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Testing the importance of native plants in facilitation the restoration of coastal plant communities dominated by exotics

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ABSTRACT

Casuarina equisetifolia was introduced to China in 1897 from Australia to reduce coastal erosion. It grows vigorously and has spread over much of the southern and southeastern coast, from Zhejiang to Guangxi, over a range of more than 10° of latitude. To date, little is known about its interactions with native species in the coastal zone.

We used a field experiment to study how the understorey species diversity and soil conditions in monoculture stands of *C. equisetifolia* were influenced by different native plant species. We also examined the effects of interplanting native species on plant numbers, leaf area index (LAI), and aboveground biomass accumulation. We planted three native species (*Hibiscus tiliaceus, Melia azedarach* and *Calophyllum inophyllum*) at two initial densities in stands of *C. equisetifolia*.

Over a period of ten years, the density and aboveground biomass were relatively low in plots planted with three native species compared to plots that were not planted. In contrast, understory diversity and soil conditions were relatively high where native species were added. Moreover, the number of dead tree, aboveground biomass increment, and diameter growth had significant difference among different native tree species because of their different natural characteristics.

The fast-growing pioneer species, *M. azedarach*, had a positive effect on LAI, regeneration, shrub diversity and grass coverage than the other two native species, and *M. azedarach* was most effective in plots that were initially planted with higher densities. The pioneer plant *H. tiliaceus* had more individuals and greater aboveground biomass than others native species. The later-succession species *C. inophyllum* had the smallest effect on the development of understory vegetation and soil conditions over 10-yrs among three native plants. For different native planted species, *M. azedarach* showed good effects on the average annual aboveground biomass and DBH increment, and *C. inophyllum* had the least dead number in coastal environments.

In summary, *C. equisetifolia* and native species have facilitation relationships that differ according to the species, and coastal conservation managers should shift from their traditional focus on *C. equisetifolia* afforestation to the recognition of multi-species configuration.

1. Introduction

Native species are those that have evolved over geological time in response to physical and biotic processes that are characteristic of a particular region; these characteristics include the climate, soil, timing of rainfall, drought, and interactions with other species in the local community (Richards et al., 1998; Palmer et al., 2003; Callaway, 2007). These interactions shape the structure and function of communities and ecosystems (Wootton and Emmerson, 2005), affecting population growth and fecundity, abundance, geographical range, soil nutrient supply, community diversity and stability (Paige and Whitham, 1987; Maron, 1998; Novak and Wootton, 2010). Facilitation has long been recognised as a regulator of community organisation and as one of the most important positive community interactions (Bertness and Callaway, 1994; He et al., 2012). Facilitation also has applications to community restoration in harsh ecosystems (Brady et al., 2002). Because facilitation by exotic species is still debated (Simberloff and Von Holle,

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1999; Rodriguez, 2006), the majority of experimental and theoretical research on facilitation focuses on native species, even if the interactions are between native and exotic species (Losos et al., 1993; Bezemer et al., 2006; Zhang et al., 2012).

Exotic plants can change the composition and function of microbial communities, alter soil food web structures and influence nutrient cycling (Scharfy et al., 2010). These effects may arise from differences between native and exotic species in functional traits and allow exotic species to colonise and flourish in a habitat. Communities of invasive may be helpful in vegetation restoration, especially when the original community has been destroyed, but they are not usually the desired vegetation for the long term. To change the conditions of exotic-dominated communities, one promising approach is to find appropriate native species (or species groups) and use facilitation to adjust the structure and function of the current community.

Casuarina equisetifolia, native to the southern and eastern coasts of Australia, was introduced to Hainan Island China to reduce coastal erosion in the 1950s, and immediately became the dominant species due to its pioneer characteristics, including fast growth, adaptability to barren soils, and ability to resist wind (Hammerton, 2001). *C. equisetifolia* has special canopy characters such as whorls of tiny scales, fine cladodes and tower-shaped morphological structure. These phenotypic traits increase wind resistance and allow better growth in hostile coastal environments (Chen et al., 2005). However, due to its high tannin content, the branches and leaves of *C. equisetifolia* decompose slowly, which decreases the speed of nutrient return and influences the growth of forest. The litter beneath *C. equisetifolia* (made up of fallen cladodes) can build up to form thick continuous deposits, which simply by their presence smother other species and prevent establishment (Hammerton, 2001; Batish et al., 2001). In addition, machine-cultivated afforestation with monocultures of *C. equisetifolia* was once the sole management approach for protecting coastal forests and this approach destroyed the composition and structure of the original community along with the soil seed bank, causing native species to disappear from reforested lands. As a result, forest productivity declined and forest succession in the tropical coastal zone was arrested by the lack of native species (Wheeler et al., 2011). To change above conditions, three native tree species (see Table 1 – *Hibiscus tiliaceus, Melia azedarach* and *Calophyllum inophyllum*) that once thrived in the coastal forest were interplanted with one-year-old *C. equisetifolia* in the monoculture. Comparing the response by such native species to their shared neighbours can reduce the harmful effects of *C. equisetifolia* and help develop management strategies for native species.

In this study, we examine the effects through which these native species have interacted with *C. equisetifolia* during 10-yrs of succession in the tropical coast of southern China. Our general objective is to understand whether an exotic forest community can be changed by other native species. The specific objectives of this study were to determine: (1) how the understorey species diversity and soil conditions in monoculture stands of *C. equisetifolia* were influenced by different native species; (2) how the effects of different mixed afforestation on dynamics of planted species (number, LAI and biomass accumulation) as the forest developed.

2. Materials and methods

2.1. Site description and experimental design

The study was conducted in the northeast coastal zone of Hainan Island, adjacent to the South China Sea, in the monsoon tropics of south China (Fig. 1). Soils were coastal sand with the following general particle size distribution:>1.0 mm: ~6.15%; 1.0–0.5 mm: ~10.23%; 0.5–0.25 mm: ~27.17%; 0.25–0.1 mm: ~53.63%; <0.1 mm: ~2.82%. The soil structure was loose, with good permeability but low water-retention properties. The organic matter content (<0.15%) and nutrient elements were also low. The tropical marine climate ensures rainfall of 1720 mm annually and temperatures (over 24-hour) averaging 22–24 °C.

We initiated the experiment to examine the effects of planting native tree species (Table 1) along with *C. equisetifolia* on the process of tropical coastal forest succession and habitat restoration. We employed 7 planting levels: *C. equisetifolia* only, *H. tiliaceus* I, *H. tiliaceus* II, *M. azedarach* I, *M. azedarach* II, *C. inophyllum* I and *C. inophyllum* II (I indicates that the proportion of *C. equisetifolia* to native species is 1:1, a II indicates a ratio of 2:1). The experimental treatments were determined using a randomised block design with three blocks. Each block contained one replicate ($20 \times 20\ m^2$) of each planting level (Fig. 1). Within each plot, one subplots of $5 \times 5\ m^2$ were placed to survey species recruitment. For each plot, we investigated the number, LAI, the DBH (diameter at breast height) and height of planted species; for each subplot, we investigated composition and number of natural regeneration and shrub; moreover, the grass coverage and soil conditions (pH value, organic matter and total nitrogen) were also investigated in each subplot. All items were investigated every two years (2000, 2002, 2004, 2006, 2008, and 2010) with the exception of soil nutrient (only 2000 and 2010). The initial density of afforestation was 2500 stems per hectare (100 per plot). With time, the number of trees in each plot was changed because of factors such as typhoon, self-thinning, competition and herbivory.

2.2. Dynamics of planted species

Each species has a survival strategy for a hostile environment. In every experimental plot, the number of trees per hectare of planted species was recorded biennially (2000–2010) to document survival in the various experimental plantings. Moreover, the number difference of dead trees among treatments and tree species were also recorded at the same time.

Relative to other parts of a tree, the crown is always impacted most by the windy climate in a coastal zone. LAI the one-sided green leaf area per unit ground surface, was used to assess the canopy condition in the plots. Canopy photographs were taken in every plot in the vertical direction (Nikon + Fisheye lens) in late August, and the LAI index was obtained by a canopy analysis system from the photographs (Hemiview 2.1, Delta-T Devices Ltd., Cambridge, Britain).

Biomass, in ecology, is the mass of living biological organisms in a given area or ecosystem at a given time and is closely correlated with stand volume in forest surveys. Biennially (2000–2010), the

Table 1
Natural characteristics of three native tree species.

Species	Family	Succession stage	Tolerance			Growth	Body size	Litter
			Shade	Barren	Wind			
H. tiliaceus	*Malvaceae*	Pioneer	Medium	High	High	Middle	Small	Medium
M. azedarach	*Meliaceae*	Pioneer	Low	High	Low	Fast	Big	Heavy
C. inophyllum	*Guttiferae*	Later	Medium	Medium	Medium	Slow	Big	Little