

## Spatial distribution and regeneration of *Laurus azorica* in a laurel forest on Tenerife

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**Abstract.** We conducted a study to assess the spatial distribution of trees (>4 cm DBH) and the effect of these distributions in the regeneration of *Laurus azorica*. Univariate spatial analysis (performed with Ripley's  $K_1$ ) revealed that all species showed significant aggregation at short distances, but two groups could be differentiated: shade-intolerant species showed a significant trend towards aggregation at all distances (especially *Erica scoparia*) and shade-tolerant species only showed significant aggregation at short distances (*L. azorica* and *Prunus lusitanica*). Spatial analysis of trees using Ripley's bivariate  $K_{1,2}$  showed no significant differences in the spatial distribution of analysed species pairs.

Univariate spatial analysis for *L. azorica* seedlings revealed that in all the plots the distribution tended to be clumped up to 3 m and the remaining distances analysed also showed clumped distributions (10 m was the maximum distance analysed), except for two plots. For saplings, five plots revealed clumped distributions up to 3 m, and only two up to 10 m.

We suggest that the high rate of asexual regeneration by basal sprouts and the environmental conditions are the most important factors in the spatial organization of trees, seedlings and saplings of *L. azorica*.

**Keywords:** Ripley's  $K$ ; Sapling; Seedling; Shade tolerance; Spatial pattern.

**Nomenclature:** Hansen & Sunding (1985).

### Introduction

Spatial patterns of trees help reveal the nature of forest dynamics. They reveal aspects of canopy replacement (Horn 1975; Busing 1996), regeneration (Condit et al. 1992; Norton 1991), changes of forest dynamics under disturbance (Alekseev & Zherebtsov 1995; Vacek & Lepš 1996) and spatial relationships between tree species (Duncan 1991; He et al. 1997). Also, the spatial distribution of trees could be an important factor in the process of management of natural areas (Moeur 1993).

This paper describes the spatial relationships among the trees of the laurel forest and the spatial distribution of the most abundant sapling and seedling species of the laurel forest, *Laurus azorica* (Arévalo 1998).

### Material and Methods

#### Study site

The study was conducted in the Anaga Natural Park in the northeast corner of Tenerife, Canary Islands (28°19' N, 16°34' W). The park encompasses a 7 to 8 million year old basaltic massif (Ancochea et al. 1990) covering ca. 130 km<sup>2</sup> and representing 7% of Tenerife's area. We selected two stations in the park as representing the best conserved laurel-forest remnants of Anaga: 'El Moquinal' on the windward slope and 'Monte de Aguirre' on the leeward slope. We chose ca. 300 ha of the best conserved forest at each station.

The canopy height of Anaga's laurel forest varies between 10 and 20 m depending on slope. Dominant species include *Laurus azorica*, *Erica scoparia*, *E. arborea*, *Ilex canariensis*, *Prunus lusitanica*, *Myrica faya* and *Viburnum tinus* (*V. tinus* is a short understorey tree which occasionally reaches the canopy, so it was not considered a canopy tree in this study). Further information about the study site is given in Arévalo (1998).

#### Data collection

In June and July of 1996, we randomly selected four 625-m<sup>2</sup> square plots in each of the two sites with different altitude and aspect (plots 1 to 4 were situated in Moquinal and plots 5 to 8 in Aguirre). We defined 'trees' as stems of at least 4 cm DBH, 'saplings' as stems taller than 50 cm and less than 4 cm DBH with a sexual origin, and 'basal sprouts' as sapling-size stems of asexual origin (connections with parent stems, with some exceptions, were apparent). Previous studies recommended these classes in accordance with the physiognomy and phenology of this forest (Fernández-Palacios & Arévalo 1998). We mapped all trees, saplings and basal sprouts of the plots (with an accuracy of 0.05 m). A detailed summary of tree density, basal area and sapling and seedling density of the plots can be found in Arévalo (1998).

#### Spatial analysis

We studied the spatial distributions of canopy tree species categories with more than 10 stems per plot using the univariate  $K_1(t)$  function, which is the expected number of other individuals within a distance  $t$  of any individual, and the bivariate  $K_{1,2}(t)$  function, which is the expected number of other individuals of other species within a distance  $t$  (Ripley 1977). These analyses are effective in detecting spatial relations between points on a map (Bailey & Gatrell 1995) and are recommended when information of multiple neighbour (closest regenerative stems to every tree) distances are available (Busing 1996). The null hypothesis is the complete randomness of the spatial distribution of tree stems of one species for  $K_1(t)$  and complete randomness of spatial distribution of tree stems for each pair of species for  $K_{1,2}(t)$ . Because a minimum number of stems is required for carrying out these analyses, the number of plots in which we ran the analyses differs for the different species.

The spatial distribution of seedlings and saplings of *Laurus azorica* were analysed with the univariate  $K_1(t)$  function. For a graphical representation we used the transfor-

mation of the  $K_1(t)$  to the  $W_1(t)$  proposed by Szwaigrzyk (1992). This graphical display allowed us to visualize in only one curve which of the values of the index at different distances differ from a random spatial distribution (for  $p < 0.05$ ). When the spatial distribution of the stem at the given distance does not differ from a random distribution, the value of the curve at that distance is 0. When aggregation is detected, the values of the curve are positive (the value will increase depending on the differences among the expected value and observed value). Negative values of the curve indicate repulsion at the given distance.

## Results

The univariate spatial analysis revealed significant clumping for species at different distances (Table 1). All species showed significant aggregation at short distances, but two groups could be differentiated: shade-intolerant and indifferent species showed significant aggregation at all distances in the majority of the plots calculated (especially *Erica scoparia*) and shade-tolerant species only showed significant aggregation at distances  $< 2$  m (*Laurus azorica* and *Prunus lusitanica*). All the trees included in the analyses use asexual reproduction (primarily by basal sprouts), and consequently all the species are aggregated at short distances. Clumped distributions of trees have been observed in other studies (Okuda et al. 1997; Kohyama et al. 1994).

As to the spatial relationships between different tree species as revealed by the Ripley's bivariate  $K_{1,2}$ , no significant differences were shown in the spatial distribution of analysed species pairs and random distributions for all of the analysed distances.

Figs. 1 and 2 represent the values of the transformation  $Wt$  of Ripley's univariate  $K_1(t)$ . Figs. 1a and 2a show that the analysis of seedlings in all the plots revealed aggregation up to 3 m in all the plots, and except for two plots, the rest of them showed significant aggregation up to 10 m (the maximum distance analysed). For saplings (Figs. 1b and 2b), the aggregation distribution is not as consistent as seen in seedlings. Only five plots showed significant aggregation up to 3 m, and only two plots up to 10 m.

**Table 1.** Results of Ripley's univariate  $K_1(t)$  function analysis for species with a density per plot  $> 10$ . No significant repulsion has been detected in any of the plots. Data in the table indicate number of plots that showed significant ( $p < 0.01$ ) aggregation at the given distance.

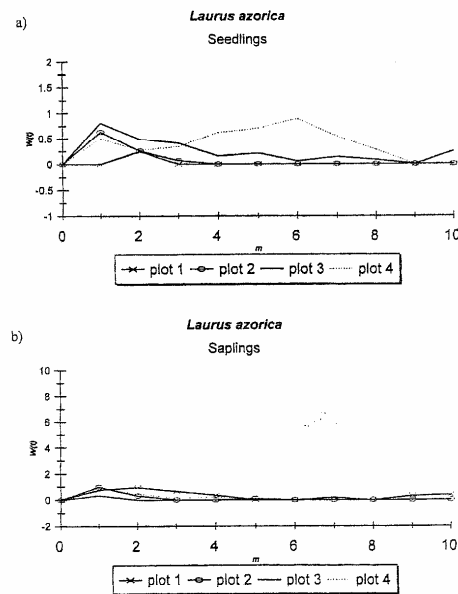
Species	Distance (m)	No. plots*									
		1	2	3	4	5	6	7	8	9	10
<i>Erica scoparia</i>		3	3	3	3	3	3	3	3	3	2
<i>Ilex canariensis</i>		8	8	8	7	5	3	3	2	2	2
<i>Laurus azorica</i>		8	8	4	2	1	0	0	0	0	0
<i>Myrica faya</i>		5	5	5	4	1	1	1	1	0	0
<i>Prunus lusitanica</i>		4	4	3	0	0	0	0	0	0	0

\*Number of plots where the analysis was developed. For the other plots the data were not sufficient to satisfactorily run the analysis.

## Discussion

Shade-intolerant species could be characterized by their dependence on light (*Myrica faya*) and the preference of the species (*Erica arborea* and *E. scoparia*) for a transitional habitat between laurel forest and pine forest or mountains peaks lashed by winds. The dependence on these habitats result in a clumped spatial distribution. The univariate spatial analysis placed *Ilex canariensis* in the group of shade-intolerant species. The effect of seed predators, herbivores, or pathogens is not documented, but since these factors should lead to spatial repulsion (Augspurger 1983; Clark & Clark 1984), our results suggest that they play a minor, if any, role. We assumed that the proximity of different or the same species would not affect the saplings' ability to reach the canopy as much as other factors (space, light, physiology of species). Asexual regeneration, mainly by basal sprouts in these forest, plays an important role in the spatial distribution of the trees.

The univariate analysis of spatial distribution of seedlings of *Laurus azorica* showed a strong trend of aggregation. This trend was less evident for the sapling class, and was almost non-existent for the trees, which maintained aggregation only at short distances due to the asexual regeneration. The change from significant clumped to significant regular spatial distribution with increasing age of the stems has been reported in different studies



**Fig. 1.** Values of the index  $Wt$  for seedlings (a) and saplings (b) in the four plots (1, 2, 3 and 4) of El Moquinal. The index was calculated every m up to 10 m.

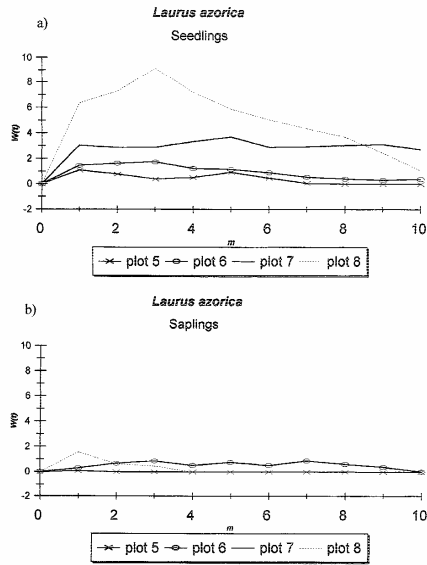


Fig. 2. Values of the index  $Wt$  for seedlings (a) and saplings (b) in the four plots (5, 6, 7 and 8) of El Monte de Aguirre. The index was calculated every m up to 10 m.

(Whipple 1980; Good & Whipple 1982). Significant regular distribution of the stems has been related with later successional stages of the forests (Oliver & Larson 1990), but in this forest, the high rate of asexual regeneration could be responsible for the lack of repulsion or random distribution.

With these results, we suggest that the environment could be a more important factor than species interactions on the spatial distribution of the trees, saplings and seedlings of *Laurus azorica*. The effect of the environment on the spatial distributions has been shown in other studies (Manabe & Yamamoto 1997). A low number of species could confirm this hypothesis for the laurel forest.

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