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Effects of selective logging on the abundance, regeneration and short-term survival of *Caryocar costaricense* (Caryocaceae) and *Peltogyne purpurea* (Caesalpinaceae), two endemic timber species of southern Central America

Jorge Lobo [a,*], Gilbert Barrantes [a], Marvin Castillo [b], Ruperto Quesada [b], Tirso Maldonado, Eric J. Fuchs [c], Silvia Solís [d], Mauricio Quesada [d]

[a] *Universidad de Costa Rica, Escuela de Biología, San Pedro, Costa Rica*
[b] *Instituto Tecnológico de Costa Rica, Escuela de Ingeniería Forestal, Cartago, Costa Rica*
[c] *Department of Plant Biology, The University of Georgia, Athens, GA 30602-7271, United States*
[d] *Centro de Investigaciones en Ecosistemas, Universidad Nacional Autónoma de México, Campus Morelia, Apartado Postal 27-3 (Xangari), Morelia, Michoacán, México 58089, Mexico*

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Abstract

In this study, we determined the effects of selective logging on the abundance of the last remnant populations of two tropical timber species with a restricted distribution, *Caryocar costaricense* and *Peltogyne purpurea*. We conducted a census of adult tree densities for these species on 94 selectively logged sites located in a tropical rain forest on the Osa Peninsula, Costa Rica. We compared the abundance of juveniles and seedlings for both tree species on 11 logged and unlogged sites. In addition, we analyzed the growth and mortality rates of adult trees of *P. purpurea* (>10 cm dbh) in a 4 ha permanent plot that was selectively logged once in 1992. Both species presented a heterogeneous density distribution over the Osa Peninsula (166,668 ha) and the highest density of both species is located in the region of the highest logging activity. For *C. costaricense*, seedling (height < 50 cm) and juvenile (height > 50 cm, dbh < 2 cm) abundance was greater in unlogged areas, while trees 2–10 cm dbh were more abundant in logged areas. For *P. purpurea*, seedlings were more abundant in unlogged areas, but small and large juvenile abundance did not differ between selectively logged treatments. The density of *P. purpurea* adult trees remained constant 15 years after selective logging but the density of trees 10–30 cm dbh decreased in the same period. We predict that recurrent 15 year cutting cycles of 50% of timber trees with restricted distribution, as it is practiced by conventional logging in Costa Rica, may lead a significant reduction of the main reproductive individuals, decreasing the regeneration of the populations subjected to exploitation and fragmentation.

Keywords: Selective logging; Tropical forests; Plant demography; Rare species; Plant biogeography

1. Introduction

Selective logging has been denoted as the practice of harvesting the most important timber species in natural forests, allowing the remaining forest to naturally regenerate over time (Bawa and Seidler, 1998). The term selective logging has been used to describe different forest management techniques that range from large-scale mechanized tree extraction over large tracts of forest to local small-scale extraction using animal traction (Bawa and Seidler, 1998; Asner et al., 2005). Selective logging has been proposed as a possible strategy for timber extraction from tropical rain forests without the destructive nature of clear-cutting techniques (World Resources Institute, 1985). Nonetheless, because of the heavy machinery and techniques used by large-scale selective logging, its impact could be important in terms of biodiversity loss, commercial extinction of species, and vegetation and soil physical damage (Nepstad et al., 1999; Asner et al., 2005; Dauber et al., 2005). There is evidence that selective logging can damage the remaining trees in natural forests, compact soils and can alter

* Corresponding author. Tel.: +506 2075958; fax: +506 2074216.
E-mail address: jorgelobosegura@gmail.com (J. Lobo).

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potential habitats for regeneration (Uhl and Guimarães-Vieira, 1989). Regardless of the extraction technique, two main variables in selective logging include the proportion of adult trees extracted per species per area, and the frequency of extraction over time (i.e. cutting cycles). The regeneration of timber species after logging has been evaluated at the community level on the germination, survival and growth rate of juvenile and adult stages in logging gaps (Cannon et al., 1998; Costa and Magnusson, 2003). However, few studies have followed the demographic dynamics of timber species in remnant populations after logging (Guariguata and Sáenz, 2001). In addition, other aspects rarely considered in studies that evaluate the impact of selective logging include the degree of endemism of exploited species, fragmentation of remnant populations and the existence of genetic reservoirs other than the exploited populations.

Selective logging is a timber harvesting practice implemented in several tropical countries and it has been proposed as a successful alternative method for the sustainable exploitation of these complex natural communities (Bawa and Seidler, 1998). An example is Costa Rica, where a national forestry law allows selective logging of natural forests and receive a special payment for environmental services through the government. According to this law, private landowners are compensated for the environmental services provided by the management of natural forests. An analysis of this policy states that this program is designed to stimulate the exploitation of natural forests outside protected areas by investing the funds obtained for conservation in economic incentives for deforestation (Quesada and Stoner, 2004). This type of management typically eliminates about 50% of commercially viable trees with densities above 0.3 individuals ha^{-1}. The number of extracted trees varies greatly with the density of commercially important timber species, which is dependent upon the botanical composition of the forest, current value of timber and the methods of exploitation. In Costa Rica, between the years 1997 and 2001, a total of 116,250 trees were extracted under management plans (Varela, personal communication). In southern Costa Rica, many of the commercial timber species are endemic or restricted to southern Central America, and southwestern Colombia (Quesada et al., 1997). The forest cover in these regions had been dramatically reduced in the last 50 years (Maldonado, 1998), and the commercial exploitation of these species may threaten their demographic and reproductive future. Osa Peninsula in southwestern Costa Rica is one of the few remnants of rain forest along the Pacific slope of Mesoamerica and many of the tree species found in this region belong to northern South American taxonomic groups (Quesada et al., 1997). The timber species evaluated in this study, *Caryocar costaricense* Donn. Sm. and *Peltogyne purpurea* Pittier, are part of this taxonomic group. On the Osa Peninsula, the logging activity on these species has been focused on the largest individuals within local populations (Barrantes et al., 1999). Therefore, the study of the logging impact on these species provides important information for the conservation and maintenance of the logged species of southern Central America.

The objectives of this study are: (1) to determine the abundance of one of the last remnant populations of two important timber species currently used for selective logging along their geographical range, *C. costaricense* and *P. purpurea* in Osa Peninsula, Costa Rica, (2) to determine the effects of selective logging on seedling and sapling abundance for these two species 4–5 years after timber extraction, (3) to reveal short-term (15 years) population growth and demographic structure of the adult stage of a managed population of *P. purpurea*.

2. Methods

2.1. Study site

This study was conducted in a tropical rain forest at Golfo Dulce Forestry Reserve (61,702 ha), Osa Peninsula, southwestern Costa Rica (8°25′–8°50′N, 83°15′–83°45′W) which is connected by a natural corridor with Corcovado National Park (42,469 ha). The Golfo Dulce Forestry Reserve is a group of properties privately owned by approximately 450 peasant landholders; land use within each property is regulated by the Costa Rican Government (Claudine et al., 2003). The size of each property ranges from 5 to 400 ha. Although Golfo Dulce Forestry Reserve was created under a Government Decree in 1978, during the years 1980–1995, deforestation within the Reserve was approximately 1000 ha $year^{-1}$ and more than 65,000 m^3 of timber were extracted during 1996–1999 (Barrantes et al., 1999; Rosero-Bixby et al., 2002). Osa Peninsula has an extension of approximately 166,668 ha, where 108,049 ha were mature forest in 1995. Average annual rainfall ranges from 3500 to 5000 mm and the mean temperature is 27 °C. Soils at Osa Peninsula are predominantly ultisols with few areas of entisols on the north side of the Reserve (Weissenhofer and Huber, 2001). Seventy percent of the topography at Osa Peninsula is dominated by steep slopes with a maximum altitude of 782 m, 23% of moderate slopes and 7% of lowland plains near the ocean.

2.2. Study species

C. costaricense Donn. Sm. (Caryocaceae) is a Neotropical emergent tree with a distribution restricted to Costa Rica and Panama (Prance, 1976). In Costa Rica, *C. costaricense* is found in very moist forests along the Pacific coast from Herradura, Nicoya Gulf, to Osa Peninsula; the latter being the most important refuge of this species throughout its distribution (Quesada et al., 1997; IUCN, 2006). *C. costaricense* is generally found in well-drained hills and mountains with slopes between 15 and 30% (Jiménez, 1999). Flowering occurs between January and February and flowers are believed to be bat pollinated. The fruits are drupes with one seed averaging 4 cm diameter average size. Fruiting occurs between March and May, there is no information regarding seed dispersal.

P. purpurea Pittier (Caesalpinaceae) is a Neotropical timber tree, endemic to Costa Rica and Panama. In Costa Rica, *P. purpurea* is mainly found in the south pacific coast between