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Demography and management of two clonal oaks: *Quercus eduardii* and *Q. potosina* (Fagaceae) in central México

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Abstract

Quercus eduardii and *Q. potosina* are the most abundant tree species of the temperate forests of Sierra Fría, Aguascalientes, Mexico, in an area ranging between 2200 and 2600 m above see level. During the last century these clonal oaks were intensively exploited to obtain charcoal and firewood for local use; in addition, sections of the forest were transformed into grasslands for livestock. The effects of disturbance on the population dynamics of these species are poorly known. Therefore, a demographic study was carried out in order to: (a) evaluate the effects of disturbance on the population growth rate of these species; (b) assess the effects of inter-annual environmental variability on the long term population dynamics; (c) evaluate the relative importance of sexual reproduction and clonal propagation on population growth rate; (d) simulate the impact of different levels of tree harvesting on the population dynamics of these species, and (e) recommend a harvesting intensity, based on the information obtained above. Annual, mean and periodic matrices as well as stochastic simulations were used. These size-classified population matrix models also were employed to devise a schedule that maximizes the percentage of individual plants that can be harvested without affecting their population growth rates. For this reason specific entries of the matrices were modified to simulate different harvesting intensities. The study was carried out in two disturbed and two undisturbed sites during a 4-years period. Two plots were established inside each site; one plot was excluded from livestock and the other was left intact. Annual population growth rates were above or equal to unity in all sites, species and years, whereas mean, periodic and stochastic simulation matrix models showed no significant differences between species, years, sites or from unity, suggesting that logging and grazing did not have a negative effect on the population growth rate of these species. Both species produced clonal offspring during the 4 years of the study, but reproduced sexually only once, suggesting a masting reproduction. Elasticity analyses showed that the contribution of clonal propagation is more important than fecundity to the population growth rate of both species. Mean annual and periodic matrix models showed that extractions as low as 5% cause a population decline, while with stochastic simulations extractions of up to 5% are possible for both species; however, the environmental stochasticity will drive populations to local extinctions.

Keywords: *Quercus*; Clonal growth; Management; Matrix and periodic analyses; Stochastic simulations

1. Introduction

Oak species are numerous and widely distributed mainly in temperate zones of the Northern Hemisphere (Nixon, 1998; Rogers and Johnson, 1998). Of the approximately 500 oak species described, nearly 135–200 are found in Mexico (Rzedowski, 1981; Nixon, 1998) and of these, 85–115 are endemic (González-Rivera, 1993; Nixon, 1998), mostly in the centre and south of Mexico (Nixon, 1998). Pine and oak trees characterize the temperate forests in Mexico (Rzedowski, 1981; Challenger, 1998); oak forests cover 9×10^6 ha of its territory, mainly in the mountainous areas (Masera et al., 1997; Challenger, 1998).

Oak forests have provided a wide variety of ecological and economic services to human populations over the centuries (Challenger, 1998; Nixon, 1998). However, human activities have partially or severely disturbed many areas; consequently, the distribution areas of oak species have been reduced considerably, regeneration of populations of many species has been affected (Rzedowski, 1981; Hernández-Reyna and

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Ramírez-García, 1995; Reyes and Gama-Castro, 1995; Bonfil, 1998, 2006), and diseases have increased (Reyes and Gama-Castro, 1995; Peña-Ramírez and Bonfil, 2003). Traditional uses of oak forests for wood and charcoal, agriculture and livestock (Challenger, 1998) are often in conflict with increasing demands for recreation, landscape and habitat preservation. Few studies have been carried out on the population biology of Mexican oak species (Bonfil, 1998, 2006; Bonfil and Soberón, 1999; Tlapa-Almonte, 2005). Accordingly, management and conservation policies of most species are scarce or non-existent (Zavala-Chávez, 1990; Bonfil, 1998). Hence, an evaluation of their current status is urgent, particularly in areas where human activities have caused a deterioration of the habitat and a reduction of oak forests (Rzedowski, 1981; Reyes and Gama-Castro, 1995; Bonfil, 1998).

Matrix models have proven to be powerful tools to evaluate the demographic conditions of particular species (Leslie, 1945; Lefkovitch, 1965). They have been widely used to project the population growth of species with complex life-cycles and under different ecological scenarios (Caswell, 2001). Matrix models disregard temporal and spatial variations in environmental conditions, because they assume that vital rates do not change (Caswell, 2001). However, fluctuations in the environment do cause changes in vital rates and therefore, produce changes in population growth rates (Nakaoka, 1997; Golubov et al., 1999; Zuidema, 2000; Mandujano et al., 2001; Picó et al., 2002; Kwit et al., 2004; Valverde et al., 2004). Periodic and stochastic population matrix models consider the occurrence of such fluctuations in the environment (Cohen, 1987 in Caswell, 2001; Nakaoka, 1996; Tuljapurkar, 1997). These models are very useful for assessing the relative contribution of clonal growth and sexual reproduction on the population dynamics of species, as in the case of *Opuntia rastrera* (Cactaceae) studied by Mandujano et al. (2001); exploring population viability of endangered species, as in the cases of *Taxus floridana* (Kwit et al., 2004), and *Mammillaria magnimamma* (Valverde et al., 2004); simulating different disturbance conditions (Valverde et al., 2004); and recommending management (Zuidema, 2000; Ticktin et al., 2002; Hernández-Apolinar et al., 2006) and conservation strategies (Kwit et al., 2004).

Quercus eduardii and *Q. potosina* are two clonal oak species endemic to the mountains of central and northern Mexico (de la Cerda, 1999), and the most abundant tree species in Sierra Fría, Aguascalientes, Mexico (SEDESO, 1993; de la Cerda, 1999). These species were heavily exploited to obtain charcoal and firewood for local use during the period between 1920 and 1950 (Minnich et al., 1994). In addition, more than 37% of the original oak forest was fragmented due to tree fell (Pérez et al., 1995). Also, some sections of the forest were transformed for agricultural (1.66%) and grazing (6.17%) activities, therefore reducing the population size of these species (SEDESO, 1993; Minnich et al., 1994). Nonetheless, accurate estimates of the rates of loss, the size of oak trees harvested, and the amount of resprouting of stems cut are lacking. According to local residents, they felled whole trees in the past, but at the present time they cut branches or collect dead wood to cover their requirements. However, it is likely that illegal extraction is being carried out in Sierra Fría, as occurs in other temperate forests of Mexico.

To provide guidelines on the adequate management and conservation strategies of *Q. eduardii* and *Q. potosina*, the population dynamics of these species were studied over a 4-years period. During the 4 years of the study both species produced clonal offspring yearly, but produced acorns only once. Field observations carried out by Minnich et al. (1994) suggested that *Q. eduardii* and *Q. potosina* regenerated efficiently mainly by clonal growth. Regeneration in the area was also supported by the analysis of a series of aerial photographs taken from 1942 to 1993 that showed minor fragmentation in the area (Minnich et al., 1994). Thus, it is likely that these species regenerated through the growth of existing clonal offspring and the resprouting of stems cut that rapidly re-established the forest canopy. However, the role of sexual reproduction and clonal propagation on the population dynamics of these species is unknown.

In order to consider the occurrence of spatial and temporal variations, we used both time-variant and time-invariant models. The aims of this study were: (a) to determine the effects of disturbance (logging and grazing) on the population growth rate of these species; (b) to assess the effects of annual environmental variability on the long term population dynamics; (c) to determine the role of sexual reproduction and clonal propagation on the population dynamics of these species; (d) to simulate the impact of different tree harvesting levels on the population dynamics of these species, and (e) to recommend a harvesting intensity, based on the information obtained above.

2. Materials and methods

2.1. Study area

This study was conducted in Sierra Fría, Aguascalientes, Mexico (21°52′45‴–23°31′17″N and 102°22′44″–102°50′53″W). Mean annual temperature is 14.5 °C, and mean annual rainfall is 651.4 mm. Vegetation in the area are oak, oak-juniper or oak-pine forests at altitudes from 1900 to 2700 m (SEDESO, 1993; Minnich et al., 1994). *Quercus-Juniperus* forests are mainly dominated by *Q. potosina*, *Q. eduardii*, *Q. grisea*, *Q. sideroxyla* and *Juniperus deppeana.*

2.2. Study species

Q. eduardii is a red oak (*Lobatae*) and *Q. potosina* is a white oak (*Quercus*). Both species coexist in Sierra Fría, Aguascalientes (SEDESO, 1993; de la Cerda, 1999); they have similar trunk heights, ranging between 5 and 10 m, although some trees of *Q. eduardii* are 12 m in height. Regeneration of these species occurs by sexual reproduction (acorn production), and clonal growth (root suckers). Flowering occurs in May in both species (de la Cerda, 1999) and fructification between August and September in *Q. potosina* and between October and November in *Q. eduardii*.