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The role of invasive pine on changes of plant composition and functional traits in a coastal dune ecosystem

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ABSTRACT

In this article we investigate how invasion by *Pinus taeda* L. alters plant community composition and functional traits in sand dunes. In invaded psammophilous vegetation in southern Brazil, we randomly selected 15 *P. taeda* individuals and measured their age based on the number of growth rings. For each tree, we sampled 1 m² quadrats beneath and 2 m away of its crown. In each quadrat, we assessed non-graminoid plant composition and performed a multivariate analysis of variance. Data on species–functional traits were scaled up to community level, and their variations were compared to tree age by linear regression. Species–composition and functional traits under *P. taeda* crown were different from control plots. Tree age affected the presence of thorns, potential height, and functional diversity. *P. taeda* individuals likely change the micro-habitat beneath their crowns, thereby benefiting species with some traits and increasing functional diversity of plants that are not characteristic of open dune communities.

Introduction

It is well documented that *Pinus* species are invasive worldwide (Richardson 2006). It has been found that some life history traits, such as short juvenile period and numerous small winged seeds, which characterize these species as pioneers in their native range, are also responsible for their invasiveness (Richardson 2006; Rejmánek 1996). Furthermore, *Pinus* invasion is more prevalent in low biomass ecosystems and communities with less competition with other tree species (Richardson & Higgins 1998). These characteristics make dune ecosystems, grasslands, and shrublands the most vulnerable environments to invasion (Richardson & Higgins 1998).

Dune ecosystems are characterized by high insolation and strong winds, strongly influenced by the sea and by severe disturbances, such as droughts and sand burial (Maun 2009). Dune species usually present characteristics of early

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successional stages, such as rapid colonization and great dispersal ability, while not adapted to low light conditions and competition (Tilman 1985). Therefore, dune communities are more susceptible to invasion by better competitors that are able to cope with such limiting abiotic conditions.

It is known that *Pinus* invasion can influence ecosystem processes by increasing shading and litter amount (Craine & Orians 2004). The release of leaf allelochemicals or root exudates may inhibit the development of plants under the crown (Fernandez *et al*. 2006). On its natural range, *Pinus* species are important in the ecological succession, from open dunes to woodlands, by means of nucleation (Maun 2009). So it is expected that a similar process may occur at the same kind of environment where *Pinus* is invasive, representing a new functional group introduced in the community and thus changing important ecosystem functions.

Changes in ecosystem processes can also arise from changes in the plant community and its functional patterns (Violle *et al*. 2007). Functional patterns are usually given by the species' functional traits. This approach is used for answering questions in community ecology that cannot be well treated using ordinary parameters such as species diversity and composition.

In the present article, we analyze the effect of *Pinus taeda* invasion on plant communities of coastal sand dunes. First, by determining the age *P. taeda* individuals, we were able to analyze the community shifts actually caused by the invader and not due to preexisting environmental conditions that affect both native and exotic species. By comparing communities under *P. taeda* trees of different ages, we investigated how time span since tree establishment is related to species composition shifts. Afterwards, a formal methodology was adopted for analyzing changes on the functional structure of plant community under invasion, evaluating convergence and divergence assembly patterns.

Material and methods

The study was performed at the Itapeva State Park (29º22'22"S, 49º45'06"W) in the highly endangered and vulnerable coastal plain of southern Brazil (SEMA 2006). The selected area had psammophilous vegetation on lowlands between the fore dunes and inland mobile dunes. *P. taeda* occurrence in the park is cited by SEMA (2006), but no precise information is given on how it was introduced. However, a population pattern of sparse individuals of many different ages indicates that the introduction was caused by invasion from adjacent areas.

We established a 100 x 100 m grid and, at each grid node (from a total of 131), we measured the tree height of all *P. taeda* individuals within a 25-meter radius from the node. The mapped *P. taeda* were stratified into three height classes (lower than 1 m, between 1 and 3 m, and more than 3 m), and five individuals were randomly sampled per stratum, totalizing 15 individuals. We determined the age of all 15 sampled *P. taeda* by trunk sampling and tree ring counting (Stokes & Smiley 1968).

We marked a 1 × 1 m plot under the crown of each sampled *P. taeda* and paired control plots of the same size, randomly located 2 m away from the crown limit of each tree (15 pairs). Preliminary observations indicated that the *P. taeda* trees in the dunes were less vigorous and had more open canopies than those in more benign environments, and there was no evidence of needle accumulation at 2 m away from the trees. Thus, we considered this distance sufficient to distinguish invaded from non-invaded communities, and closer plots more likely had similar environmental conditions before the invasion than distant plots.

The presence of all non-graminoid species in each plot was recorded. We used presence/absence data in accordance with Wilson (2012), who demonstrated that species incidence may give equal or better results than abundance data.

Data on species' functional traits were compiled from the scientific literature, information from specialists, and observation of herbarium specimens. The selected traits (linked to survival strategies) and their functional importance are shown in Table 1.

For the evaluation of an overall effect of *P. taeda* in community composition and functional traits, we performed a multivariate analysis of variance (MANOVA) with permutation test (Pillar & Orlóci 1996, Anderson 2001) comparing *P. taeda* to control plots. Euclidean distances, restricting permutations within paired plots (Pillar & Orlóci 1996), were used for this purpose. Compositional differences were accessed directly on

Table 1 - Traits used for the description of species found at psammophilous vegetation under *P. taeda* individuals. Functional importance follows Pérez-Harguindeguy et al. (2013).

Traits	Scale	Description	Functional importance
Spinescence	Binary	Presence of any kind of thorns cited in literature = 1, absence or non-cited = 0	Anti-herbivory defense, heat and drought stress protection. Also linked to creeping species
Pubescence	Binary	Notable hairiness cited in literature = 1	Protection against leaf drought and heating.
Maximum height	Centimeter	Maximum height cited on literature	Energy investment trade-off and light competition
Leaf area	Centimeter	Leaf width times leaf length	Light absorption per leaf
Leaf form	Centimeter	Leaf width divided by length	Wind resistance
Leaf edge	Binary	If serrated or indented = 1, if continuous = 0	Gas exchange capacity
Growth form	Expanded in binary (dummy)	Herb, forb, creeper, and tree	Resource use and perennating strategy