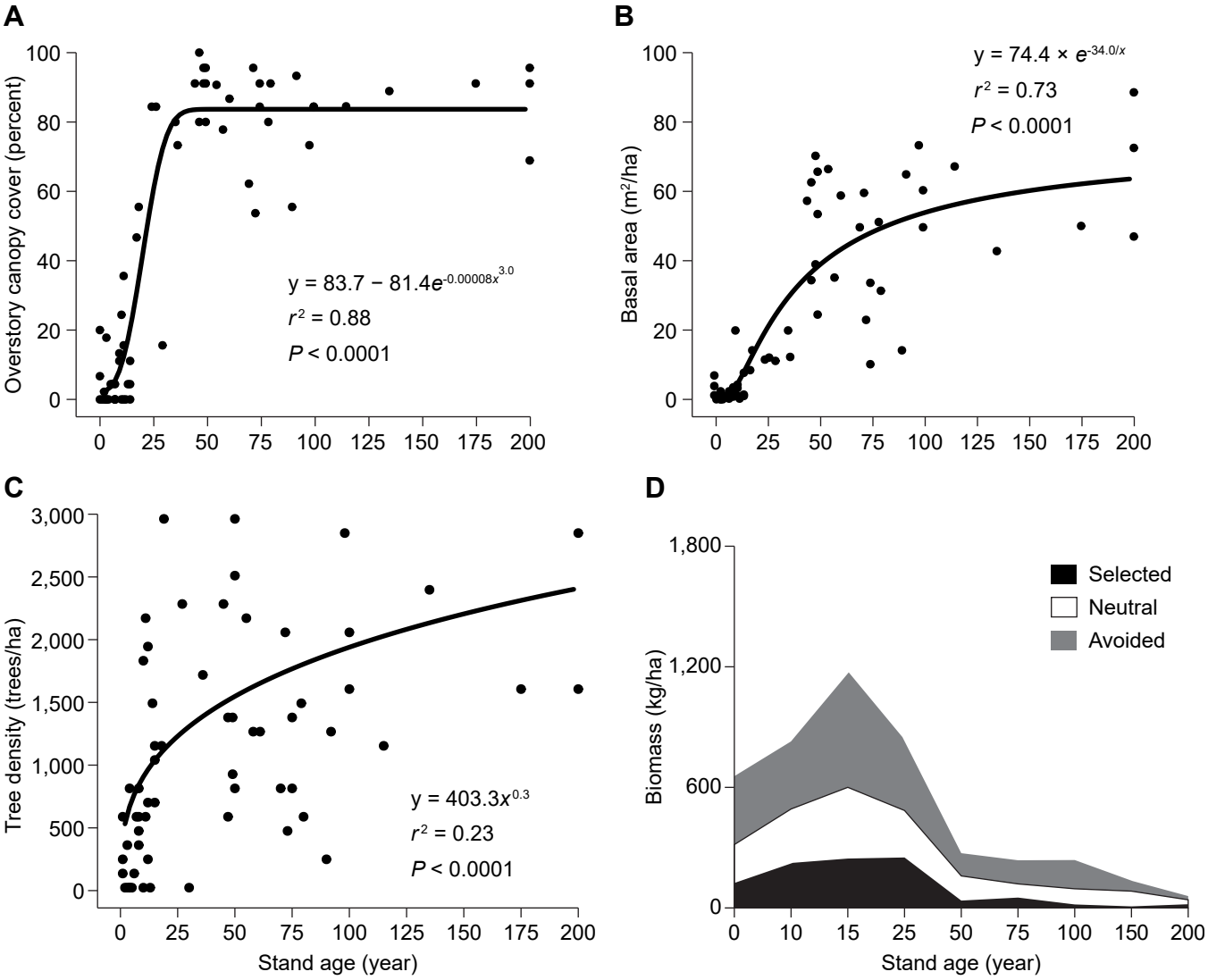

Figure 3.19—Relationships in the western redcedar series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

Forage resources—

Prominent neutral and selected (i.e., accepted) graminoid species (table 3.4) were sparse in the western redcedar series but included *Carex geyeri*, *Bromus vulgaris*, and *Festuca idahoensis*; accepted forbs and ferns included *Pteridium aquilinum* (see footnote a in table 3.4), *Chamerion angustifolium*, *Cirsium* spp., and *Mitella* spp.; and accepted shrubs included *Symphoricarpos albus*, *Rubus parviflorus*, *Ribes viscosissimum*, *Vaccinium membranaceum*, and *Ceanothus sanguineus* (table 3.4; app. 3). Avoided species that were well represented included *Cirsium* spp. (i.e., invasive species with pronounced spines), *Ceanothus velutinus*, *Xerophyllum tenax*, *Polystichum munitum*, *Carex* spp., and annual forbs. Most of the 15 most-abundant plant species were either selected or neutral plant species, including deciduous shrubs (n = 5), forbs (n = 3), and ferns (n = 1) (table 3.4).

Total undergrowth biomass peaked at ~1200 kg/ha by 15 years after disturbance and declined markedly after a stand age of 25 years; avoided biomass composed about half of total biomass across all stand ages (fig. 3.19). Correlations of accepted biomass with overstory canopy cover and basal area were moderate and stronger than they were

Table 3.4—Biomass of the 15 most abundant plant species in the western redcedar potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Pteridium aquilinum[a]	Fern	Neutral	43.8 ± 18.2
Avoided thistles[b]	Forb	Avoided	28.5 ± 21.8
Symphoricarpos albus	Deciduous shrub	Selected	26.2 ± 6.9
Ceanothus velutinus	Evergreen shrub	Avoided	24.4 ± 54.9
Rubus parviflorus	Deciduous shrub	Selected	22.3 ± 7.5
Ribes viscosissimum	Deciduous shrub	Selected	14.9 ± 11.8
Xerophyllum tenax	Forb	Avoided	11.3 ± 21.8
Chamerion angustifolium	Forb	Selected	11.0 ± 4.6
Polystichum munitum	Fern	Avoided	10.9 ± 8.1
Carex spp.	Graminoid	Avoided	9.9 ± 2.8
Annual herbs	Graminoid/forb	Avoided	9.6 ± 3.7
Vaccinium membranaceum	Deciduous shrub	Neutral	9.1 ± 4.6
Cirsium spp.[c]	Forb	Neutral	9.1 ± 12.2
Mitella spp.	Forb	Neutral	7.8 ± 3.7
Ceanothus sanguineus	Deciduous shrub	Neutral	7.5 ± 11.5

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] We listed *P. aquilinum* as neutral because elk eat this plant in limited amounts, but as it is toxic to livestock (USDA ARS 2022), we assumed that the amount elk can eat of this species is limited.

[b] This includes thistles that are heavily defended by spines in the genera of *Cirsium*, *Carduus*, and *Onopordum*.

[c] This includes those species of *Cirsium* that elk consume and excludes those species which elk avoid evidently because of heavy spines.

in the Douglas-fir and grand fir series (fig. 3.20), probably reflecting the greater levels of overstory cover in older stands. Accepted and selected biomass averaged ~425 and 185 kg/ha, respectively, in early-seral communities, roughly four and eight times greater than in mid- and late-seral stands, respectively (fig. 3.21). Biomass of accepted species during early-seral communities was again highly variable, ranging from 80 to ~1100 kg/ha because of variation in seed source, type, time since disturbance, site potential, foraging by herbivores, and other factors (Cooper et al. 1991). Our data indicated that in mid- and late-seral stages, or in stands with >60 percent overstory canopy cover or >30 m^2/ha basal area, accepted biomass levels were generally much too low to support forage intake rates that satisfy daily nutrient requirements.

Overall forage quality levels were similar to those in the grand fir and western hemlock series but lower than those in the spruce-fir moist series (Monzingo et al. 2023). Community DE tended to decline between early and late summer but not significantly. Community DE declined with advancing succession but averaged higher than basic requirements even in late-seral stands during the late summer-autumn period (fig. 3.21). Community DP declined from early to late summer but increased with advancing succession and averaged above nutrient requirements in most season-seral stage combinations (fig. 3.21). Biomass of basic and optimal suitable vegetation averaged about 290 and 190 kg/ha in early-seral communities during early summer but declined markedly to ≤100 kg/ha in all other seral stages and seasonal periods, levels that were among the lowest for mid- and late-seral stages in our study (fig. 3.21).

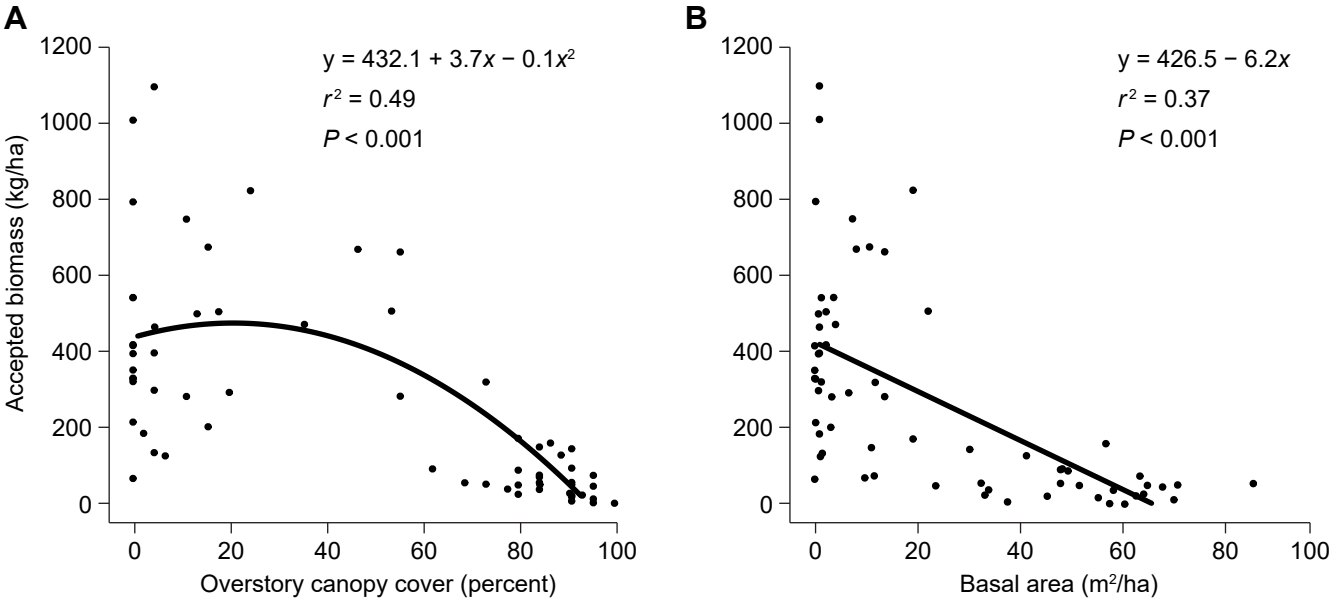

Figure 3.20—Relationships in the western redcedar series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

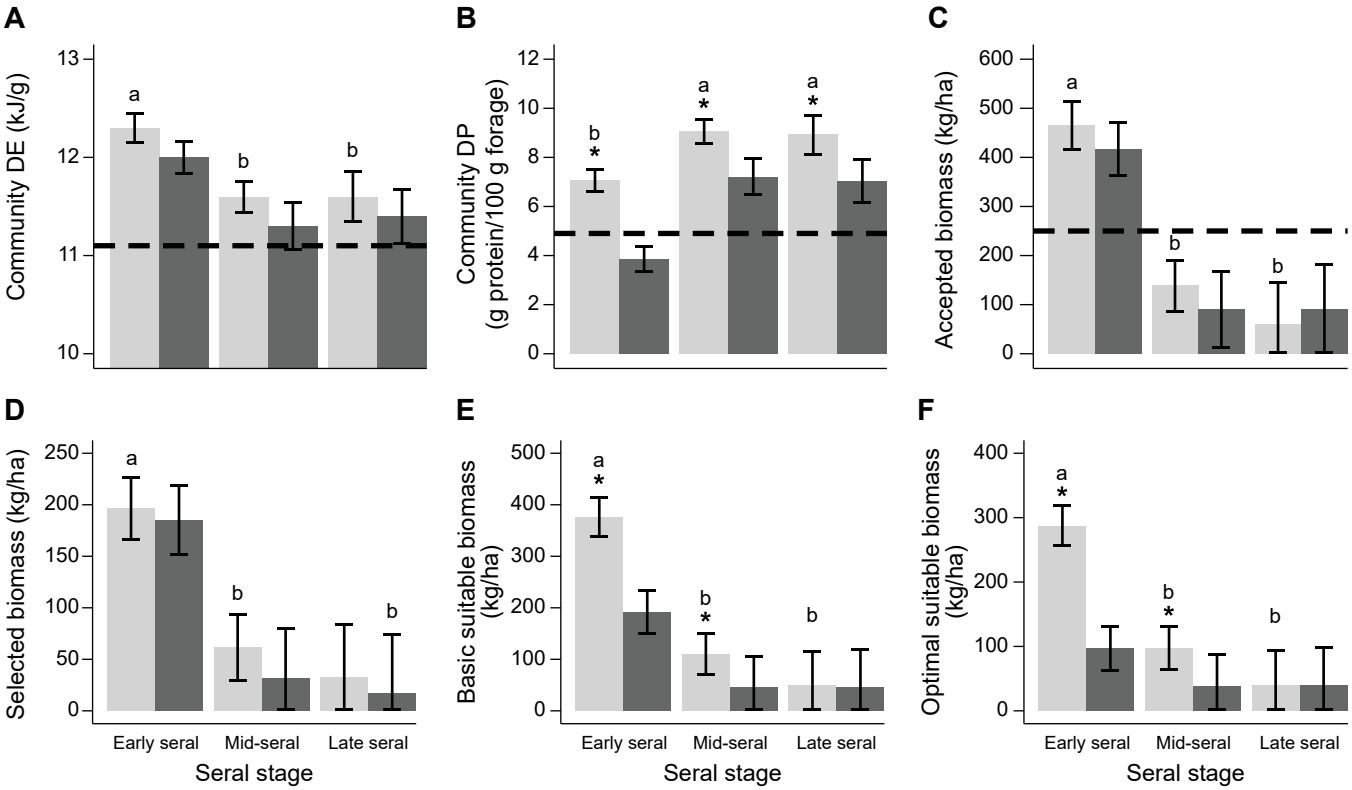

Figure 3.21—Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the western redcedar series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, and late = >81 years) and season (light gray = May 31–August 10, dark gray = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within seral stage, different letters denote significant differences among seral stages, and dashed lines denote requirements for lactating elk in summer.

Management considerations—

As with all PV series at mid-elevations (grand fir, western redcedar, and western hemlock series), our data indicated that stand-replacing disturbance greatly improves forage resources in the western redcedar series, providing some of the best summer nutrition for elk. Most mid- and late-seral stands provide poor foraging habitat for lactating elk in summer. This series has high potential for responding positively to habitat management designed to improve forage resources for elk.

The relatively moist, productive soils of this series supported rapid development of forage resources soon after stand-replacing disturbance but also resulted in rapid development of the overstory, terminating the elevated forage biomass present in early seral stages. Silvicultural strategies that reduce the rate of overstory closure, such as precommercial thinning, or reduce the density of seedling plantings, for example, might extend the persistence of early-seral undergrowth vegetation. After canopies close and forage production wanes, it is unclear the extent to which commercial thinning might be used to enhance forage resources. Forage response to thinning was muted and of minor value in forests of western Oregon and western Washington

(Alaback and Herman 1988, Jenkins and Starkey 1996, Thomas et al. 1999). Cook et al. (2016) reported that commercial thinning increased abundance of undergrowth, but avoided species composed much of the increase. In the cedar-hemlock series of northern Idaho, Mueggler (1965) linked deciduous shrub frequency to overstory tree cover and time since disturbance, and Irwin and Peek (1979) reported that deciduous shrub response was highest in clearcuts followed by seed tree, shelterwood, thinning, and lowest in selective harvests. Our data showed that western redcedar stands with closed canopies predictably rebound to provide nutrition levels at or above the needs of lactating elk after stand-replacing disturbances. This series would be among the highest priorities for silvicultural treatments to restore or maintain early-seral conditions, given its predictably strong response to overstory reduction.

Western Hemlock Series

General description—

The western hemlock series was largely restricted to the St. Joe River basin at mid-elevations (760 to 1680 m) in the northern extent of our study region (4 percent of our study region; 11 percent of the St. Joe River basin) (fig. 2.1). *Tsuga heterophylla* was among the most intolerant conifer species of frost pockets and drought; thus, this series was restricted to relatively moist sites (>75 cm of annual precipitation and 20 cm during the warm season) with moderate temperature regimes and strong influences of maritime climate (Cooper et al. 1991). Common seral tree species included *Thuja plicata*, *Pseudotsuga menziesii*, *Abies grandis*, *Pinus monticola*, *Picea engelmannii*, and *Larix occidentalis*. This series occurred across a variety of landforms with moist soils, excluding bottomlands (figs. 3.22 through 3.24) (Cooper et al. 1991).

Figure 3.22—Early-seral western hemlock series ~7 years old, ~18 km east of Hayden, Idaho. The dominant tree species was *Tsuga heterophylla*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was 620 kg/ha and primarily included *Physocarpus malvaceus*, *Symphoricarpos albus*, and *Mahonia repens*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.23—Mid-seral western hemlock series ~78 years old, ~22 km northwest of Pinehurst, Idaho. With *Tsuga heterophylla* dominating the overstory, biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was 69 kg/ha and primarily included *Mahonia repens*, *Smilacina stellata*, and *Paxistima myrsinites*. This level of forage would probably support forage intake rates too low to satisfy daily forage needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

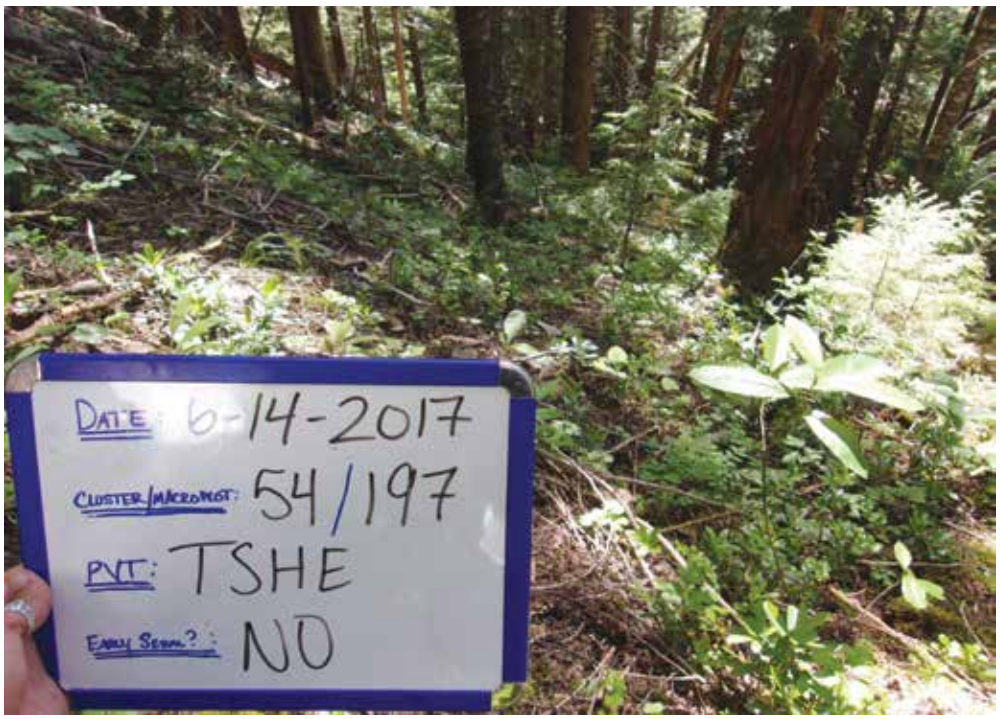

Figure 3.24—Late-seral western hemlock series ~96 years old, ~16 km north of Murray, Idaho. This site had an overstory dominated by *Tsuga heterophylla* and *Thuja plicata*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) on this site averaged 42 kg/ha and primarily included *Chimaphila umbellata* and *Disporum hookeri*. This level of forage would support forage intake rates too low to satisfy daily forage needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

Stand age explained 55 to 94 percent of the variation in overstory canopy cover, basal area, and tree density in the western hemlock series (fig. 3.25), the strongest correlations between stand age and forest development in our study (Monzingo et al. 2023). Overstory canopy cover achieved an asymptote of 84 percent by 30 years of age, basal area increased rapidly until 50 years of age and slowed thereafter, and tree density peaked at ~35 years post disturbance and declined thereafter (fig. 3.25). Overstory development after stand-replacing disturbance was at least as rapid as in the western redcedar series and, on average, the fastest of the PV series in our study (Monzingo et al. 2023).

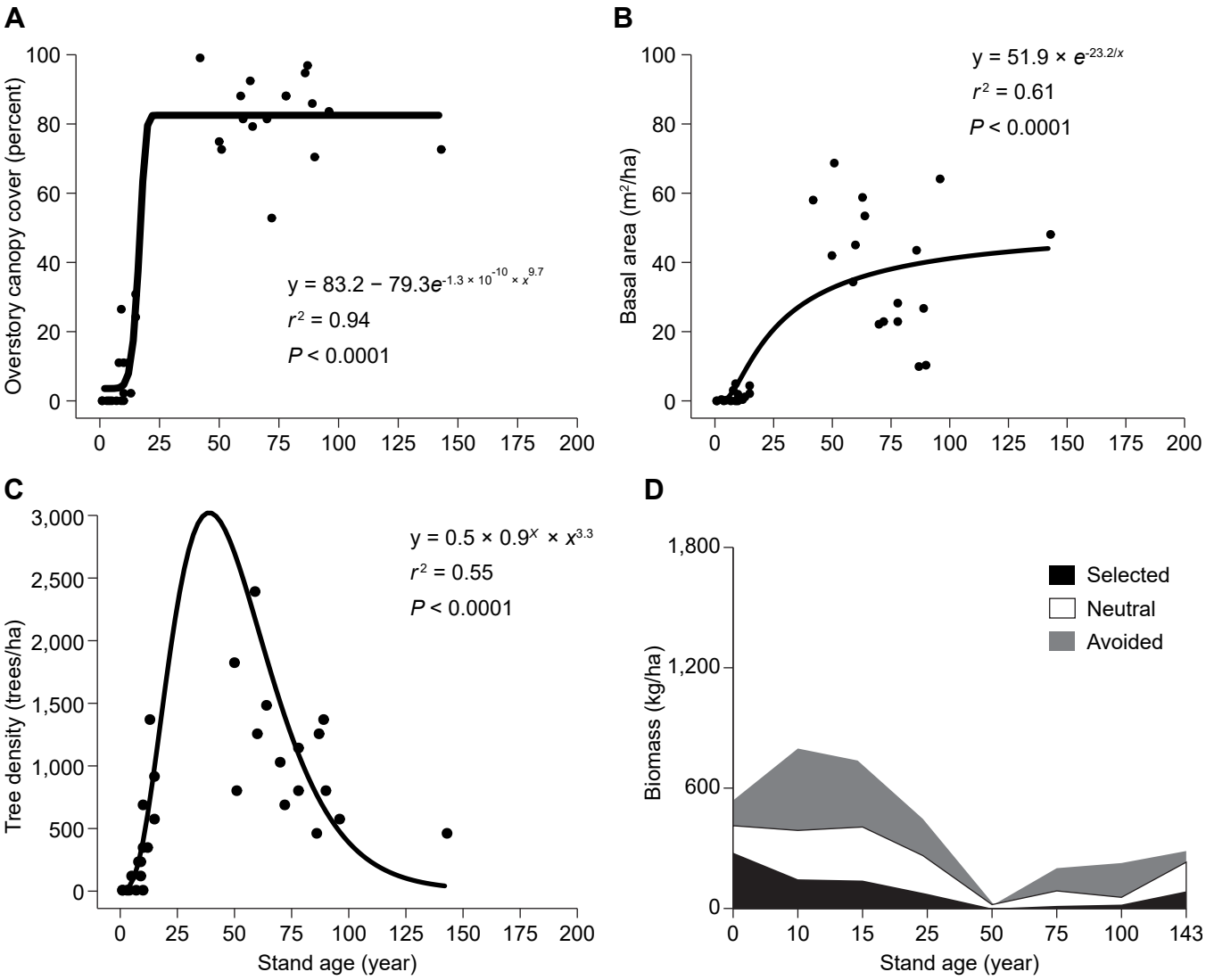

Figure 3.25—Relationships in the western hemlock series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

Forage resources—

Sampling of the western hemlock series was conducted only during a single year (2017), and thus, results were based on a smaller sample size (n = 33) than in the other PV series (n = 46 to 79). Neutral and selected (i.e., accepted) graminoid species (table 3.5) were not prominent in this series but included *Dactylis glomerata*, *Carex geyeri*, and *Bromus vulgaris*. Common accepted forbs and ferns included *Pteridium aquilinum* (see footnote a in table 3.5), and *Chamerion angustifolium*; and accepted shrubs included *Physocarpus malvaceus*, *Symphoricarpos albus*, *Vaccinium membranaceum*, *Mahonia repens*, *Spiraea betulifolia*, *Holodiscus discolor*, and *Amelanchier alnifolia* (table 3.5; app. 3). Avoided species that were well represented included *Xerophyllum tenax*, *Ceanothus velutinus*, *Hypericum perforatum*, *Linnaea borealis*, and *Carex* spp. (table 3.5).

Total undergrowth biomass peaked at ~800 kg/ha at ~10 years after disturbance and declined markedly in stands >15 years old; avoided biomass composed half to two-thirds of total biomass across most stand ages (fig. 3.25). Correlations of accepted biomass with overstory canopy cover and basal area were the highest of

Table 3.5—Biomass of the 15 most abundant plant species in the western hemlock potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Physocarpus malvaceus	Deciduous shrub	Neutral	32.9 ± 20.4
Symphoricarpos albus	Deciduous shrub	Selected	29.6 ± 19.6
Pteridium aquilinum[a]	Fern	Neutral	29.0 ± 23.2
Xerophyllum tenax	Forb	Avoided	22.0 ± 10.8
Vaccinium membranaceum	Deciduous shrub	Neutral	17.1 ± 6.5
Ceanothus velutinus	Evergreen shrub	Avoided	14.3 ± 14.4
Hypericum perforatum	Forb	Avoided	12.8 ± 12.2
Linnaea borealis	Evergreen shrub	Avoided	9.6 ± 5.6
Coptis occidentalis[b]	Forb	Avoided	9.0 ± 2.8
Mahonia repens	Evergreen shrub	Selected	8.6 ± 4.0
Carex spp.	Graminoid	Avoided	8.4 ± 5.1
Chamerion angustifolium	Forb	Selected	8.1 ± 11.1
Spiraea betulifolia	Deciduous shrub	Selected	7.9 ± 2.9
Holodiscus discolor	Deciduous shrub	Selected	7.1 ± 8.6
Amelanchier alnifolia	Deciduous shrub	Selected	6.0 ± 3.1

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] We listed *P. aquilinum* as neutral because elk eat this plant in limited amounts, but as it is toxic to livestock (USDA ARS 2022), we assumed that the amount elk can eat of this species is limited.

[b] *C. occidentalis* was considered to be a neutral species when samples were collected (2016–2017) for laboratory analysis of digestible energy and protein content. However, we had very little data reflecting elk preferences of this species, and we now consider it to be an avoided species given its evergreen growth form, which is typically avoided by elk, and low digestible energy content.

any series in our study (fig. 3.26), again confirming the strong pattern of rapidly increasing canopy cover corresponding to high levels and rapid declines in forage biomass in the wetter PV series at mid-elevations. Accepted and selected biomass averaged ~390 and 170 kg/ha, respectively, in early-seral communities, roughly five and eight times greater than in mid- and late-seral stands, respectively (fig. 3.27). Our data indicated that in mid- and late-seral stages, or in most stands with >50 percent overstory canopy cover or >25 m^2/ha basal area, accepted biomass levels were ≤100 kg/ha and were much too low to support forage intake rates that satisfy daily nutrient requirements of lactating elk in summer.

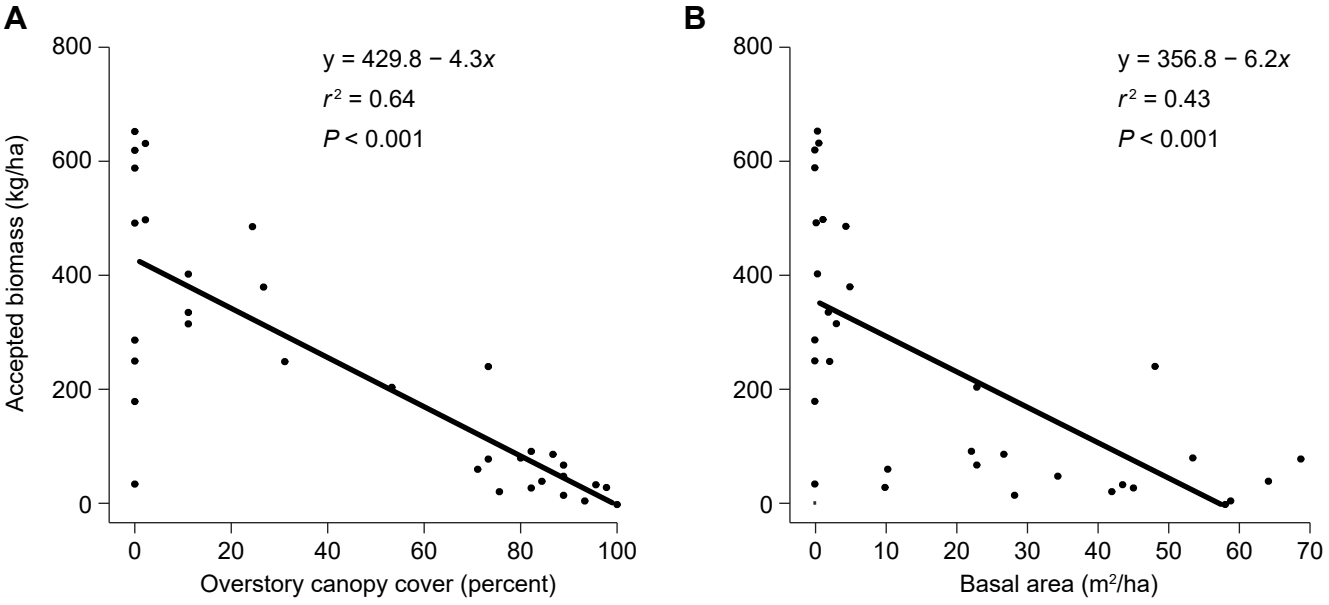

Figure 3.26—Relationships in the western hemlock series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

Forage quality levels averaged modestly lower in certain seral stage-season categories compared to those in the grand fir and western redcedar series and consistently lower than those in the spruce-fir moist series (Monzingo et al. 2023). Similar to other PV series, community DE declined significantly between early-seral versus mid- and late-seral communities. However, community DE levels were unusually low during early summer in mid- and late-seral stages and were lower than during late summer (fig. 3.27), patterns that were anomalous with other PV series. In many mid- and late-seral stands sampled in the western hemlock series, *Coptis occidentalis* was the dominant understory species. It is an evergreen (Hitchcock and Cronquist 1973), a life form that typically has relatively low levels of DE (Cook et al. 2016) and thus should have been considered an avoided plant species and would have been excluded from forage quality analyses. However, it was treated as an accepted species during field sampling and thus composed a

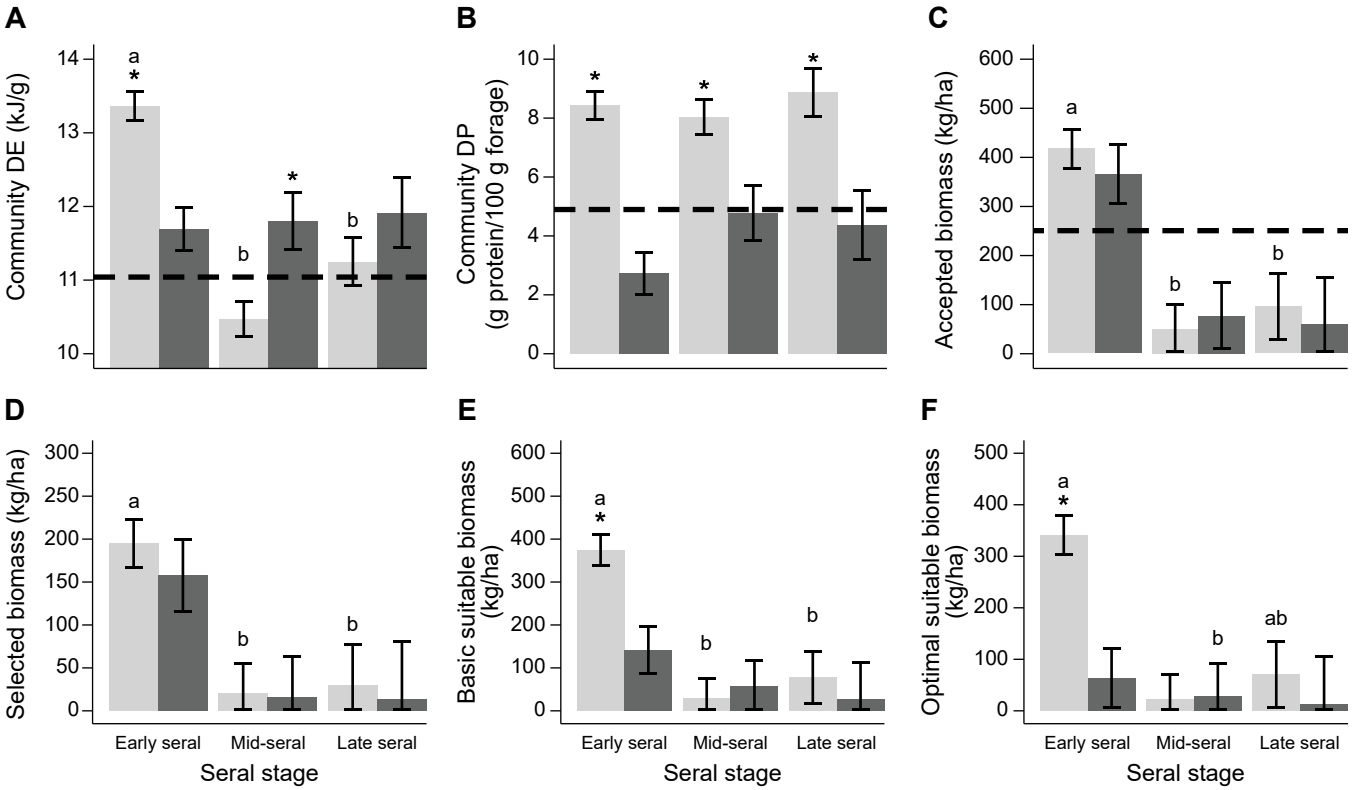

Figure 3.27—Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the western hemlock series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, and late = >81 years) and season (light gray = May 31–August 10, dark gray = 11 August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within a seral stage, different letters denote significant differences among seral stages, and dashed lines denote requirements for lactating elk in summer.

large portion of the forage quality samples collected in mid- and late-seral stages. If *C. occidentalis* had been classified as avoided and thus not collected, we suspect the anomalous pattern regarding community DE would not have emerged. The seasonal-seral stage pattern of community DP was more typical—significant declines occurred between early and late summer, with higher levels in mid- and late-seral stands versus early-seral stands. In late summer, community DP averaged at or below requirement for lactating elk in summer in all seral stages (fig. 3.27). Biomass of basic and optimal suitable vegetation averaged about 275 and 200 kg/ha, respectively, in early-seral communities in early summer but declined markedly to ≤75 kg/ha in all other seral stages and seasonal periods, levels that averaged the lowest for mid- and late-seral stages in our study (fig. 3.27).

Management considerations—

Given the similar ecological setting, management considerations of the western hemlock series are similar to those for the western redcedar series: (1) forage resources in mid- and late-seral stages provided poor foraging habitat for lactating elk in summer; (2) forage production and quality in early-seral communities after stand-replacing disturbances should adequately provide for the nutritional needs of lactating elk during most of summer; and (3) overstory development after disturbance was very rapid, probably the most rapid of any PV series, and it eliminated most forage within ~30 years after disturbance. This series has high potential for responding positively to habitat management designed to maintain forage resources for elk.

Persistence of abundant forage was short after disturbance, and strategies that maintain an adequate creation rate of early-seral communities over relatively long time periods would benefit elk. As in the western redcedar series, some form of even-age regeneration harvest, such as clearcutting, seed-tree, or shelterwood prescriptions, which results in early-seral conditions when applied to mid- and late-seral stands, may achieve ecologically meaningful, positive forage responses.

Spruce-Fir Dry Series

General description—

The spruce-fir dry series occurred at the highest elevations (1495 to 2320 m) and occupied the coldest, most unproductive sites in our study region (figs. 3.28 through 3.30) (Cooper et al. 1991). It occurred in forests dominated by *Abies lasiocarpa* and *Tsuga mertensiana*, in frost pockets often with coarse-textured soils with low water retention or on ridgelines with shallow soils (Cooper et al. 1991). It included sites that Cooper et al. (1991) listed as plant association groups in the *T. mertensiana* and *A. lasiocarpa* series. The *A. lasiocarpa*- and *T. mertensiana-Xerophyllum tenax* and *A. lasiocarpa*- and *T. mertensiana-Menziesia ferruginea* probably best represented the plant association groups from which our data were derived, groups that were generally dominated by *X. tenax*, *Vaccinium scoparium*, *V. membranaceum,* and *M. ferruginea* (Cooper et al. 1991). The tree layer was usually dominated by *T. mertensiana* and *A. lasiocarpa*, with associated seral tree species such as *Picea engelmannii*, *Pinus contorta*, and *P. albicaulis* (Cooper et al. 1991). The spruce-fir dry series was common mainly in the eastern and south-central backcountry areas of our study region, where it composed 20 to 30 percent of the land area (12 percent of our study region) (fig. 2.1).

Figure 3.28—Early-seral spruce-fir dry series ~6 years old, ~10 km east of Red River Hot Springs, Idaho. The regenerating conifer component in this burned stand was dominated by *Abies lasiocarpa* and *Pinus contorta*. Although this stand was early seral, accepted plant species (those species that elk consume in equal proportion to available or in greater proportion than available) were largely absent (80 kg/ha), and its value as foraging habitat to lactating elk in summer was low, given the relatively high abundance of *Xerophyllum tenax* and other avoided species. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.29—Mid-seral spruce-fir dry series ~50 years old, ~35 km southwest of Quartz, Montana. The relatively open overstory canopy (dominated by *Pinus contorta*) in this stand supported a moderately productive undergrowth layer with a total biomass of ~900 kg/ha but with only 160 kg/ha of accepted biomass (those species that elk consume in equal proportion to available or in greater proportion than available), primarily *Vaccinium membranaceum* and *Chimaphila umbellata*. Thus, this stand may fail to support forage intake levels that would satisfy daily nutritional needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.30—Late-seral spruce-fir dry series ~66 years old, ~10 km east of Red River Hot Springs, Idaho. With a relatively open canopy dominated by *Abies lasiocarpa,* the stand supported more than 1000 kg/ha of total biomass of which only 9 kg/ha was accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available). Thus, this stand probably would fail to support forage intake levels that would satisfy daily nutritional needs of lactating elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

Stand age explained 29 to 72 percent of the variation in overstory canopy cover, basal area, and tree density in spruce-fir dry series (fig. 3.31) (Monzingo et al. 2023). Overstory canopy cover achieved an asymptote of only 41 percent by 45 years of age, basal area increased rapidly the first ~30 years after disturbance but slowed thereafter, and tree density peaked at about 80 years post disturbance and also declined thereafter (fig. 3.31). Overstory development after stand-replacing disturbance was among the slowest and lowest of the PV series in our study (Monzingo et al. 2023).

Forage resources—

Prominent neutral and selected (i.e., accepted) graminoid species in the spruce-fir dry series (table 3.6) included *Carex geyeri*; accepted forbs and ferns included *Chamerion angustifolium* and *Pteridium aquilinum* (see footnote a in table 3.6 regarding *P. aquilinum*); and accepted shrubs included *Vaccinium membranaceum*, *Spiraea betulifolia*, *Chimaphila umbellata*, and *Alnus viridis* (table 3.6; app. 3). Avoided species that were well represented included *Xerophyllum tenax*, *V. scoparium*, *Carex* spp., *Menziesia ferruginea*, *Calamagrostis rubescens*, *Lupinus* spp., *Rhododendron albiflorum*, and *Poa* spp. (table 3.6). The most abundant plant species across the spruce-fir dry series was the avoided species *X. tenax;* its biomass averaged 755.8 ± 57.7 kg/ha, more than all the other species in the series combined (table 3.6).

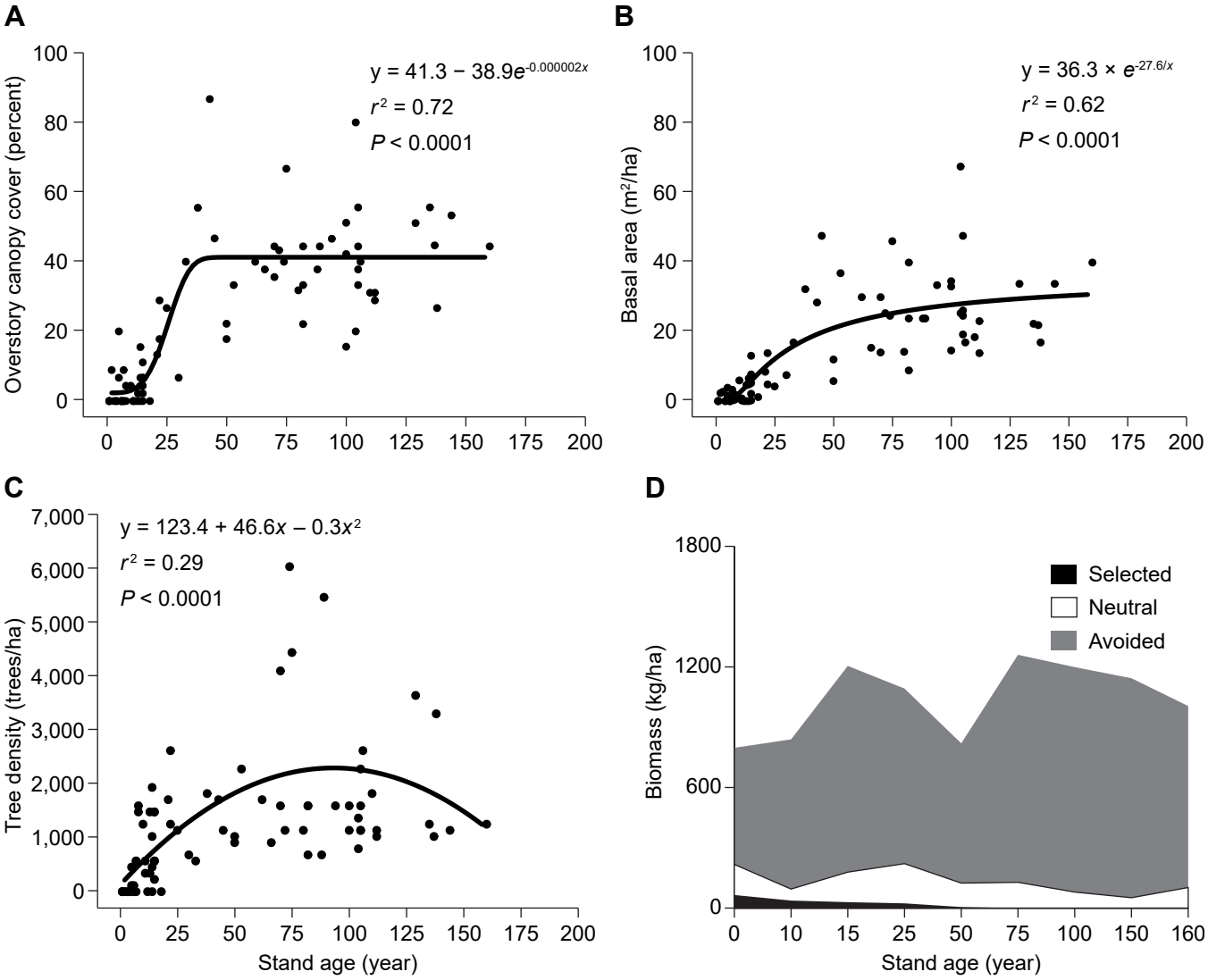

Figure 3.31—Relationships in the spruce-fir dry series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

Total undergrowth biomass averaged between 900 and 1200 kg/ha and exhibited no significant relationship with stand age as stands developed (Monzingo et al. 2023) (fig. 3.31). To a greater extent than in any other PV series, avoided biomass dominated, averaging nearly 10 times more abundant than accepted biomass (fig. 3.31). Only weak trends in accepted and selected biomass with stand age existed (fig. 3.31), as did significant, although modest, trends between accepted biomass and overstory canopy cover and basal area (fig. 3.32). Relationships between accepted biomass and overstory development were similar to those in the Douglas-fir and spruce-fir moist series, evidently because of the slow rate of overstory development after disturbance and sparse overstories in late-seral stages. Nevertheless, the spruce-fir dry series overall supported the lowest levels of selected and accepted species in our sample (Monzingo et al. 2023). Accepted

Table 3.6—Biomass of the 15 most abundant plant species in the spruce-fir dry potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Xerophyllum tenax	Forb	Avoided	755.8 ± 57.7
Vaccinium membranaceum	Deciduous shrub	Neutral	70.8 ± 10.6
Vaccinium scoparium	Deciduous shrub	Avoided	58.3 ± 8.5
Carex spp.	Graminoid	Avoided	30.8 ± 11.0
Carex geyeri	Graminoid	Neutral	20.6 ± 6.8
Chamerion angustifolium	Forb	Selected	17.1 ± 7.3
Menziesia ferruginea	Deciduous shrub	Avoided	12.2 ± 4.5
Calamagrostis rubescens	Graminoid	Avoided	6.5 ± 3.8
Pteridium aquilinum[a]	Fern	Neutral	4.3 ± 14.1
Spiraea betulifolia	Deciduous shrub	Selected	4.0 ± 2.5
Lupinus spp.	Forb	Avoided	4.0 ± 4.8
Rhododendron albiflorum	Deciduous shrub	Avoided	3.9 ± 6.3
Poa spp.	Graminoid	Avoided	3.2 ± 14.3
Chimaphila umbellata	Evergreen shrub	Neutral	3.0 ± 1.3
Alnus viridis	Deciduous shrub	Neutral	2.9 ± 9.7

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] We listed *P. aquilinum* as neutral because elk eat this plant in limited amounts, but as it is toxic to livestock (USDA ARS 2022), we assumed that the amount elk can eat of this species is limited.

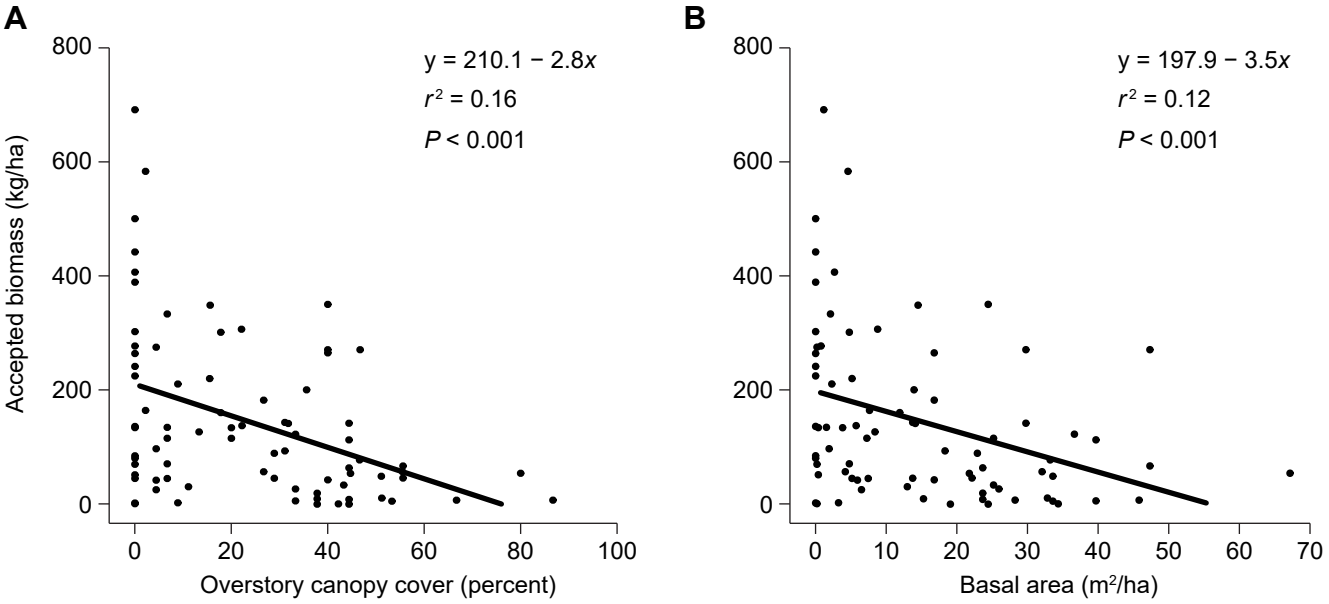

Figure 3.32—Relationships in the spruce-fir dry series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

and selected biomass averaged ~190 and 50 kg/ha, respectively, in early-seral communities, roughly one-half to one-fourth that in the other PV series and averaged ~100 and 8 kg/ha in mid- and late-seral stands, respectively, ranging one-half or less of that in other PV series (fig. 3.33). Even in early-seral stands in early summer, our data indicated that accepted biomass levels were too low to support forage intake rates that satisfy daily nutrient requirements.

In contrast, community DE averaged higher than in any other PV series (Monzingo et al. 2023), exceeding basic and optimal requirements in all seral stage-season combinations (fig. 3.33). Community DE exhibited no significant declines from early to late summer, probably because initiation of forage growth was relatively late compared to most PV series. Levels of community DP, however, were similar to those of other PV series, declining between early and late summer and increasing with stand age (fig. 3.33). Community DP averaged at or below basic requirements in early- and mid-seral stages during late summer. Biomass of basic and optimal suitable vegetation averaged about 175 and 100 kg/ha, respectively, in early-seral communities and <100 kg/ha in all other seral stages and seasonal periods (fig. 3.33).

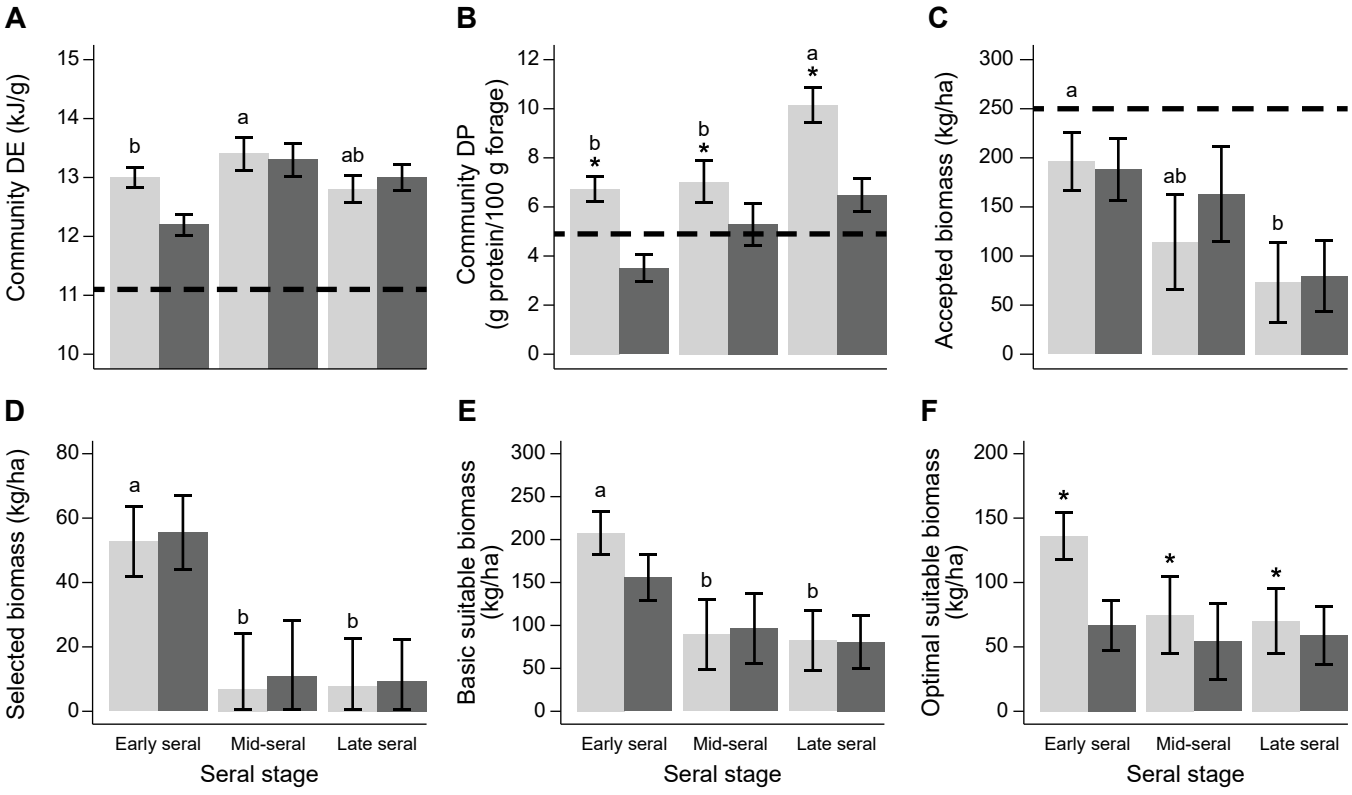

Figure 3.33—Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the spruce-fir dry series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, and late = >81 years) and season (light gray = May 31–August 10, dark gray = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within a seral stage, different letters denote significant differences among seral stages, and dashed lines denote requirements for lactating elk in summer.

Management considerations—

Based primarily on biomass levels of accepted and selected species, our data indicated that forage resources in the spruce-fir dry series were unusually poor for lactating elk during summer in the spruce-fir dry series. Plant communities were strongly dominated by plant species that elk generally rarely eat (except for flowers and berries), predominantly *Xerophyllum tenax* but also *Vaccinium scoparium* and *Menziesia ferruginea*. Despite the high DE and DP levels of forage in this type, the low abundance of accepted species will generally prevent elk from eating rapidly enough to satisfy their daily nutritional requirements, and for this reason, lactating elk and their calves may fare poorly if restricted to this PV series in summer. Accepted biomass did appear to be substantively elevated in a few of the sites that we sampled (fig. 3.32) suggesting some value of stand-replacing disturbance, but our data show that only minor increases in abundance of accepted species can be expected after disturbance. Consequently, we conclude that, on average, use of wildfires or other types of overstory management to improve forage resources in this series will produce comparatively little benefit for elk.

Spruce-Fir Moist Series

General description—

The second series at the highest elevations (1495 to 2320 m) that we evaluated was the spruce-fir moist series, which occurred on relatively deep, moist soils, where vegetation was more diverse and productive than in the spruce-fir dry series (Cooper et al. 1991). It included plant association groups that Cooper et al. (1991) listed as in the *Tsuga mertensiana* and *Abies lasiocarpa* series. The *A. lasiocarpa*- and *T. mertensiana-Streptopus amplexifolius* and *A. lasiocarpa*- and *T. mertensiana-Clintonia uniflora* (Cooper et al. 1991) best represent the plant association groups that we sampled in this series (figs. 3.34 through 3.36). The tree layer in the spruce-fir moist series was usually dominated by either *T. mertensiana* or *A. lasiocarpa*, with associated seral tree species such as *Picea engelmannii*, *Abies grandis*, *Pinus contorta*, *P. monticola*, and *Larix occidentalis* (Cooper et al. 1991). The spruce-fir moist series was common mainly in the eastern backcountry areas, primarily north of the Selway River, where it composed 20 to 30 percent of the land area and 11 percent of our entire study region (fig. 2.1).

Figure 3.34—Early-seral spruce-fir moist series ~15 years old, ~31 km north of Weir Hot Springs, Idaho, on Highway 12. *Larix occidentalis* and *Abies lasiocarpa* dominated the regenerating conifer layer in this logged stand. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) was 285 kg/ha and primarily included *Vaccinium membranaceum*, *Lonicera utahensis*, and *Chamerion angustifolium*. Early-seral communities in the spruce-fir moist series typically supported diverse and productive undergrowth layers and was among the highest digestible protein and energy levels of any series in our study, providing for unusually suitable foraging sites for female elk in summer. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.35—Mid-seral spruce-fir moist series ~80 years old, ~2 km east of Elk Summit Road 360, Idaho, off Highway 12. The overstory in this stand was dominated by *Abies lasiocarpa* and *Tsuga mertensiana*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 276 kg/ha and primarily included *Vaccinium membranaceum* and *Acer glabrum*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Figure 3.36—Late-seral spruce-fir moist series ~130 years old, ~30 km northwest of Lochsa Lodge, Idaho, on Highway 12. The overstory in this stand was dominated by *Abies lasiocarpa* and *Tsuga mertensiana*. Biomass of accepted forage (those species that elk consume in equal proportion to available or in greater proportion than available) in this stand was 168 kg/ha and primarily included *Vaccinium membranaceum*, *Arnica latifolia*, and *Chimaphila umbellata*. Information on the whiteboard was used to pair photos with sampled macroplots. Clearwater Basin Collaborative photo.

Overstory development after disturbance—

Stand age explained 1 to 60 percent of the variation in overstory canopy cover, basal area, and tree density in the spruce-fir moist series (fig. 3.37) (Monzingo et al. 2023). Overstory canopy cover achieved an asymptote of 54 percent by 45 years of age, basal area increased rapidly through the first 50 years after disturbance and slowed gradually thereafter, and tree density gradually increased throughout the time period represented in our sample (fig. 3.37). As in the spruce-fir dry series, rate of overstory development after a stand-replacing disturbance was among the slowest of all series, although overstory canopy closure in older stands was intermediate to that in other series (Monzingo et al. 2023).

Forage resources—

Prominent neutral and selected (i.e., accepted) graminoid species (table 3.7) included *Carex geyeri*; accepted forbs and ferns included *Chamerion angustifolium*, *Pteridium aquilinum*, *Arnica latifolia*, and *A. cordifolia*; and accepted shrubs included *Vaccinium membranaceum*, *Lonicera utahensis*, and *Alnus* spp. (table 3.7; app. 3). Avoided species that were well represented included *Xerophyllum tenax*, *Menziesia ferruginea*, *V. scoparium*, *Carex* spp., *Linnaea borealis*, *Thermopsis montana*, and *Rhododendron albiflorum* (table 3.7). *X. tenax* represented a dominant portion of the biomass, averaging 392.1 ± 67.4 kg/ha (table 3.7).

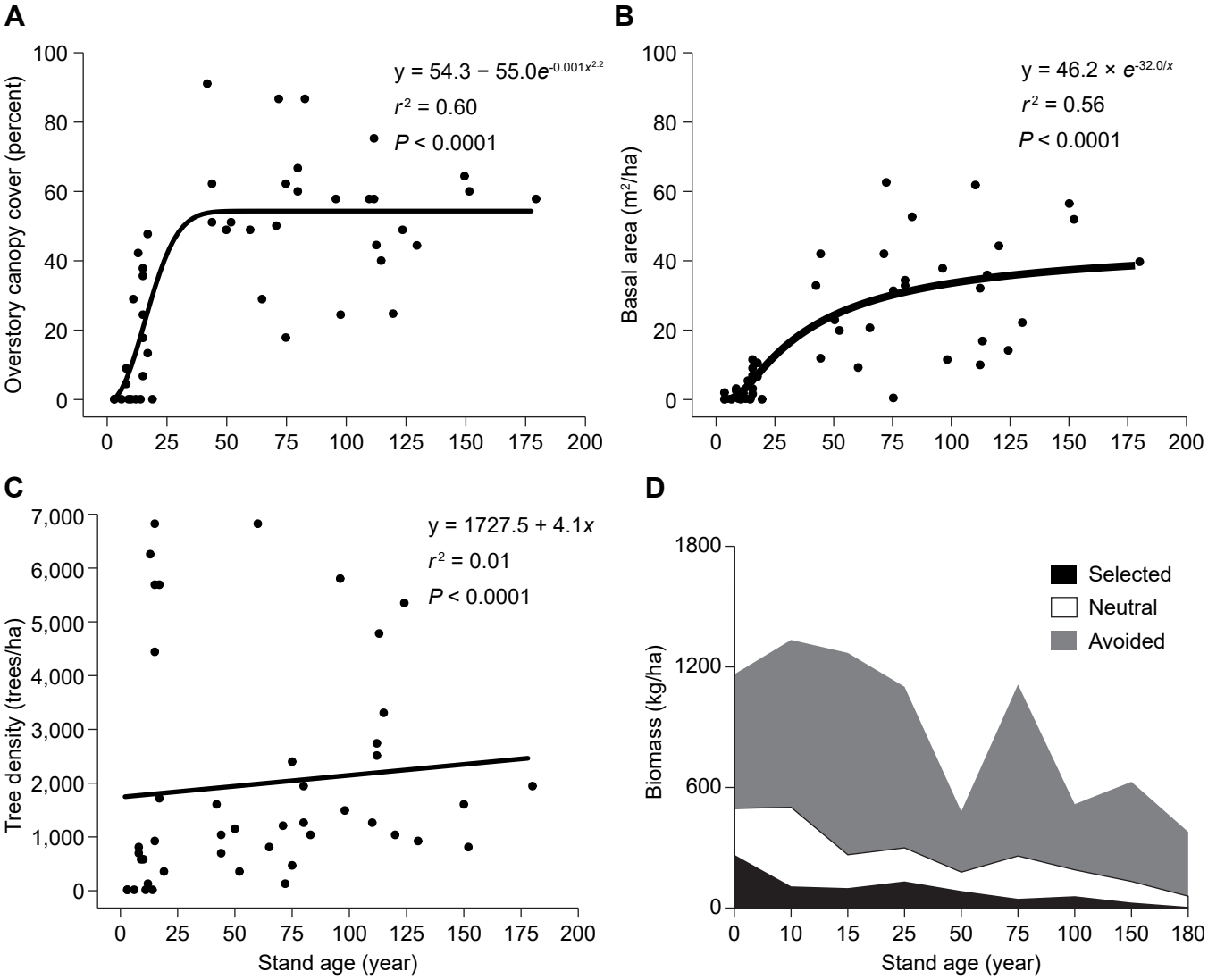

Figure 3.37—Relationships in the spruce-fir moist series between stand age and (A) overstory canopy cover; (B) basal area; (C) tree density; and (D) biomass of selected, neutral, and avoided undergrowth plants (excluding conifer biomass) calculated using 5-year moving averages (where selected species are those consumed in greater proportion than available, neutral species are those consumed in equal proportion to available, and avoided species are those consumed in lower proportion than available). Data were collected in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017.

Total undergrowth biomass peaked at ~1200 kg/ha at ~5 to 10 years after disturbance and gradually declined thereafter. Avoided biomass dominated the undergrowth layer, averaging two to three times more abundant than accepted biomass across all stand ages (fig. 3.37). Accepted biomass levels declined as stand age increased (fig. 3.37) and as overstory canopy cover and basal area increased (fig. 3.38). But unlike in most other PV series, declines in accepted and selected biomass were not significant between early- and mid-seral stages, only between early- and late-seral stages (fig. 3.39). Accepted and selected biomass averaged ~350 and 110 kg/ha, respectively, in early-seral communities and averaged ~160 and 40 kg/ha in mid- and late-seral stands, respectively (fig. 3.39). As in the spruce-fir dry series, we found no consistent differences between accepted and selected forage biomass between early and late summer. Our data indicated that

Table 3.7—Biomass of the 15 most abundant plant species in the spruce-fir moist potential vegetation series during field sampling in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017

Scientific name	Life form group	Elk selection	Mean biomass ± standard error
			Kilograms/hectare
Xerophyllum tenax	Forb	Avoided	392.1 ± 67.4
Vaccinium membranaceum	Deciduous shrub	Neutral	79.6 ± 12.9
Menziesia ferruginea	Deciduous shrub	Avoided	35.8 ± 5.9
Chamerion angustifolium	Forb	Selected	29.5 ± 14.0
Pteridium aquilinum[a]	Fern	Neutral	16.7 ± 49.9
Vaccinium scoparium	Deciduous shrub	Avoided	9.9 ± 4.3
Lonicera utahensis	Deciduous shrub	Selected	8.7 ± 2.6
Alnus spp.	Deciduous shrub	Neutral	8.2 ± 5.2
Carex geyeri	Graminoid	Neutral	8.1 ± 9.9
Carex spp.	Graminoid	Avoided	7.4 ± 3.7
Arnica latifolia	Forb	Neutral	7.4 ± 2.4
Linnaea borealis	Evergreen shrub	Avoided	6.6 ± 7.3
Thermopsis montana	Forb	Avoided	6.6 ± 15.9
Arnica cordifolia	Forb	Selected	6.1 ± 4.8
Rhododendron albiflorum	Deciduous shrub	Avoided	6.0 ± 8.5

Note: Taxa categories: selected (use > availability), neutral (use = availability), avoided (use < availability). Taxa categories are based on data collected from tractable elk in western Oregon and Washington and eastern Oregon (Cook et al. 2014, 2016).

[a] We listed *P. aquilinum* as neutral because elk eat this plant in limited amounts, but as it is toxic to livestock (USDA ARS 2022), we assumed that the amount elk can eat of this species is limited.

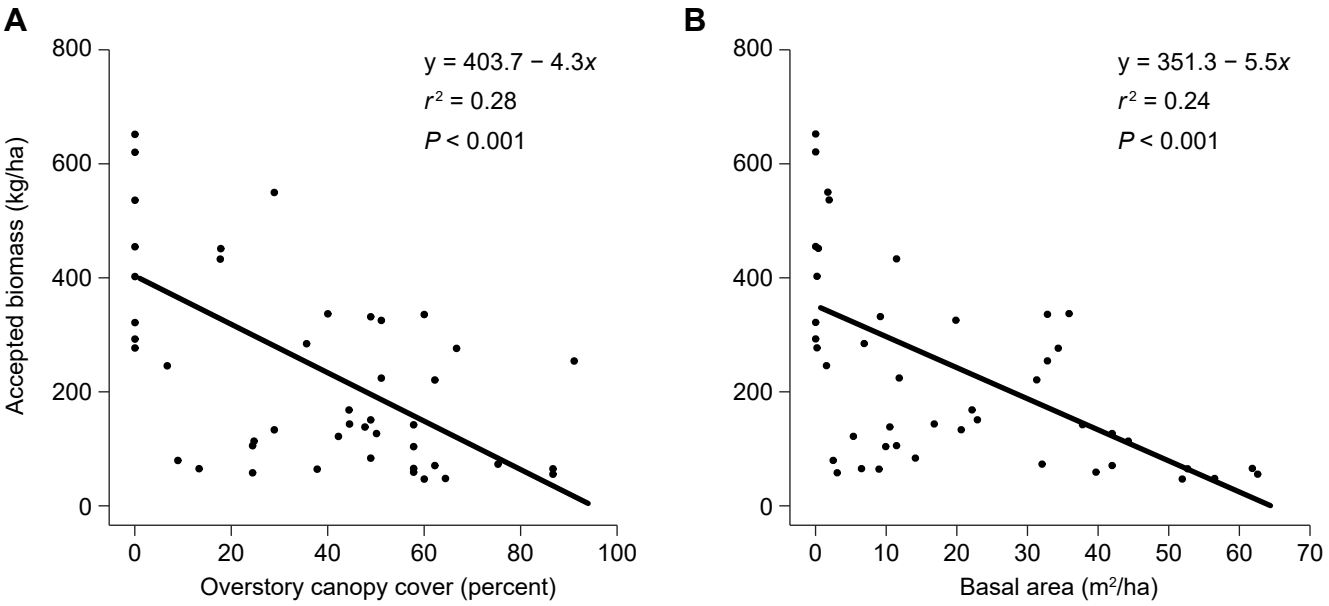

Figure 3.38—Relationships in the spruce-fir moist series between accepted forage biomass and (A) overstory canopy cover and (B) basal area sampled in the Clearwater and St. Joe River basins, Idaho, in summer, 2016 and 2017. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid.

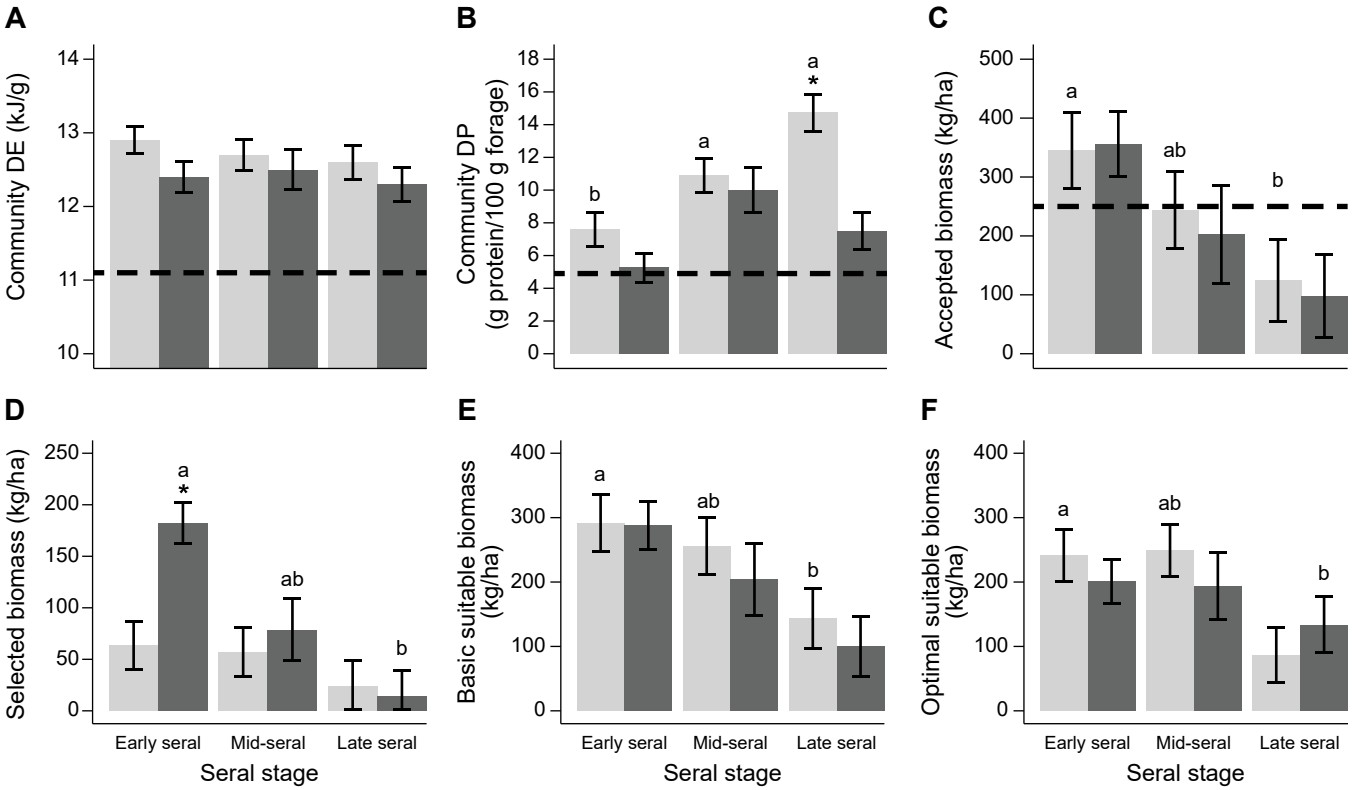

Figure 3.39— Estimates of six forage resource metric least-square means (± 1 standard error) for elk in the spruce-fir moist series among seral stages (early = 0 to 25 years, mid = 26 to 80 years, and late = >81 years) and season (light gray = May 31–August 10, dark gray = August 11–October 4) in the Clearwater and St. Joe River basins, Idaho, 2016 and 2017. Metrics include (A and B) community-wide averages for digestible energy and protein (DE and DP) calculated for the high-quality portions (e.g., foliage excluding stems) of accepted plant species; (C and D) biomass of accepted and selected plant species; and (E and F) biomass of suitable species, i.e., biomass of those accepted species that satisfy basic and optimal nutritional requirements for lactating female elk in summer. Selected forage species are those that elk consume in greater proportion than available. Accepted forage species are those that elk consume in equal proportion to available or in greater proportion than available and exclude plant species that elk avoid. Asterisks denote significant differences between season within a seral stage, different letters denote significant differences among seral stages, and dashed lines indicate requirements for lactating elk in summer.

accepted biomass levels were sufficient to satisfy requirements in early-seral stands, were marginal in mid-seral stands but were too low to satisfy requirements in late-seral stands.

Community DE averaged among the highest of any PV series (Monzingo et al. 2023) and exhibited no significant declines among seral stages nor between early to late summer. It exceeded basic and optimal requirements in all seral stage-season combinations (fig. 3.39). The lack of declines during summer was probably caused by persistent snow into late spring that delays initiation of forage growth and initiation of senesce in very high elevation series compared to PV series at lower elevations (Monzingo et al. 2023). Community DP also was among the highest of any PV series (Monzingo et al. 2023) and tended to decline from early to late summer and increase as stands aged, although these patterns were variable across seasons and stages (fig. 3.39). Community DP averaged at or above basic requirements in all seral stage-season combinations. Biomass of basic and optimal suitable vegetation averaged about 290 and 220 kg/ha, respectively, in early-seral stands with little indication of declines between early- and mid-seral stages. In late-seral stands, basic and optimal suitable

biomass averaged 120 and 110 kg/ha, respectively (fig. 3.39). Overall, basic and optimal suitable biomass during late summer was greatest of all PV series that we sampled.

Management considerations—
Our data indicated exceptional nutritional value of the spruce-fir moist series for summering elk. Compared to other PV series, it offered among the highest community DE and DP levels with no evidence of meaningful limitations of either forage quality metric on animal performance even in late summer, above-average accepted biomass levels, and the highest basic and optimal suitable biomass levels in late summer. Using captive elk in western Oregon and Washington, Cook et al. (2016) documented significantly higher forage intake rates and DE content in elk diets in early-seral communities in the *Tsuga mertensiana* series, the highest elevation PV series in that study, than in other series at lower elevations. Cook et al. (2013, 2018) reported that wild elk that occupied summer ranges in this PV series had the highest body condition and had among the highest pregnancy rates among 17 elk populations they sampled in the northern half of the Western United States. Finally, the persistence of relatively abundant accepted forage biomass into mid-seral stages suggests that the positive effects of stand-replacing disturbance will persist substantially longer than in most PV series. Consequently, within our study area, this series has high potential for responding positively to habitat management designed to maintain forage resources for elk. Although the spruce-fir moist series is not typically subjected to silvicultural treatments or prescribed burning in our study region, its nutritional response to wildfires, which are common at the elevations at which this series occurs, is likely to be the most positive of any of the PV series. This contrasts with the spruce-fir dry series, which has low nutritional value for elk, regardless of disturbance, and occurs at similar elevations.

Management Implications

In general, our data demonstrated two overall, dominant trends in summer: the tendency for forage quality to increase among series from low to high elevation (dry to moist) and the tendency for forage quantity to decline as forest stands age (tables 3.8 and 3.9). At moderate scales, such as those involving forest stands, our findings have direct implications: removal of much or all the overstory canopy generally improves the forage base for elk and often converts stands that provide virtually no foraging value to stands that can provide high forage quality and quantity that satisfy nutritional needs of elk and their calves. This trend was most apparent in the western hemlock, western redcedar, and spruce-fir moist series and the more productive, wetter extents of the grand fir series. But the magnitude of the effect varied among PV series, such that in some series, removal of the overstory may provide little improvement in the production of palatable species despite relatively high levels of DE and DP because of low accepted biomass (spruce-fir dry series) or, alternatively, may increase forage production but in a setting in which forage quality may only marginally provide for the needs of summering elk (Douglas-fir

Table 3.8—Mean values ± standard errors of forage resource attributes in late spring and early summer (May 31–August 10) by seral stage and seven potential vegetation series in northern Idaho based on field sampling conducted in northern Idaho during, 2017–2018

Forage attribute[a]	Seral stage[b]	Range/ ponderosa pine[c]	Douglas-fir	Grand fir	Western redcedar	Western hemlock	Spruce-fir dry	Spruce-fir moist
Community DE (kJ/g)	E		12.2 ± 0.2	12.3 ± 0.1	12.3 ± 0.1	13.0 ± 0.1	13.0 ± 0.2	12.9 ± 0.3
	M/L	10.9 ± 0.2	12.0 ± 0.2	11.7 ± 0.2	11.6 ± 0.1	10.7 ± 0.2	13.0 ± 0.2	12.7 ± 0.1
Community DP (g protein/100 g forage)	E		8.2 ± 0.6	5.9 ± 0.4	7.1 ± 0.6	8.4 ± 0.7	6.7 ± 0.6	7.6 ± 0.7
	M/L	6.3 ± 0.5	7.5 ± 0.6	7.9 ± 0.3	9.0 ± 0.2	8.4 ± 0.4	8.8 ± 0.8	12.7 ± 1.3
Selected biomass (kg/ha)	E		232.8 ± 43.1	210.8 ± 27.9	201.9 ± 46.4	194.9 ± 40.4	52.7 ± 19.0	63.5 ± 22.2
	M/L	168.1 ± 30.2	198.0 ± 43.4	83.2 ± 16.6	54.7 ± 17.7	23.6 ± 7.6	7.5 ± 2.9	41.4 ± 11.5
Accepted biomass (kg/ha)	E		508.4 ± 90.1	469.7 ± 48.6	465.5 ± 57.9	417.4 ± 60.1	196.3 ± 38.2	244.9 ± 121.0
	M/L	250.9 ± 38.6	373.8 ± 70.9	165.3 ± 32.8	116.4 ± 37.9	66.0 ± 18.8	90.6 ± 23.2	187.7 ± 32.7
Basic suitable biomass (kg/ha)	E		535.3 ± 90.1	496.7 ± 52.3	376.3 ± 57.3	374.7 ± 58.6	207.4 ± 28.6	291.8 ± 48.5
	M/L	242.5 ± 40.2	380.8 ± 69.1	170.1 ± 35.3	92.9 ± 34.2	47.1 ± 17.3	85.3 ± 21.6	203.6 ± 31.8
Optimal suitable biomass (kg/ha)	E		451.3 ± 89.7	381.7 ± 52.2	287.2 ± 43.8	341.7 ± 63.4	136.0 ± 19.6	240.8 ± 52.2
	M/L	147.6 ± 28.5	327.2 ± 71.3	143.5 ± 31.3	81.0 ± 32.4	40.0 ± 17.6	72.1 ± 21.4	195.0 ± 31.3

[a] DE = digestible energy; DP = digestible protein.

[b] E = early seral ≤ 25 years old; M/L = mid- and late seral > 25 years old.

[c] Age of stands was undetermined for the rangeland/ponderosa pine potential vegetation series, but based on field observations, most stands sampled were best classified as mid- or late-seral stands.

Table 3.9—Mean values ± standard errors of forage resource attributes in late summer and early autumn (August 11–October 4) by seral stage and potential vegetation series in northern Idaho based on field sampling conducted in northern Idaho, 2017–2018

Forage attribute[a]	Seral stage[b]	Range/ ponderosa pine[c]	Douglas-fir	Grand fir	Western redcedar	Western hemlock	Spruce-fir dry	Spruce-fir moist
Community DE (kJ/g)	E		11.1 ± 0.3	12.5 ± 0.1	12.0 ± 0.2	11.5 ± 0.3	12.2 ± 0.3	12.4 ± 0.3
	M/L	10.7 ± 0.2	11.7 ± 0.3	11.9 ± 0.3	11.4 ± 0.2	11.6 ± 0.2	13.1 ± 0.1	12.4 ± 0.2
Community DP (g protein/100 g forage)	E		2.6 ± 0.4	3.7 ± 0.5	3.9 ± 0.6	2.7 ± 0.2	3.5 ± 0.3	5.3 ± 0.7
	M/L	3.7 ± 0.4	3.6 ± 0.4	5.1 ± 0.5	7.1 ± 0.7	4.6 ± 0.3	6.0 ± 0.6	8.5 ± 0.5
Selected forage (kg/ha)	E		155.0 ± 48.5	154.0 ± 56.0	190.4 ± 42.3	157.6 ± 58.9	55.6 ± 11.5	182.0 ± 35.1
	M/L	158.6 ± 23.3	124.6 ± 29.6	24.1 ± 6.4	26.5 ± 7.2	15.1 ± 5.4	9.9 ± 2.4	40.7 ± 13.0
Accepted forage (kg/ha)	E		387.6 ± 66.5	334.7 ± 56.4	417.5 ± 75.4	364.9 ± 59.8	188.3 ± 40.9	355.9 ± 60.7
	M/L	219.4 ± 29.3	233.5 ± 37.0	77.6 ± 8.8	90.0 ± 24.0	70.4 ± 31.5	110.0 ± 21.9	141.6 ± 26.2
Basic suitable forage (kg/ha)	E		106.6 ± 25.6	189.4 ± 40.6	191.9 ± 34.5	142.0 ± 34.7	155.7 ± 40.5	288.1 ± 53.8
	M/L	153.3 ± 28.0	125.1 ± 20.4	59.5 ± 11.0	45.9 ± 14.4	46.6 ± 24.1	86.7 ± 13.7	143.0 ± 26.4
Optimal suitable forage (kg/ha)	E		26.1 ± 8.2	82.3 ± 33.9	96.6 ± 25.1	63.9 ± 19.8	66.8 ± 25.7	200.8 ± 43.9
	M/L	85.9 ± 20.3	54.6 ± 14.6	30.6 ± 5.6	38.4 ± 14.1	23.6 ± 13.9	57.1 ± 10.2	131.3 ± 25.8

[a] DE = digestible energy; DP = digestible protein.

[b] E = early seral ≤ 25 years old; M/L = mid- and late seral > 25 years old.

[c] Age of stands was undetermined for the rangeland/ponderosa pine potential vegetation series, but based on field observations, most stands sampled were best classified as mid- or late-seral stands.

series). In the drier PV series, work in eastern Oregon using tame elk in foraging experiments suggested that retention of some overstory cover of 10 to 40 percent may be useful to maintain higher forage quality later in summer than in similar settings with complete overstory removal (Cook et al. 2014). Nevertheless, if abundance of accepted forage falls below about 250 kg/ha—and certainly if it falls below 150 kg/ha—the site may be of little value to lactating elk in summer no matter the forage quality levels, because forage intake rates in these stands are typically too low to satisfy the daily nutritional needs of elk.

We also found a third significant trend that was related to rate of overstory recovery after disturbance and waxing and waning of undergrowth vegetation in response. The rate of overstory recovery and undergrowth decline was slow in dry, low-elevation forests, rapid in mid-elevation forests with relatively high levels of precipitation (western hemlock, western redcedar, and wetter extents of the grand fir series), and slow in high-elevation spruce-fir sites, particularly those near tree line. As such, the duration of improved forage resources after disturbance may vary greatly among PV series from as little as one and a half decades after disturbance to four to five decades or more after disturbance (Cook et al. 2016). These timeframes of recovery have implications to long-term land use planning. In addition, management that effectively extends the duration of elevated forage resources in highly productive mid-elevation PV series where overstory recovery is rapid would be of considerable interest. Although beyond the scope of this study, reduced tree planting densities, precommercial and commercial thinning, and other silvicultural techniques that might extend the duration of the early-seral window may be useful approaches for consideration.

Effective landscape planning to account for the nutritional needs of elk populations considers broad-scale patterns of forage resources. To provide a better perspective of within-stand forage quality and quantity patterns at broad scales across our study area, we developed maps that represent nutritional "capacity" and nutritional "value" (see methods in app. 4). We defined nutritional capacity as the combination of two factors: nutritional site potential and nutritional responsiveness to stand-replacing disturbances. Nutritional site potential represents the inherent productivity of each potential vegetation type within a series to provide abundant, forage of high quality during summer. Nutritional responsiveness of forage resources reflects the magnitude of forage response to stand-replacing disturbance. The nutritional value maps are intended to describe forage resources that currently exist in our study area in ways that reflect the ability of these resources to satisfy nutritional requirements of lactating elk and their calves in summer. We defined nutritional value based on the relationship between biomass of accepted species and forage intake rates needed to satisfy daily forage intake needs (fig. 3.1) and the relationship between community DE levels of accepted species and forage DE requirements (see methods in app. 4).

Across the Clearwater and St. Joe Rivers basins, a patchwork of policy and regulation from wilderness to commercial timberlands greatly complicates managing for large herbivores such as elk. Costs required to implement habitat restoration projects can be substantial, and thus knowing how to obtain the greatest benefit per unit of cost will be a key component of landscape planning to provide adequate forage resources in the future. Our maps of nutritional capacity and nutritional value (app. 4: fig. 3.40) provide a mid- and large-scale basis for integrating nutritional site potential, current state of forage resources, and varying land management policy for land use planning. For example, active silviculture that removes the overstory in the western redcedar series may yield relatively high nutritional return on investment per unit area in the front range where even-age regeneration harvest is common on private and public lands. Similarly, a let-burn policy for higher elevation areas of the subalpine fir moist series where wildfire starts are common (Smith and Fischer 1997) would yield some of the highest nutritional benefits to elk in roadless or wilderness areas where logging is precluded or unduly expensive to conduct (but the same is not true for the less

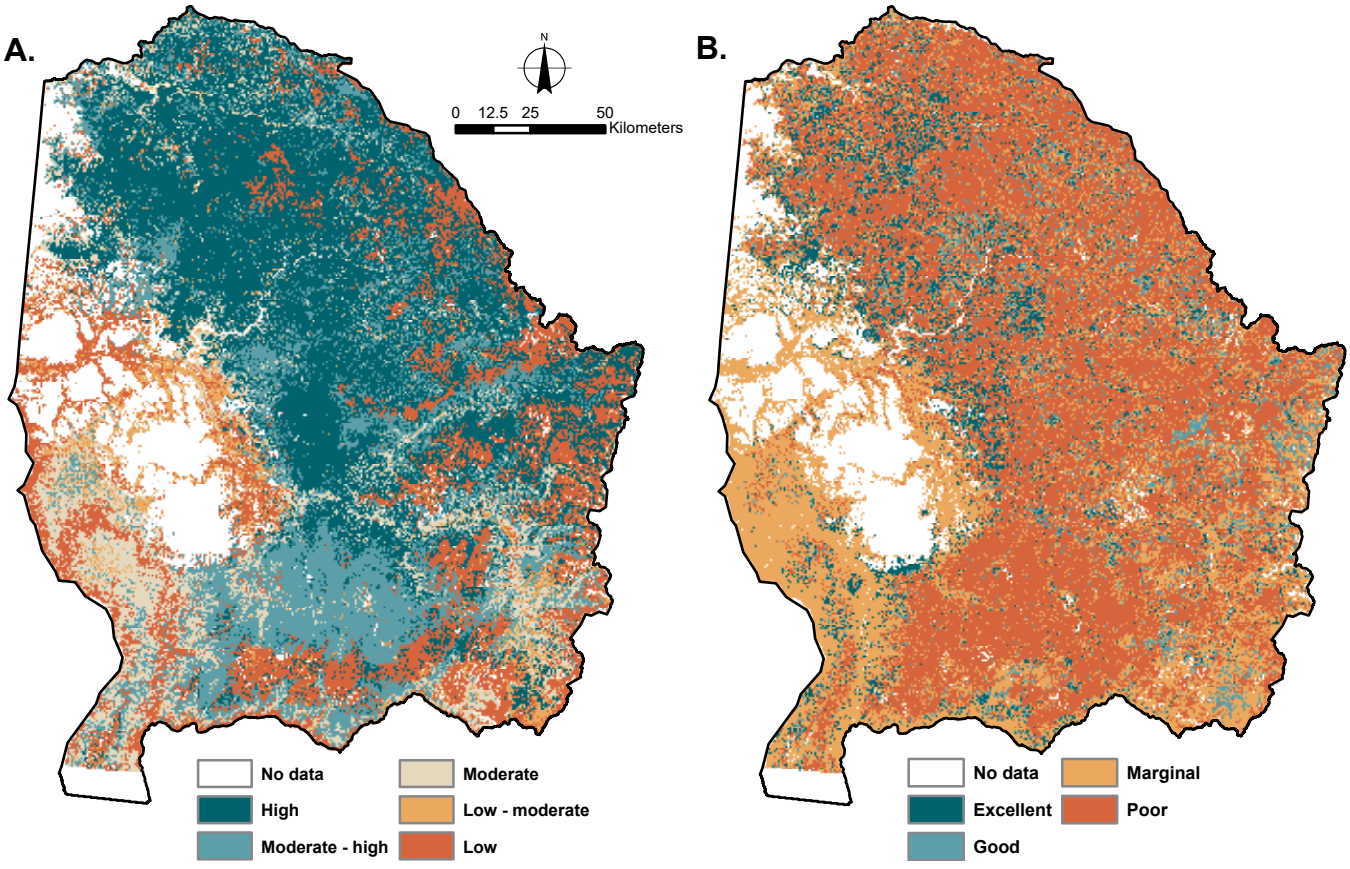

Figure 3.40—(A) Predicted nutritional capacity and (B) current (as of 2016) nutritional value in the Clearwater and St. Joe River basins in Idaho. Nutritional capacity reflects the potential for vegetation types to provide high-quality forage that satisfies nutritional needs of lactating elk in summer as a function of management (such as stand-replacing timber harvest or fire). Nutritional value reflects the current ability of sites to provide sufficient forage biomass and forage quality to satisfy the nutritional needs of lactating elk in summer. It is predicted based on stand age, overstory canopy cover, potential vegetation series, and other site attributes that currently exist on the site. Additional details of methods to derive both maps are provided in app. 4 and Monzingo et al. (n.d.).

productive spruce-fir dry series). Because forest planning often is at a watershed scale (e.g., areas encompassing hydrologic boundaries of 20 000 ha or larger), the specific composition of PV series could be summarized, and spatial priorities established, based on the series yielding the greatest return per unit area. As examples, this would result in the Douglas-fir and particularly the grand fir series potentially being of focus in the southern areas of our study region and the western redcedar and spruce-fir moist series in the north-central and northeastern areas (fig. 3.40).

Our maps of nutritional capacity and nutritional value (fig. 3.40) suggest areas having the lowest nutritional value but also the greatest potential for improvement occur across the north-central (St. Joe River basin) and northeastern sections of our study area. More area rated as good and excellent nutritional value exists in western portions of these areas, where private lands accommodate higher levels of stand-replacing disturbance primarily through even-age regeneration harvest (Monzingo et al., n.d.). Large areas of low nutritional value currently exist in south-central portions of the study area extending from the towns of Grangeville and Elk City on federal lands around and north of the Clearwater River. However, nutritional potential appears to be lowest in southeastern, extreme south-central, and southwestern portions of the study area where rangelands, dry forests at low elevation, and high-elevation spruce-fir dry forests are common or dominant vegetative series (fig. 3.40). This pattern suggests less potential for increasing the nutritional value for elk through stand-replacing disturbance.

Chapter 4: Discussion

Our data support increasing evidence that early-seral communities in western forests are critical for satisfying ungulate nutritional requirements (Cook et al. 2014, 2016; Monzingo et al., n.d.; Schrempp et al. 2019). At least three examples exist in the Western United States of marked increases in ungulate populations following substantial increases in early-seral communities after large-scale events: the Tillamook burns starting in the 1930s for Columbian black-tailed deer (*Odocoileus hemionus columbianus*) (Einarson 1946), the eruption of Mount St. Helens in 1980 for elk (Merrill 1987), and the vast fires of northern Idaho for elk in the early 1900s. The fires of 1910 in northern Idaho alone burned an estimated 12 200 km^2 primarily from Libby, Montana, south nearly to Grangeville, Idaho, and Hamilton, Montana, providing the single largest creation of early-seral vegetation communities in U.S. history. Elk populations increased across the region, although population size over the subsequent decades is unknown. Peek et al. (2020) estimated 5,000 to 6,000 in the Lochsa drainage alone in the 1950s compared to ~1,000 elk currently. As a part of our northern Idaho forage analysis, we found that carrying capacity of elk summer range increased five- to tenfold from the late-1800s to the mid-1900s, an increase that has largely disappeared across much of the Clearwater and St. Joe River basins (Monzingo et al., n.d.), primarily because of reduced wildfire and timber harvest on public lands (Hessburg and Agee 2003). Similar changes at smaller scales caused by large-scale wildfire events (Hansen et al. 1973, Spencer and Chatelain 1953) and long-term forest succession (Gill et al. 1996, Peek et al. 2002) also have been reported. Based on the analysis by Monzingo et al. (n.d.), elk populations in most game management units across our study area are far more constrained by forage resources in recent decades than they were 50 years ago and markedly so when compared to 75 to 100 years ago.

Recent research on the influences of summer nutrition reveals that nutrition in summer greatly affects most ungulate physiological processes that in turn affect performance and productivity (Cook et al. 1996, 2004; Tollefson et al. 2010), and summer ranges of many western ungulate populations fail to fully support these processes (Cook et al. 2013, 2018, 2021; Hurley et al. 2014; Proffitt et al. 2016). Juvenile growth rate and development during summer affect their capacity to survive their first winter and the age at which they become reproducing members of the population (Cook et al. 2004). Similarly, the rate of fat accretion by lactating females during summer not only affects their ability to survive the subsequent winter but determines whether they breed and produce a calf the subsequent year (Cook et al. 2001, 2004). Inadequate forage resources available to lactating females during summer can result in alternate-year production of calves; significant fat depletion experienced by reproducing females often requires a “year off” to restore fat reserves needed for breeding (Cook et al. 2013).

Particularly in northern Idaho, where snow even on low-elevation winter ranges is deep in some years, large-scale die-offs of elk occasionally occur (Peek et al. 2020). We do not discount the substantial negative influences of extreme undernutrition during these harsh winters. Rather, we emphasize that elk in northern Idaho face nutritional limitations across most of the annual cycle, winter and summer, and that adequate nutrition in summer plays a far greater role in helping elk satisfy their nutritional requirements and support high levels of performance, year after year, than was recognized in the past. By maintaining summer cover types with nutritious high-quality forage, elk populations will most likely be more resilient to harsh winters.

Much research has been conducted suggesting the importance of "cover" provided by forests mainly for protection from harsh weather (thermal cover) and as areas for elk to hide from predators and human activities (security cover) (Thomas et al. 1988). The relevance of thermal cover was directly addressed in a variety of studies two decades ago for elk (Cook et al. 1998) and other ungulates (Freddy 1984, 1985, 1986; Gilbert and Bateman 1983; Robinson 1960), all of which reported virtually no evidence that thermal cover provided the assumed bioenergetic benefits (i.e., protection from harsh weather). Providing security cover as a refugia for elk is intended to maintain desired population distributions of elk on public or other lands; however, this objective can be more efficiently met through integrated landscape management of adequate nutrition, strategic road closures to facilitate elk use of areas of adequate nutrition, and provision of cover (Wisdom et al. 2018).

As context for landscape management of cover and nutrition, Monzingo et al. (n.d.) reported that only 11 percent of the area within five elk management zones analyzed in that study area (i.e., southern Panhandle, Lolo, Dworshak, Selway, and Elk City zones) provided elk summer nutrition that rated as good or excellent, 69 percent of the area was rated as having virtually no nutritional value, and 20 percent was rated as having marginal value for lactating females (derived from fig. 3.40). These estimates represent a marked decline from the mid-1900s, when areas rated as good or excellent composed 25 to 50 percent of the region. In other words, relatively dense forests currently (i.e., 2016) compose the vast majority of these elk management zones where forage resources are generally too poor to support elk in summer, and elk populations are substantially lower than the mid-1900s when early-seral vegetation communities were abundant. Thus, available information indicates elk populations would benefit far more from creating and sustaining more early-seral communities than from creating more areas of dense forest cover.

Large areas of northern Idaho are designated as roadless and wilderness areas, thus limiting or barring active silvicultural prescriptions (i.e., commercial timber harvest, prescribed burning) that could substantially enhance summer nutrition for ungulates in these designations. These expansive backcountry areas have been subjected to many decades of active wildfire suppression, creating vast areas of dense forests that provide good security for elk. For example, application of the

Hillis et al. (1991) elk security guidelines indicates that most of northern Idaho elk ranges (excluding some areas in the Dworshak elk management zone) currently far exceed the conditions defined for security. Moreover, the strategic, spatially prioritized use of wildfire in backcountry areas in all but the cold, dry extent of the spruce-fir series will substantially enhance summer nutrition but not reduce elk security, because of the dearth of roads (Hillis et al. 1991). Nevertheless, the potential benefits of early-seral communities may be significantly reduced if these occur in areas where elk feel insecure such as near roads (Rowland et al. 2018) or in centers of large burns or clearcuts. Maintaining a landscape mosaic of areas of security with areas of good to excellent nutrition would likely be a successful strategy for managing elk habitat.

Although this report focuses on elk, landscape management that increases the extent of early-seral vegetation will potentially provide benefits for a host of species of flora and fauna that depend on the abundant vegetation that establishes soon after disturbance (Swanson et al. 2014). Structure and composition of floral and faunal communities in the northern Rocky Mountain region has been shaped by periodic, stand-replacing wildfire over many millennia (Hessburg and Agee 2003). Studies involving lake sediments and dendrochronology clearly show that periodic wildfires were a component of these ecosystems since the last ice age, with 10 to 15 wildfire events per 1,000 years in prehistoric times (10,000 years before present) to 3 to 5 wildfire events per 1,000 years over the past two millennia (Millspaugh et al. 2004). Increasing forage via managing for more early-seral communities would likely benefit deer (Hull et al. 2020, Ulappa et al. 2020) and moose (Schrempp et al. 2019) through nutritional pathways, just as it would for elk.

Because our data were collected from existing stands in our study region, most of which were created either by wildfire or clearcut regeneration harvest (Smith and Fischer 1997), our approach to managing elk habitat primarily involves stand-replacing disturbance. We have little data with which to compare the effects of various commercial timber harvest strategies, silvicultural prescriptions, season and intensity of these treatments, and differences between silvicultural practices and wildfire on forage resources for elk. The work that does exist generally suggested that the greater the removal of overstory, the greater the response of undergrowth, much of which is shade-intolerant, relatively palatable plant species (Cook et al. 2016, Hull et al. 2020, Irwin and Peek 1979, Ulappa et al. 2020). However, this trend should not be generalized across all site potentials in the region. For example, disturbance that retains some overstory canopy (10 to 40 percent) may provide forage of higher quality for elk in the drier forest potential vegetation (PV) series in eastern Oregon (primarily the Douglas-fir and grand fir series) (Cook et al. 2014). In addition, strategies that extend the early-seral window particularly in PV series where forest regeneration is very rapid (e.g., western redcedar, western hemlock, and wetter extent of the grand fir series) may be especially useful, because their soil moisture regimes support abundant growth of palatable forage with high digestible

energy and digestible protein content. Developing a better understanding of ways to effectively extend the early-seral window in these types and understanding which forest management options provide the best nutritional return per unit investment are key topics for future research.

Acknowledgments

We acknowledge the Idaho Department of Fish and Game for providing logistical and technical support, especially C. Hickey, J. Horne, B. Felts, K. Growth, Z. Swearingen, and J. White, as well as the contributions made by O. Daniels, J. Hansen, A. Irby, B. Miller, and K. Rosellini of the Clearwater Basin Collaborative. B. Davitt, M. Camp, and S. Cai at the Washington State University Wildlife Habitat and Nutrition Laboratory and J. Braden at the Soil, Plant, and Waste Analytical Laboratory at Washington State University provided laboratory analysis and assistance. Thanks to S. Robatcek and A. Reeder for laboratory assistance. Field technicians N. Andresen, E. Colberg, N. Estrada, A. Hatcher, W. Marks, J. Moine, R. Reishus, J. Sandquist, and S. Schuler contributed to the vegetation sampling. B. Carroll, L. Irwin, K. Labrum, and Z. Swearingen provided review comments. This work was supported by members of the Clearwater Basin Collaborative, consisting of the U.S. Department of Agriculture (USDA) Forest Service (Nez-Perce Clearwater National Forests, Rocky Mountain Regional Office, and Pacific Northwest Research Station), Rocky Mountain Elk Foundation, and Idaho Department of Fish and Game and additional support of the National Council for Air and Stream Improvement and the USDA National Institute of Food and Agriculture, McIntire-Stennis Project WNP00848.

U.S. Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches
Centimeters per year (cm/year)	0.394	Inches per year
Meters (m)	3.28	Feet
Meters	1.094	Yards
Hectares (ha)	2.47	Acres
Square kilometers (km^2)	0.386	Square miles
Square meters (m^2)	10.76	Square feet
Square meters per hectare (m^2/ha)	4.37	Square feet per acre
Grams (g)	0.0352	Ounces
Grams	0.0022	Pounds
Kilograms per hectare (kg/ha)	0.893	Pounds per acre
Degrees Celsius (°C)	1.8 °C + 32	Degrees Fahrenheit
Kilojoules per gram (kJ/g)	0.239	Kilocalories per gram

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Appendix 1: Scientific and Common Names, Life Forms, and Elk Selection Categories of Plant Species

Life form	Scientific name	Common name	Elk selection[a]
Conifer	*Abies grandis* (Douglas ex D. Don) Lindl.	Grand fir	Avoided
	Abies lasiocarpa (Hook.) Nutt.	Subalpine fir	Avoided
	Larix occidentalis Nutt.	Western larch	Avoided
	Picea engelmannii Parry ex Engelm.	Engelmann spruce	Avoided
	Pinus albicaulis Engelm.	Whitebark pine	Avoided
	Pinus contorta Douglas ex Loudon	Lodgepole pine	Avoided
	Pinus monticola Douglas ex D. Don	Western white pine	Avoided
	Pinus ponderosa Lawson & C. Lawson	Ponderosa pine	Avoided
	Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir	Avoided
	Thuja plicata Donn ex D. Don	Western redcedar	Avoided
	Tsuga heterophylla (Raf.) Sarg.	Western hemlock	Avoided
	Tsuga mertensiana (Bong.) Carrière	Mountain hemlock	Avoided
Fern	*Adiantum aleuticum* (Rupr.) Paris	Aleutian maidenhair	Neutral
	Gymnocarpium dryopteris (L.) Newman	Western oakfern	Neutral
	Polystichum munitum (Kaulf.) C. Presl	Western swordfern	Avoided
	Pteridium aquilinum (L.) Kuhn	Western brackenfern	Neutral
Forb	*Achillea millefolium* L.	Common yarrow	Neutral
	Adenocaulon bicolor Hook.	Pathfinder	Selected
	Arnica cordifolia Hook.	Heartleaf arnica	Selected
	Arnica latifolia Bong.	Broadleaf arnica	Neutral
	Aster spp.	Aster	Neutral
	Aster conspicuus Lindl.	Western showy aster	Selected
	Astragalus spp.	Milkvetch	Selected
	Astragalus canadensis L.	Canadian milkvetch	Selected
	Balsamorhiza incana Nutt.	Hoary balsamroot	Neutral
	Balsamorhiza sagittata (Pursh) Nutt.	Arrowleaf balsamroot	Selected
	Chamerion angustifolium (L.) Holub	Fireweed	Selected
	Cirsium spp.	Thistle	Neutral
	Cirsium, Carduus, Onopordum spp. (spines pronounced)	Thistle	Avoided
	Clintonia uniflora (Menzies ex Schult. & Schult. f.) Kunth	Bride's bonnet	Selected
	Coptis occidentalis (Nutt.) Torr. & A. Gray	Idaho goldthread	Neutral
	Disporum hookeri (Torr.) G. Nicholson	Drops-of-gold	Selected
	Eriogonum heracleoides Nutt.	Parsnipflower buckwheat	Selected
	Fragaria vesca L.	Woodland strawberry	Neutral
	Frasera fastigiata (Pursh) A. Heller	Clustered green gentian	Neutral
	Galium triflorum Michx.	Fragrant bedstraw	Selected
	Geum triflorum Pursh	Old man's whiskers	Selected
	Helianthella uniflora (Nutt.) Torr. & A. Gray	Oneflower helianthella	Selected
	Hieracium spp.	Hawkweed	Selected

Life form	Scientific name	Common name	Elk selection[a]
Forb	*Hieracium albertinum* Farr	Scouler's woollyweed	Selected
	Hieracium albiflorum Hook.	White hawkweed	Selected
	Hieracium cynoglossoides Arv.-Touv.	Houndstongue hawkweed	Selected
	Hypericum perforatum L.	Common St. Johnswort	Avoided
	Lomatium ambiguum (Nutt.) J.M. Coult. & Rose	Wyeth biscuitroot	Avoided
	Lupinus spp.	Lupine	Avoided
	Mitella spp.	Miterwort	Neutral
	Montia cordifolia	Heartleaf springbeauty	Avoided
	Potentilla gracilis Douglas ex Hook.	Slender cinquefoil	Selected
	Prunella vulgaris L.	Common selfheal	Selected
	Rudbeckia occidentalis Nutt.	Western coneflower	Avoided
	Sedum spp.	Stonecrop	Avoided
	Smilacina racemosa L.	Feathery false lily of the valley	Neutral
	Smilacina stellata L.	Starry false lily of the valley	Selected
	Streptopus amplexifolius (L.) DC.	Claspleaf twistedstalk	Selected
	Taraxacum spp.	Dandelion	Selected
	Thermopsis montana Nutt.	Mountain goldenbanner	Avoided
	Trifolium spp.	Clover	Selected
	Valeriana sitchensis Bong.	Sitka valerian	Selected
	Viola spp.	Violet	Selected
	Xerophyllum tenax (Pursh) Nutt.	Common beargrass	Avoided
Graminoid	*Bromus vulgaris* (Hook.) Shear	Columbia brome	Selected
	Calamagrostis rubescens Buckley	Pinegrass	Avoided
	Carex spp.	Sedge	Avoided
	Carex geyeri Boott	Geyer's sedge	Neutral
	Dactylis glomerata L.	Orchardgrass	Selected
	Danthonia unispicata (Thurb.) Munro ex Macoun	Onespike oatgrass	Selected
	Elymus spp.	Wildrye	Neutral
	Elymus elymoides (Raf.) Swezey	Squirreltail	Avoided
	Elymus glaucus Buckley	Blue wildrye	Neutral
	Festuca idahoensis Elmer	Idaho fescue	Selected
	Koeleria cristata Pers.	Prairie Junegrass	Selected
	Phleum pratense L.	Timothy	Neutral
	Poa spp.	Bluegrass	Avoided
	Poa secunda J. Presl	Sandberg bluegrass	Avoided
	Pseudoroegneria spicata (Pursh) Á. Löve[b]	Bluebunch wheatgrass	Selected
Shrub	*Acer glabrum* Torr.	Rocky Mountain maple	Neutral
	Alnus spp.	Alder	Neutral
	Alnus rubra Bong.	Red alder	Selected
	Alnus viridis (Chaix) DC.	Sitka alder	Neutral
	Amelanchier alnifolia (Nutt.) Nutt. ex M. Roem.	Saskatoon serviceberry	Selected
	Ceanothus sanguineus Pursh	Redstem ceanothus	Neutral
	Ceanothus velutinus Douglas ex Hook.	Snowbrush ceanothus	Avoided
	Cornus stolonifera Michx.	Western dogwood	Neutral

Life form	Scientific name	Common name	Elk selection[a]
Shrub	*Chimaphila umbellata* (L.) W.P.C. Barton	Pipsissewa	Neutral
	Holodiscus discolor (Pursh) Maxim.	Oceanspray	Selected
	Linnaea borealis L.	Twinflower	Avoided
	Lonicera ciliosa (Pursh) Poir. ex DC.	Orange honeysuckle	Selected
	Lonicera utahensis S. Watson	Utah honeysuckle	Selected
	Mahonia repens (Lindl.) G. Don	Creeping barberry	Selected
	Menziesia ferruginea Sm.	Rusty menziesii	Avoided
	Paxistima myrsinites (Pursh) Raf.	Oregon boxleaf	Neutral
	Philadelphus lewisii Pursh	Lewis' mock orange	Selected
	Physocarpus malvaceus (Greene) Kuntze	Mallow ninebark	Neutral
	Prunus emarginata (Douglas ex Hook.) D. Dietr.	Bitter cherry	Neutral
	Prunus virginiana L.	Chokecherry	Neutral
	Rhododendron albiflorum Hook.	Cascade azalea	Avoided
	Ribes cereum Douglas	Wax currant	Selected
	Ribes viscosissimum Pursh	Sticky currant	Selected
	Rosa spp.	Rose	Selected
	Rosa gymnocarpa Nutt.	Dwarf rose	Selected
	Rosa nutkana C. Presl	Nootka rose	Selected
	Rosa woodsii Lindl.	Woods' rose	Selected
	Rubus parviflorus Nutt.	Thimbleberry	Selected
	Salix scouleriana Barratt ex Hook.	Scouler's willow	Selected
	Sambucus spp.	Elderberry	Neutral
	Sorbus scopulina Greene	Greene's mountain ash	Selected
	Spiraea betulifolia Pall.	White spirea	Selected
	Symphoricarpos albus (L.) S.F. Blake	Common snowberry	Selected
	Vaccinium membranaceum Douglas ex Torr.	Thinleaf huckleberry	Neutral
	Vaccinium scoparium Leiberg ex Coville	Grouse whortleberry	Avoided

[a] Selected: use > availability; neutral: use = availability; avoided: use < availability). Taxa categories are for plant species found in the Clearwater and St. Joe River basins, Idaho, during summer-early autumn sampling, 2016 and 2017.

[b] Cooper et al. (1991) refers to this species as *Agropyron spicatum.*

Appendix 2: Key to Potential Vegetation Series

We adapted the dichotomous key provided by Cooper et al. (1991) to identify potential vegetation series in our study. We present the key for information purposes and recommend that that users refer to Cooper et al. (1991) for additional instructions and vegetative details in northern Idaho.

Key to Series Level: Northern Idaho Refinement—Revised 1990

1a. Habitats where the canopy dominant is *Alnus viridis* or *Pteridium aquilinum*; no indication of successful tree reproduction or that past tree density was greater than 25 trees per hectare (10 trees per acre), though scattered *Picea engelmannii* (seedlings and saplings) may be present
——— **go to number 2**

1b. Not as above; sites capable of supporting forest even if savanna-like or currently dominated by shrub fields
——— **go to number 3**

2a. *Alnus viridis* dominated shrub/low tree layer; undergrowth is depauperate (five or fewer herbaceous species present) and *Montia cordifolia* well represented (5 percent)
——— **SITKA ALDER SERIES (refer to Cooper et al. 1991)**

2b. Not as above
——— **OTHER VEGETATION TYPES (refer to Cooper et al. 1991)**

3a. Habitats with unstable broken rock substrate usually on steep slopes (>30 degrees); sparse, poorly developed, and spatially variable undergrowth
——— **SCREE (refer to Cooper et al. 1991)**

3b. Habitats with stable substrates and some soil development; undergrowth well developed and spatially somewhat uniform
——— **go to number 4**

4a. *Tsuga heterophylla* present and reproducing successfully
——— **WESTERN HEMLOCK SERIES (p. 35)**

4b. *T. heterophylla* absent or if present not reproducing successfully
——— **go to number 5**

5a. *Thuja plicata* present and reproducing successfully, though success may be considerably less than competing species and often episodic or missing
WESTERN REDCEDAR SERIES (p. 29)

5b. *T. plicata* absent or not as above
go to number 6

6a. *Tsuga mertensiana* present and reproducing successfully
SPRUCE-FIR SERIES (p. 41 and p. 47)

6b. *T. mertensiana* absent, or, if present, not reproducing successfully
go to number 7

7a. *Abies lasiocarpa* present and reproducing more successfully than *Abies grandis* (or other tree species)
SPRUCE-FIR SERIES (p. 41 and p. 47)

7b. Not as above or *A. grandis* reproduction greater than that of *A. lasiocarpa*
go to number 8

8a. *A. grandis* or *Taxus brevifolia* present and reproducing successfully
GRAND FIR SERIES (p. 22)

8b. *A. grandis* and *T. brevifolia* absent or not reproducing successfully
go to number 9

9a. *Pseudotsuga menziesii* present and reproducing successfully, though perhaps episodically
DOUGLAS FIR SERIES (p. 16)

9b. *P. menziesii* absent or not reproducing successfully
go to number 10

10a. Virtually pure stands of *Pinus contorta* that may or may not be self-reproducing and little evidence as to climax tree species
LODGEPOLE PINE SERIES (refer to Cooper et al. 1991)

10b. *Pinus ponderosa* present and reproducing, perhaps episodically
PONDEROSA PINE SERIES (p. 12)

Appendix 3: Plant Species for Targeted Management

This appendix lists plant species that may be especially important for elk habitat improvement programs designed to enhance elk nutrition during summer in northern Idaho. Species are those that elk typically select (where the proportion in elk diets exceeds the proportion available in plant communities in which they forage), are nutritious, and are reasonably abundant, at least in certain successional stages or potential vegetation series. Plant species in boldface are those that provide relatively high bite mass (>0.4 g/bite) that enhance the ability of elk to maintain forage intake rates required to satisfy total daily nutritional requirements (Cook et al. 2014, 2016).

Scientific name	Range/ ponderosa pine	Douglas-fir		Grand fir		Western redcedar		Western hemlock		Spruce-fir dry		Spruce-fir moist	
		E	M/L	E	M/L	E	M/L	E	M/L	E	M/L	E	M/L
	Kilograms/hectare												
Deciduous shrubs													
***Alnus* spp.**[a]	—	—	—	**0.2 (0.6)**	—	**2.5 (3.8)**	**0.6 (0.9)**	**0.6 (0.9)**	—	**6.8 (8.9)**	**0.9 (2.4)**	**9.3 (6.8)**	**9.3 (6.0)**
Amelanchier alnifolia	0.5 (0.8)	10.0 (5.4)	9.7 (3.7)	9.0 (4.5)	2.5 (1.0)	4.0 (1.6)	1.4 (2.1)	11.1 (4.6)	1.2 (0.6)	0.1 (0.2)	0.02 (0.1)	0.3 (0.5)	1.5 (3.9)
Holodiscus discolor	**0.9 (1.4)**	**9.2 (4.8)**	**18.1 (5.8)**	**9.9 (3.6)**	**3.8 (1.8)**	**4.6 (5.1)**	**2.1 (1.3)**	**14.3 (10.3)**	**0.4 (0.5)**	—	—	—	—
Lonicera ciliosa	—	—	0.3 (0.4)	0.7 (0.4)	2.1 (1.4)	0.8 (1.4)	0.7 (0.7)	2.2 (2.5)	0.01 (0.01)	—	—	0.3 (0.6)	0.1 (0.1)
Lonicera utahensis	**0.01 (0.03)**	—	**0.02 (0.1)**	**0.2 (0.3)**	**0.7 (0.4)**	**1.4 (0.7)**	**1.4 (1.4)**	**2.2 (1.2)**	**0.9 (0.4)**	**1.2 (1.4)**	**2.1 (0.9)**	**12.8 (4.4)**	**5.9 (1.9)**
Philadelphus lewisii	—	—	**0.1 (0.1)**	**1.8 (2.2)**	—	—	—	—	—	—	—	—	—
Ribes spp.[b]	—	1.6 (1.2)	0.1 (0.4)	9.9 (7.6)	0.3 (0.2)	32.0 (12.3)	0.1 (0.2)	1.1 (1.2)	—	1.5 (2.1)	0.1 (0.3)	2.2 (2.8)	0.2 (0.3)
Rosa spp.[c]	0.4 (0.4)	8.7 (2.3)	7.1 (1.7)	5.4 (1.2)	2.3 (0.9)	3.6 (1.0)	1.1 (0.4)	5.8 (2.1)	1.8 (0.7)	0.3 (0.4)	0.2 (0.5)	0.1 (0.1)	0.5 (0.5)
Rubus parviflorus	—	—	—	**15.3 (5.2)**	**4.7 (3.4)**	**37.8 (9.1)**	**7.4 (5.4)**	**9.8 (4.0)**	**0.6 (0.3)**	—	—	**7.5 (5.6)**	**1.8 (0.8)**
Salix scouleriana	**0.8 (2.1)**	**2.9 (5.2)**	—	**6.0 (4.2)**	—	**9.7 (7.7)**	**0.3 (1.0)**	**0.1 (0.2)**	—	**2.1 (1.7)**	**0.8 (1.0)**	**12.8 (5.9)**	**1.2 (3.2)**
Sorbus scopulina	—	—	—	**0.4 (1.3)**	**0.1 (0.2)**	**0.7 (1.1)**	—	**0.9 (0.9)**	—	**0.8 (2.5)**	**0.2 (0.5)**	**0.8 (1.4)**	**1.7 (2.0)**
Spiraea betulifolia	**0.5 (0.3)**	**20.3 (5.5)**	**13.1 (2.5)**	**11.4 (2.5)**	**2.6 (0.9)**	**4.3 (2.4)**	**1.1 (1.0)**	**14.9 (4.0)**	**1.3 (0.9)**	**6.3 (3.7)**	**1.9 (0.8)**	**2.7 (1.8)**	**0.7 (0.5)**
Symphoricarpos albus	**6.8 (3.7)**	**66.4 (16.2)**	**28.6 (4.2)**	**76.2 (13.3)**	**11.6 (3.0)**	**47.0 (10.1)**	**6.4 (1.8)**	**60.0 (27.6)**	**1.0 (0.4)**	—	—	**4.0 (3.8)**	**0.1 (0.3)**
Acer glabrum	—	**2.1 (3.2)**	**0.8 (0.9)**	**2.8 (1.6)**	**1.2 (0.8)**	**6.4 (2.9)**	**1.0 (0.4)**	**9.6 (4.4)**	**0.4 (0.2)**	—	—	**5.7 (6.9)**	**3.0 (3.9)**
Ceanothus sanguineus	—	**7.1 (14.4)**	**0.7 (1.1)**	**11.1 (9.1)**	**2.3 (5.2)**	**5.4 (3.0)**	**9.2 (27.0)**	**0.7 (0.8)**	—	—	—	**3.0 (6.7)**	—
Cornus stolonifera	—	—	—	**0.1 (0.3)**	—	—	**0.2 (0.5)**	—	—	—	—	**2.3 (5.1)**	—
Prunus emarginata	—	—	**0.5 (1.0)**	**0.5 (0.7)**	**0.02 (0.04)**	**2.4 (2.7)**	**0.2 (0.4)**	—	—	**0.5 (1.5)**	—	—	—
Prunus virginiana	—	**1.3 (3.1)**	**0.3 (0.8)**	**1.2 (2.5)**	**0.1 (0.2)**	**0.5 (0.3)**	—	**0.4 (0.9)**	—	—	—	—	—
***Sambucus* spp.**	—	**1.0 (2.0)**	—	**0.1 (0.3)**	**0.02 (0.03)**	**0.9 (0.6)**	**0.2 (0.5)**	—	—	**0.5 (1.2)**	—	**0.4 (0.4)**	**1.2 (3.2)**
Vaccinium membranaceum	**0.02 (0.1)**	**2.3 (3.1)**	**1.7 (2.3)**	**30.4 (6.6)**	**10.2 (3.2)**	**15.1 (6.2)**	**3.3 (1.5)**	**23.2 (8.8)**	**11.4 (5.5)**	**62.6 (12.9)**	**78.4 (12.9)**	**82.6 (21.2)**	**77.5 (16.4)**

Scientific name	Range/ ponderosa pine	Douglas-fir		Grand fir		Western redcedar		Western hemlock		Spruce-fir dry		Spruce-fir moist	
		E	M/L	E	M/L	E	M/L	E	M/L	E	M/L	E	M/L
	Kilograms/hectare												
Evergreen shrubs													
Paxistima myrsinites	—	—	—	2.7 (2.3)	0.03 (0.1)	3.6 (1.0)	1.7 (1.2)	6.5 (3.1)	2.0 (0.7)	—	0.04 (0.1)	—	0.01 (0.03)
Perennial forbs													
Adenocaulon bicolor	—	—	0.1 (0.1)	0.4 (0.3)	6.7 (2.2)	0.5 (0.2)	3.1 (0.7)	0.1 (0.1)	1.8 (1.5)	—	—	—	—
Arnica cordifolia	0.02 (0.04)	1.8 (1.6)	3.9 (1.3)	2.4 (1.8)	3.6 (1.5)	1.7 (1.8)	0.2 (0.3)	—	0.9 (0.9)	0.03 (0.1)	0.2 (0.4)	0.4 (0.8)	10.1 (5.3)
Aster conspicuus	**—**	**0.7 (0.7)**	**0.9 (1.4)**	**3.0 (3.2)**	**1.4 (2.4)**	**—**	**—**	**1.5 (0.9)**	**—**	**—**	**—**	**0.3 (0.6)**	**0.1 (0.2)**
***Astragalus* spp.**[d]	**0.02 (0.1)**	**0.3 (0.7)**	**0.8 (1.3)**	**1.8 (3.6)**	**0.04 (0.1)**	**5.1 (7.2)**	**0.002 (0.01)**	**—**	**—**	**—**	**—**	**0.1 (0.2)**	**—**
Balsamorhiza sagittata	**4.6 (5.2)**	**0.5 (1.1)**	**4.9 (14.3)**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Clintonia uniflora	—	—	0.05 (0.1)	0.7 (0.3)	1.2 (0.6)	3.1 (1.0)	2.2 (0.3)	1.6 (0.9)	1.8 (0.4)	0.1 (0.1)	0.03 (0.1)	2.2 (1.0)	4.8 (0.9)
Disporum hookeri	**—**	**—**	**0.1 (0.1)**	**0.4 (0.6)**	**1.5 (1.3)**	**0.4 (0.1)**	**3.8 (0.9)**	**0.2 (0.1)**	**1.2 (0.5)**	**—**	**—**	**0.1 (0.2)**	**0.03 (0.1)**
Chamerion angustifolium	**—**	**3.8 (2.7)**	**0.8 (1.1)**	**7.8 (4.2)**	**0.8 (1.9)**	**22.4 (5.7)**	**0.2 (0.4)**	**16.7 (11.7)**	**—**	**34.5 (8.6)**	**1.0 (2.3)**	**71.1 (18.6)**	**0.2 (0.2)**
Eriogonum heracleoides	**17.5 (5.7)**	**—**	**0.1 (0.3)**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
Galium triflorum	0.03 (0.04)	—	0.2 (0.1)	1.6 (0.4)	1.1 (0.3)	1.8 (0.7)	0.8 (0.2)	0.4 (0.2)	0.4 (0.2)	—	—	0.4 (0.6)	1.1 (0.5)
Geum triflorum	**4.5 (3.6)**	**0.4 (0.9)**	**0.01 (0.02)**	**0.01 (0.03)**	**—**	**0.3 (0.7)**	**—**	**0.1 (0.2)**	**—**	**—**	**—**	**—**	**—**
Helianthella uniflora	**1.3 (4.9)**	**0.6 (1.4)**	**0.02 (0.1)**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
***Hieracium* spp.**[e]	**0.01 (0.01)**	**0.1 (0.1)**	**0.3 (0.2)**	**1.7 (0.7)**	**1.0 (0.4)**	**1.3 (0.7)**	**0.3 (0.3)**	**10.6 (5.6)**	**0.5 (0.2)**	**1.9 (0.8)**	**0.1 (0.1)**	**0.7 (0.7)**	**0.3 (0.3)**
Mushrooms	**0.02 (0.02)**	**—**	**0.1 (0.1)**	**0.1 (0.1)**	**0.04 (0.1)**	**0.02 (0.03)**	**0.01 (0.01)**	**—**	**0.01 (0.03)**	**—**	**0.02 (0.1)**	**0.03 (0.1)**	**0.02 (0.02)**
Potentilla gracilis	**12.0 (12.9)**	**0.6 (0.6)**	**1.3 (0.8)**	**2.4 (3.0)**	**0.03 (0.1)**	**0.03 (0.04)**	**—**	**0.1 (0.1)**	**—**	**—**	**—**	**—**	**—**
Prunella vulgaris	0.01 (0.03)	0.5 (1.2)	0.03 (0.07)	0.7 (0.7)	—	0.1 (0.1)	0.1 (0.3)	—	—	—	—	—	—
Smilacina stellatum	—	0.02 (0.04)	0.3 (0.5)	5.0 (1.5)	4.1 (1.0)	3.2 (0.8)	5.4 (1.1)	2.5 (0.8)	3.5 (0.9)	0.2 (0.5)	0.1 (0.4)	3.1 (1.8)	1.3 (0.4)
Taraxacum spp.	0.3 (0.5)	0.4 (0.7)	0.3 (0.3)	1.1 (0.8)	0.03 (0.1)	1.1 (1.2)	0.1 (0.2)	0.1 (0.1)	—	0.03 (0.1)	—	—	—

Scientific name	Range/ ponderosa pine	Douglas-fir		Grand fir		Western redcedar		Western hemlock		Spruce-fir dry		Spruce-fir moist	
		E	M/L	E	M/L	E	M/L	E	M/L	E	M/L	E	M/L
	Kilograms/hectare												
Trifolium spp.	2.4 (1.6)	13.3 (12.4)	7.4 (3.9)	0.9 (0.7)	0.6 (0.8)	0.5 (0.4)	0.002 (0.01)	5.1 (2.5)	0.1 (0.1)	—	0.03 (0.1)	—	—
Valeriana sitchensis	—	—	—	—	—	—	**0.02 (0.1)**	—	—	—	**0.2 (0.4)**	—	**1.1 (2.4)**
Viola spp.	0.001 (0.004)	0.2 (0.3)	0.1 (0.1)	0.8 (0.2)	1.8 (0.3)	0.6 (0.2)	2.0 (0.3)	0.3 (0.2)	1.0 (0.2)	0.04 (0.03)	0.5 (0.1)	1.4 (0.7)	3.0 (0.5)
Achillea millefolium	**22.3 (3.8)**	**15.4 (4.0)**	**11.5 (2.2)**	**15.7 (5.2)**	**1.3 (1.0)**	**5.4 (3.7)**	**0.3 (0.7)**	**2.5 (1.7)**	**0.1 (0.3)**	**4.3 (2.9)**	—	**0.1 (0.3)**	—
Balsamorhiza incana	**2.4 (2.0)**	—	—	—	—	—	—	—	—	—	—	—	—
Smilacina racemosa	—	1.0 (1.4)	1.3 (1.5)	0.2 (0.2)	—	1.5 (1.1)	—	0.4 (0.6)	0.1 (0.2)	—	—	0.9 (1.4)	—
Aster spp.[f]	0.6 (1.1)	0.9 (1.0)	0.4 (0.5)	0.5 (0.5)	—	1.0 (1.6)	0.1 (0.2)	0.1 (0.2)	—	0.4 (0.6)	0.02 (0.1)	0.4 (0.4)	0.1 (0.2)
Perennial graminoids													
Pseudoroegneria spicata	**65 (10.6)**	**9.7 (8.5)**	**2.0 (2.5)**	**1.1 (1.1)**	—	**5.2 (14.6)**	—	—	—	**3.1 (5.6)**	—	—	—
Bromus vulgaris (native)	—	0.5 (0.4)	0.5 (0.2)	0.6 (0.2)	2.4 (0.5)	0.9 (0.3)	1.2 (0.3)	1.0 (0.5)	0.6 (0.3)	0.1 (0.2)	—	1.1 (0.4)	0.5 (0.2)
Dactylis glomerata	—	**38.7 (31.1)**	**32.4 (16.1)**	**3.4 (1.8)**	**2.0 (3.8)**	**1.3 (2.0)**	**0.1 (0.1)**	—	—	—	—	**1.0 (2.2)**	—
Danthonia unispicata	12.6 (3.5)	—	—	0.1 (0.1)	—	—	—	0.1 (0.2)	—	—	—	—	—
Festuca idahoensis	**23.9 (10.3)**	**2.6 (2.6)**	**4.2 (3.1)**	**0.3 (0.4)**	**0.04 (0.1)**	**0.8 (1.3)**	—	—	—	—	—	**2.8 (5.3)**	—
Koeleria cristata	5.7 (2.2)	1.9 (4.7)	0.1 (0.2)	0.3 (1.0)	—	—	—	—	—	—	—	—	—
Elymus spp.[g]	7.7 (15.4)	20.2 (7.4)	6.1 (1.5)	12.7 (5.7)	2.8 (2.6)	7.3 (3.2)	12 (1.1)	3.2 (1.5)	—	1.2 (1.7)	0.02 (0.1)	13.1 (12.5)	—

— = not applicable.

Note: Data presented are mean abundance (± SE) by potential vegetation series and seral stage (E = early seral; M/L = mid- and late seral combined). Abundance data are based on field sampling conducted during summer in 2016 and 2017 in the Clearwater and St. Joe River basins in northern Idaho.

[a] Included *Alnus rubra* and *A. viridis*.

[b] Included *Ribes cereum* and *R. viscosissimum*.

[c] Included *Rosa gymnocarpa*, *R. woodsii*, and *R. nutkana*.

[d] Included *Astragalus canadensis*.

[e] Included *Hieracium albertinum*, *H. albiflorum*, and *H. cynoglossoides*.

[f] Included all *Aster* spp. except *A. conspicuus*.

[g] Included only native species of *Elymus* (e.g., *E. glaucus*).

Appendix 4: Current Nutritional Value and Nutritional Capacity Maps

We developed two maps for our study area to show (A) nutritional capacity and (B) current (2016) nutritional value (fig. A4.1). The first is intended to identify areas where greatest potential (or lack of potential) exists for improving forage resources; the latter portrays spatial variation in the value of forage resources in relation to nutritional requirements of lactating female elk in summer.

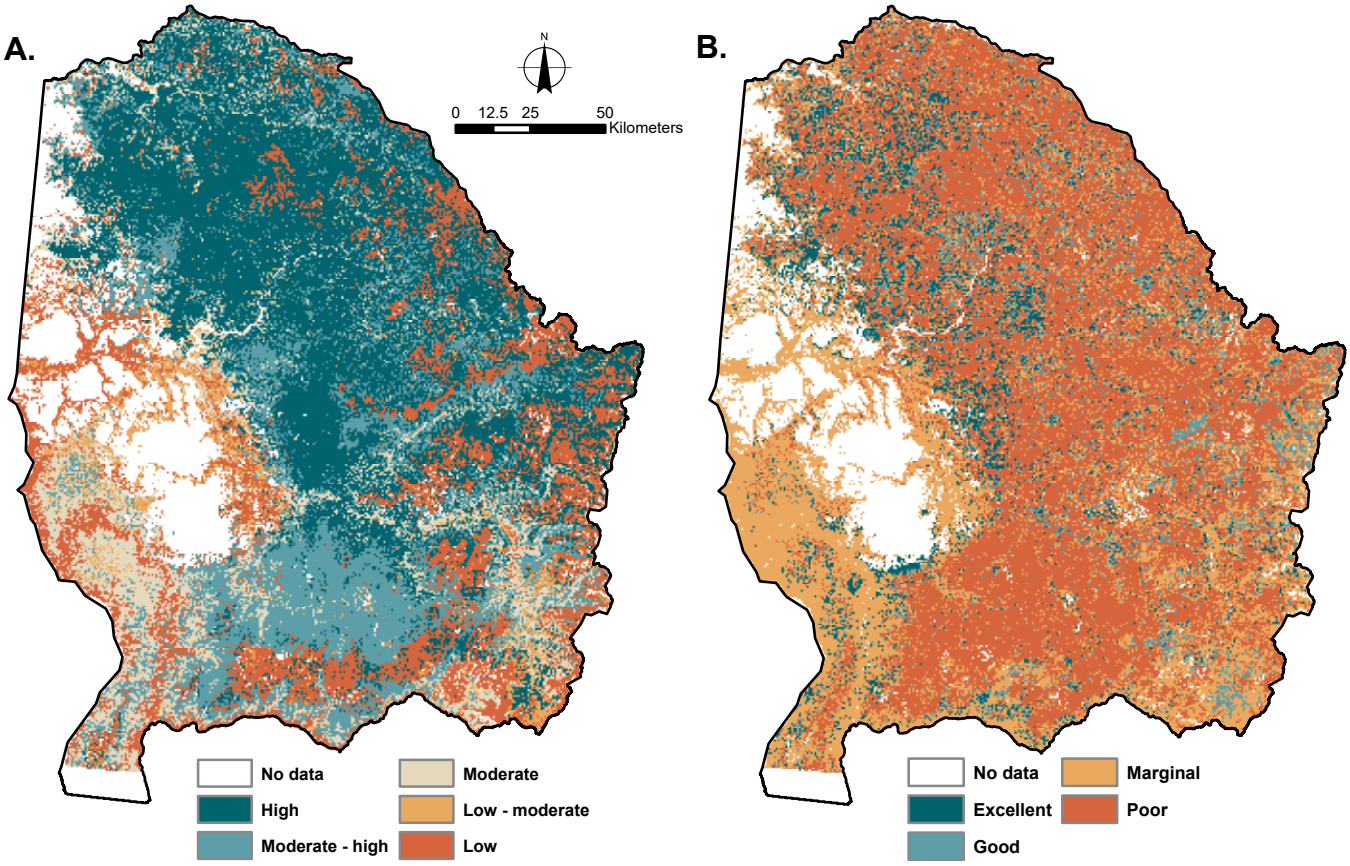

Figure A4.1—(A) Predicted nutritional capacity and (B) current (as of 2016) nutritional value in the Clearwater and St. Joe River basins in Idaho. Nutritional capacity reflects the potential for vegetation types to provide high-quality forage that satisfies nutritional needs of lactating elk in summer as a function of management (such as stand-replacing timber harvest or fire). Nutritional value reflects the current ability of sites to provide sufficient forage biomass and forage quality to satisfy the nutritional needs of lactating elk in summer. It is predicted based on stand age, overstory canopy cover, potential vegetation series, and other site attributes that currently exist on the site.

To develop current maps of nutritional value, we first predicted the biomass of accepted forage and community digestible energy (DE) and then converted these estimates to categories reflecting how well biomass and DE satisfy nutritional requirements of lactating elk in summer. We used generalized linear models with a gamma family and a log link function to model relationships between environmental covariates and our two forage response variables (biomass of

accepted forage species and community DE) for each of the seven potential vegetation series across the Clearwater and St. Joe River basins (Monzingo 2020). Gamma family and log link function methods are more robust than least squares regression to assumptions of normality and equal variance and eliminate predictions below 0. We used these models to predict community DE and accepted biomass for each pixel of our study area based on four primary environmental covariates: sampling date, overstory canopy cover, aspect-slope-latitude, and potential vegetation series. Sampling date and overstory canopy cover ranged from 5.9 (late May) to 10.25 (early October) (Cook et al. 2016, Monzingo 2020) and 0 to 100 percent, respectively. Slope, aspect, and latitude were continuous variables arithmetically combined using a folded aspect (i.e., aspect reflects the northeast/southwest latitudinal effect rather than the north/south effect) and equation 3 in McCune and Keon (2002) to develop a variable that reflected and is referred to hereafter as potential direct incident radiation. Models were created individually for each PV series, thereby allowing differences in forage attributes among PV series to be reflected in the models. After we created candidate models with all potential covariates, we conducted a corrected Akaike information criterion (AICc) stepwise regression (R package: MuMIn, R Core Team 2018) to select top models, i.e., those within two ΔAICc units of the model with the lowest AICc (Monzingo et al. 2020).

Based on top models (table A4.1), we predicted levels of community DE and accepted biomass in each 30- by 30-m pixel in the study area for August 15. We used ArcGIS and Program R (Vienna, Austria, R Core Team 2018) to develop the GIS rasters using packages: rasters (Hijmans 2022), rgdal (Bivand et al. 2022), and stringi (Gagolewski 2021). We used National Land Cover Database 2016–Tree Canopy for overstory canopy cover (Coulston et al. 2012) and created individual rasters for PV series and potential direct incident radiation. Given the significant effect of date on forage metrics (Monzingo et al. 2023), we chose a constant date (August 15) for applying our models to simplify the analyses. Late summer (i.e., mid-August) reflects a period when nutritional demands are still high for lactation, for recovery of body condition lost the previous winter, and to support rapid growth of calves (Cook et al. 2004). At this time, forage quantity should be near peak, and forage quality levels would be intermediate between late spring highs and lower levels in early autumn (Cook 2002).

We converted the predictions of accepted biomass and community DE to reflect nutritional requirements of lactating elk using four nutritional adequacy classes ranging from poor to excellent. The ranking was based on published requirement levels of DE levels in forage (kilocalories per gram) presented for elk by Cook et al. (2004) and relationships between forage intake rate and abundance of accepted forage based on several studies of elk in North America (fig. 3.1). The four categories were developed independently for community DE and accepted biomass (table A4.2) and served as the basis for developing our map of forage resources by reassigning to each pixel a nutritional adequacy class

Table A4.1—Models used to predict community digestible energy (kilojoules per gram of forage) and accepted biomass (kilograms per hectare) based on stand and environmental variables for seven potential vegetation series during spring-summer within the Clearwater and St. Joe River basins, Idaho

				Odds ratios[c]		
Potential vegetation series[a]	Forage resource prediction model[b]	N	Pseudo R^2	OCC	D	PDIR
Range/ponderosa pine DE	Exp[2.38]	52	NA	NA	NA	NA
Douglas-fir DE	Exp[2.69 – 0.03(D)]	57	0.15	NA	−2.96	NA
Grand fir DE	Exp[2.52 – 0.0007(OCC)]	67	0.15	0.07	NA	NA
Western redcedar DE	Exp[2.51 – 0.0007(OCC) – 0.01(D) + 0.12(PDIR)]	63	0.40	0.07	−1.00	−12.75
Western hemlock DE	Exp[2.54 – 0.002(OCC)]	32	0.43	0.20	NA	NA
Spruce-fir dry DE	Exp[2.65 + 0.0007(OCC) – 0.01(D)]	77	0.08	-0.07	−1.00	NA
Spruce-fir moist DE	Exp[2.74 – 0.03(D)]	46	0.15	NA	−2.96	NA
Range/ponderosa pine AB	Exp[5.47]	52	NA	NA	NA	NA
Douglas-fir AB	Exp[6.38 – 0.02(OCC) – 0.17(D) + 1.51(PDIR)]	57	0.31	1.98	15.63	−352.67
Grand fir AB	Exp[8.75 – 0.02(OCC) – 0.32(D)]	67	0.50	1.98	27.39	NA
Western redcedar AB	Exp[6.00 + 0.03(OCC) – 0.0006(OCC^2)]	63	0.66	NA	NA	NA
Western hemlock AB	Exp[6.24 – 0.03(OCC)]	33	0.56	−2.96	NA	NA
Spruce-fir dry AB	Exp[5.44 – 0.02(OCC)]	79	0.15	1.98	NA	NA
Spruce-fir moist AB	Exp[6.01 – 0.02(OCC)]	46	0.33	1.98	NA	NA

NA = not applicable.

Note: Models were created to develop study-area-wide maps of current (2016) forage conditions (Monzingo 2020: 168–190). Pseudo R^2 (i.e., approximation of R^2 values for generalized linear models; Smith and McKenna 2013) indexes the predictive ability of the equation.

[a] Potential vegetation series was separated by forage resource metrics (i.e., DE = community digestive energy and AB = accepted biomass).

[b] Variables were OCC = overstory canopy cover (percent), D = sample date [month # + (day of month/31.1)], PDIR = potential direct incident radiation (equation 3 in McCune and Keon 2002).

[c] Odds ratios (percent) could not be calculated for quadratic terms and assumes all other conditions were held constant.

Table A4.2—Categories of nutritional adequacy of forage based on community digestible energy (DE) content of accepted forage and biomass of accepted forage for elk (*Cervus canadensis*)

Metric[a]	Poor[b]	Marginal[c]	Good[d]	Excellent[e]
Community DE (kJ/g)	<10.8	10.8 to <11.5	11.5 to <12.1	≥12.1
Accepted biomass (kg/ha)	<150	150 to <250	250 to <350	≥350

[a] Community DE is the mean digestible energy content of high-quality portions (e.g., leaves without stems) of accepted plant species by vegetation community type, and accepted biomass is the amount of forage in plant species that elk consume in equal proportion to available or in greater proportion than available.

[b] Poor = levels that result in daily nutrition substantially below requirements of lactating elk and would substantially reduce their performance (Cook 2002; Cook et al. 2004, 2016). We consider areas ranked as poor to be nonforaging areas.

[c] Marginal = levels that approach or satisfy basic nutritional requirements for maintenance of body fat of lactating elk, where maintenance is defined as the level of nutrition required to prevent loss of body fat of lactating adults over summer. Particularly at lower levels of this category, growth rates of calves and yearlings and body fat levels of adult females would be substantially affected.

[d] Good = levels that modestly exceed maintenance requirements and support moderate accretion rates of fat and high pregnancy rates of lactating adults and good, but less than maximum, growth rates of juveniles (Cook et al. 2004, 2016).

[e] Excellent = levels that fully satisfy daily DE needs for virtually all life functions of calves and their mothers in summer (Cook et al. 2004).

based on the lower of the nutritional adequacy categories of accepted biomass and community DE. For example, we labeled pixels as "poor" if either accepted biomass or community DE was "poor," whereas we labeled the pixel as "excellent" only if both accepted biomass for that pixel was "excellent" and community DE was "excellent." These analyses provided a broad overview of prominent spatial patterns of the influences of disturbance and succession on forage resources in respect to the nutritional needs of elk.

To develop the map of nutritional capacity (fig. A4.1), we first ranked in a tabular format the summer nutritional capacity of the PV series that we evaluated in our study (table A4.3). For this, we divided the PV series into potential vegetation types (PVTs) as described in a "look-up" table in the Entity and Attribute Information section at https://www.fs.usda.gov/detail/r1/landmanagement/gis/?cid=fseprd1088576. The PVTs comprise a mapping system used by the USDA Forest Service Northern Region for land management and represent an amalgamation of ecologically similar plant association groups (i.e., habitat types) primarily described by Cooper et al. (1991) and composed at least 1 percent of the study area. For example, the grand fir PV series was divided into three PVTs (abgr1, abgr2, and abgr3), each of which consists of two to four plant association groups and differed by soil moisture, productivity, and plant composition. To be clear, our data were collected at the series level, whereas our mapping of nutritional capacity was based on the PVTs as defined in the "Entity and Attribute Information" section indicated above. This potentially represents a mismatch in resolution. Thus, to construct the matrix of nutritional capacity rankings by PVTs, we used a combination of field data of accepted forage biomass and community DE and our expert opinion that largely reflected many years of using tame elk and deer in foraging studies in the Northwestern United States.

We defined nutritional capacity as the combination of two factors: nutritional site potential and nutritional responsiveness to stand-replacing disturbances. Nutritional site potential represents the inherent productivity of each PVT within a series to provide forage resources adequate to meet the needs of a lactating female elk during late summer. This estimate is roughly analogous to site potential as defined by silviculturists (Ferguson and Adams 1980) indicating the productivity of tree species based on a combination of edaphic and climatological regimes. Nutritional responsiveness is the expected magnitude of response of forage quality and particularly quantity of forage to stand-replacing disturbances. For example, PVTs in the western redcedar series have both high nutritional site potential and nutritional responsiveness to stand-replacing disturbance (table A4.3), in agreement with our empirical nutrition results showing high forage abundance and forage quality in early-seral communities and very low amounts of forage in stands with closed overstory canopies. In contrast, the range/ponderosa pine series has low nutritional site potential and nutritional responsiveness to disturbance, while the Douglas-fir and grand fir series have intermediate but variable nutritional capacity,

Table A4.3—Summary of potential vegetation series and the overall nutritional characteristics for vegetation communities in the Clearwater and St. Joe River basins

Potential vegetation series[a]	Potential vegetation type (PVT) description[b]	PVT code[b]	Nutritional site potential[c]	Nutritional responsiveness[c]	Overall nutritional capacity[c]
Spruce-fir moist	*Abies lasiocarpa* moist type 2	abla2	High	High	High
Spruce-fir moist	*Abies lasiocarpa* wet type 1	abla1	High	High	High
Spruce-fir moist	*Tsuga mertensiana* without whitebark pine	tsme1	High	High	High
Spruce-fir dry	*Abies lasiocarpa* cold type 4	abla4	Low	Low	Low
Spruce-fir dry	*Abies lasiocarpa* dry type 3	abla3	Low	Low	Low
Spruce-fir dry	*Tsuga mertensiana* with *Pinus albicaulis* in ID only	tsme3	Low	Low	Low
Spruce-fir dry	*Tsuga mertensiana* (TSME2)	tsme2	Low	Low	Low
Western redcedar	*Thuja plicata* moist type 2	thpl2	High	High	High
Western redcedar	*Thuja plicata* wet type 1	thpl1	High	High	High
Western hemlock	*Tsuga heterophylla* type	tshe	High	High	High
Grand fir	*Abies grandis* wet type 3	abgr3	Moderate-high	Moderate-high	Moderate-high
Grand fir	*Abies grandis* moist type 2	abgr2	Moderate-high	Moderate-high	Moderate-high
Grand fir	*Abies grandis* dry type 1	abgr1	Moderate	Moderate	Moderate[d]
Douglas-fir	*Pseudotsuga menziesii* moist type 2	psme2	Moderate	Moderate	Moderate
Douglas-fir	*Pseudotsuga menziesii* cool dry type 3	psme3	Low-moderate	Low	Low-moderate[d]
Douglas-fir	*Pseudotsuga menziesii* warm dry type 1	psme1	Low-moderate	Low	Low-moderate[d]
Douglas-fir	Mesic species shrubland type	mesicshrub	Low-moderate	Low	Low-moderate[e]
Range/ponderosa pine	*Pinus ponderosa* type	pipo	Low	Low	Low
Range/ponderosa pine	Dry species shrubland type	dryshrub	Low	Low	Low
Range/ponderosa pine	*Festuca idahoensis* grassland type	fesida	Low	Low	Low
Range/ponderosa pine	Dry species grassland type	drygrass	Low	Low	Low

[a] As defined by Monzingo (2020) and Monzingo et al. (n.d.); see study area description herein.

[b] As defined at https://www.fs.usda.gov/detail/r1/landmanagement/gis/?cid=fseprd1088576 from the "Entity and Attribute Information" section of the online metadata (USDA FS 2004).

[c] Nutritional site potential is a relative qualitative ranking that represents the ability of plant communities to satisfy nutritional needs of lactating elk in summer during successional stages where forage is abundant (usually early-seral stands). Nutritional responsiveness is a ranking that reflects the extent of improvement the vegetation type is likely to experience after stand-replacing disturbance. Overall nutritional capacity represents a qualitative combination of potential and responsiveness. Rankings are primarily intended to reflect state of forage resources in late summer (August and September), when forage quality is declining yet nutritional requirements of elk remain high.

[d] For grand fir and Douglas-fir series, we ranked nutritional value of the drier PVTs modestly lower than that of the moister PVTs (in the same series) based on the assumption that forage quality declines more rapidly in late summer in the drier types.

[e] We have no data for the mesic species shrubland PVT, but we assumed based on dominant shrub species that nutritional value of this PVT is equivalent to the drier PVTs in the Douglas-fir series.

based on the associated differences in potential vegetation types composing these series. Based on forage quality and quantity data (Monzingo et al. 2023) and expert opinion of the authors largely based on extensive tame elk and deer foraging studies (Cook et al. 2014, 2016, 2018; Rowland et al. 2018; Ulappa et al. 2020; Wagoner et al. 2013) in the Northwestern United States, we classified nutritional responsiveness of each of our seven PVTs (table A3.3). Using this table, we assigned in a geographical information system nutritional capacity rankings for each 30-m pixel to construct the nutritional capacity map for our study area (fig. A4.1).

The nutritional capacity map (fig. A4.1) and table A4.3 can be used to plan and implement early-seral restoration based on proposed silvicultural or fire prescriptions. For example, a stand replacing wildfire may result in little or no improvement in nutrition of foraging elk in late summer and early autumn in the spruce-fir dry series (table A4.3). By contrast, the same wildfire in the spruce-fir moist series should provide substantial improvement in late summer and early autumn nutrition for elk at the highest level possible of any series. Similarly, regeneration harvest in the western redcedar series should result in similarly high improvement in elk nutrition, whereas this same silvicultural prescription in the Douglas-fir series would only be expected to provide a low to moderate increase. The nutritional value map can be used to identify areas where, under current conditions, forage resources are poor and in particular need of improvement on behalf of elk, or areas where recent stand-replacing disturbances have been sufficiently frequent such that additional improvement may not be overly beneficial for elk.

Thus, the combination of nutritional capacity and nutritional value maps (fig. A4.1) and table A4.3 can be used to assign spatial priorities for areas where a given set of silvicultural or fire prescriptions can be strategically assigned to obtain the greatest return on investment, e.g., to make decisions about where on the landscape a decision to let wildfires burn would yield positive returns versus areas where little nutritional benefit from wildfires would occur. This type of landscape evaluation would support planning for efficient and strategic early-seral restoration in time and space in line with available budgets and staffing.

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