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Invasive and native plant responses to shrubland fuel reduction: comparing prescribed fire, mastication, and treatment season

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ABSTRACT

Fuel reduction in the wildland–urban interface is a widely used international strategy for assisting human communities regarding wildfire threats, but very little research has examined whether certain fuel reduction methods and their seasonal timing promote nonnative invasion. To address this issue, we evaluated nonnative and native plant response to five of the most commonly-practiced shrubland fuel reduction methods in Mediterranean climates, including (a) fall prescribed fire, (b) winter prescribed fire, (c) spring prescribed fire, (d) fall mastication (slashing) and (e) spring mastication. Treatments were replicated four times in mature northern California chaparral and surveyed for three years after treatment; treatment type was randomly assigned. We found that the effects of treatment type (fire/mastication) were more apparent than the effects of treatment season (fall/winter/spring), but there were some differences among seasons of prescribed fire. Mastication treatments had the highest number of nonnative invasive species. Mastication treatments also had 34% higher nonnative annual grass abundance than the fire treatments. Winter and spring prescribed fire treatments were most resistant to nonnative invasion since these areas had the fewest nonnative species, lowest nonnative species abundances, and highest relative proportions of native plants. In shrublands where controlling nonnative annual grass is an important objective, managers should consider cool season prescribed fire as a viable fuel reduction treatment. In cases where prescribed fire is not feasible, mastication provides an alternative that can exacerbate nonnative grass production in the short term but may maintain native plant seedbanks over the long term if the site remains undisturbed for several decades. Results from this study could be applicable to other areas of Mediterranean shrublands.

1. Introduction

Fuels management has become a top priority in the wildland–urban interface in the United States (Stephens et al., 2009a), south-east Australia (Cary et al., 2003), and southern Europe (Camia et al., 2003) due to an increasing loss of homes to wildfire and the escalating costs of fire suppression. Strategic removal of flammable fuels can be part of an effective approach to help protect homes and communities from fire, but it can also facilitate nonnative species invasion (Briese, 1996; Keeley, 2001, 2006; Rossiter et al., 2003; Merriam et al., 2006).

Nonnative species invasion is considered one of the greatest threats to conserving native ecosystems because of its potential to alter species diversity (Di Castri et al., 1990; Vitousek et al., 1996; Chapin et al., 2000; Abbott and Burrows, 2003; Paynter and Flanagan, 2004; Franklin et al., 2008), change fire regimes (Mack and D'Antonio, 1998; Brooks et al., 2004), and convert shrublands to grasslands (Zedler et al., 1983; D'Antonio and Vitousek, 1992). Consequently, fire managers are caught in the middle of a difficult dilemma: how to preserve natural shrubland ecology while simultaneously protecting humans from wildfire (Burrows et al., 2008). Very little research has addressed this conflict, and managers need more information to determine whether certain fuel reduction strategies promote nonnative species invasion. To address research needs, our study compares native and nonnative plant response to two common shrubland fuel reduction practices (prescribed fire and mechanical mastication (slashing)) performed in three seasons (fall, winter and spring).

California chaparral has some of the highest native plant diversity and rare or endangered species of any Mediterranean ecosystem (Cowling et al., 1996; Keeley, 2005). In California, chaparral occupies only 6% of the state's land area but contains one-quarter of the state's native vascular plant species (Keeley and Davis, 2007). Periodic disturbance, historically in the form of summer or fall wildfire, is considered necessary to maintain a full suite of native chaparral plants because many species depend on fire cues (heat, smoke and charate) for germination. But recent anthropogenic disturbance, such as fuel reduction, is shifting the ecological

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balance from native fire-stimulated species to invasive nonnative annuals that invade from the nearby urban areas (Sauvajot, 1995; Eliason and Allen, 1997; Rundel, 2000; Keeley, 2006; Keeley et al., 2008).

Nonnative annual grass invasion along the wildland–urban interface has serious implications not only for native shrubland conservation but also for human safety and wildfire risk. Annual grasses have flammable fuel characteristics that can increase the probability of ignition near homes, expand fuel continuity between structures, increase rates of fire spread, and lengthen the fire season by curing earlier and persisting later than native species (Regelbrugge, 2000; Keeley, 2001; Brooks et al., 2004). In addition to presenting fire control challenges, annual grass invasion can magnify the risk of erosion and flooding since grass roots are much shallower and uptake less water than native chaparral vegetation (Mooney and Parsons, 1973; Spittler, 1995; Keeley, 2002).

Managers face tremendous pressure to control nonnative species invasion after fuel reduction (Keeley, 2006), but often select fuel reduction methods for their logistical ease rather than biological outcome partly due to a lack of research. Prescribed fire, for instance, is a frequently-favored fuel treatment because it can be applied to large areas of steep, complex terrain at a relatively low cost. Unfortunately, prescribed fire is often deemed unfeasible because of air quality regulations, public disapproval, weather constraints, or the risk of fire escape (Stephens and Ruth, 2005). Mechanical methods have become an increasingly popular fuel reduction alternative (Cary et al., 2003; Western Governors Association, 2006), but very little science has examined their ecological effects.

Seasonal timing of fuel reduction is another key management decision that is frequently swayed by operational considerations rather than conservation impact. Shrubland prescribed fire treatments are often performed in the winter or spring because escape risk is lower, air quality constraints are minimized, and personnel/equipment are more available outside of the wildfire season. But these wet season treatments can have detrimental effects on native obligate seeding species if fire intensity is too low to break physical dormancy or if seeds have imbibed water and become more sensitive to heat (Sweeney, 1956; Williams and Lame, 1999; Odion and Davis, 2000; LeFer and Parker, 2005). Dry season prescribed fires, on the other hand, may actually favor native obligate seeders by destroying the seedbanks of heat-sensitive nonnative annuals (Keeley, 1987; Moreno and Oechel, 1991; Beyers and Wakeman, 2000). Post-treatment plant germination, growth, and survival are strongly influenced by the timing of precipitation and temperature relative to treatment (Fig. 1) and should also be considered in fuel management decisions. In addition, natural seasonal fluctuations in resource availability, competition and seed dispersal can have pivotal influences on post-treatment plant recovery patterns (Horton and Kraebel, 1955; Florence and Florence, 1988; Meyer and Schiffman, 1999; Williams et al., 2003).

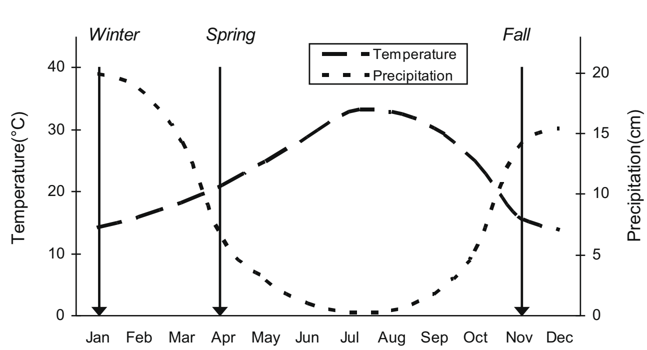

Fig. 1. Monthly temperature and precipitation averages for the study area. Arrows indicate the three different seasons of treatment implementation.

Early studies provide an important foundation for understanding plant community succession after disturbance (Sampson, 1944; Horton and Kraebel, 1955; Sweeney, 1956; Hanes, 1971; Mooney and Parsons, 1973; Biswell, 1974), but these studies often lack applicability to contemporary fuel management issues, particularly regarding mechanical methods and nonnative species invasion. Recent literature addresses nonnative species response to wildfire (Briese, 1996; Harrison et al., 2003; Keeley et al., 2005; Keeley, 2006), one or two seasons of prescribed fire (Dunne et al., 1991; LeFer and Parker, 2005) or fuel break construction (Keeley, 2001; Merriam et al., 2006), but the literature lacks a replicated comparison among prescribed fire, mastication, and season of treatment.

To address this research gap, we designed our experiment to compare nonnative plant response to five common fuel reduction treatments used in Mediterranean shrublands, including fall prescribed fire, winter prescribed fire, spring prescribed fire, fall mastication, and spring mastication. Winter mastication was not included because of limited road access and undesirable machinery impacts in wet soil conditions. In our study, we focus on three conservation questions: (1) which shrubland fuel reduction technique minimizes nonnative species richness and abundance (i.e. extent of invasion), (2) which technique minimizes the abundance of nonnative annual grasses (i.e. site flammability), and (3) which technique maximizes native species richness and abundance.

2. Methods

2.1. Study region

We conducted our study in chamise (*Adenostoma fasciculatum*) dominated chaparral of northern California's Coast Range, approximately 50 km inland from the Pacific coast and 175 km north of San Francisco, CA (39 N, 123 W). The research area experiences a typical Mediterranean climate with hot, dry summers and cool, wet winters (Fig. 1). Maximum mean temperatures vary widely throughout the year, averaging 34 °C in summer and 7 °C in winter. The 30-year rainfall average is 100 cm, with nearly all precipitation occurring between October–May. Annual rainfall during our 2001–2005 study averaged 99.0 cm and ranged from 90.7–124.5 cm. Treatment areas were located 700–1000 m above sea level on south and west aspects with slopes of 25–55%. Soils are derived from weathered sandstone and shale and are classified as shallow, rocky and moderately acidic. Fire and other major disturbances were absent from the study area for at least 40 years prior to treatment.

Our study sites are representative of California chamise chaparral, with chamise comprising >65% of the overstory vegetation, and buckbrush (*Ceanothus cuneatus*) and manzanita (*Arctostaphylos spp.*) occupying more minor overstory components. Pre-treatment vegetation averaged 1.5–2 m in height and nearly 100% shrub cover. Understory native herbaceous plants were uncommon in pretreatment conditions, and nonnative annual grasses were rare, occasionally occurring in gaps or along roadsides.

2.2. Study design

Each of the five fuel reduction treatments is replicated four times, for a total of 20 experimental units. Each unit is approximately two hectares in size and are distributed across a <2 km distance. Treatment type (prescribed fire/mastication) and season (fall/winter/spring) were randomly assigned to the experimental units, although mastication was restricted to sites with slightly