Spatial Distribution and Population Structure of *Zamia obliqua* in Pacific Coast, Chocó, Colombia

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Introduction

Zamia obliqua (Cycadales: Zamiaceae) is a beautiful understory long-lived plant with a large leaves set and rich gold new leaves, represented one of the oldest seed plants. *Zamia obliqua* extends from southern Panama to the southern Chocó of Colombia, deforestation for logging and expanding agriculture in the Chocó region could have a dramatic effect on *Zamia* populations.

Chocó region extends from eastern Panama along the Pacific coast of Colombia and Ecuador (figure). It is considered one of the most species-rich lowland areas in the word (WWF 2007). In the region, 20% of forest has been destroyed during the past years and the deforestation rate per year is near to 600 km2, the resource at river and coastal zones have been over-exploited for decades.

Plant populations in tropical forests are seriously affected by increasing deforestation and constant extractive activities. In South America, cycad populations are sensitive to habitat degradation and prone to extinction because the small effective population sizes, the isolation among the dioecity of the plants (male or female plants), and the dependence of Curculionidae beetles in the pollination process (Donaldson 2003). Reproductive failure contributes to declination of cycad population (Donaldson 2003). Particularly, *Zamia obliqua* is highly endangered in Panama as a result of habitat destruction (Stevenson 2004), in Colombia little is known about population status and life history.

In this study, the population structure and distribution of *Zamia obliqua* in an area of the pacific coast at Colombian Chocó was examined. The study goals were to: (1) analyze the distribution of the life cycle-stages according to environmental, distance and topographic factors, and (2) evaluate the conservation status of the studied populations and life history. There are an increasingly interests in documenting and understanding the spatial structure and population structure of plants in tropical forest, it is hoped that this preliminary results obtained provide valuable information for conservation and management guidelines that will allow efficient long term conservation actions.

Methods

Study species **Zamia obliqua**

Zamia obliqua is one of the most beautiful New World cycads (Stevenson 2004). *Zamia obliqua* is a forest understory species that is widespread in primary and secondary rain forest from near sea level to 500 m in southern Panama to the southern Chocó of Colombia (Donaldson, 1997). This species has arborescent habit and individuals up to 4,5 m tall can be found, bearing up to 90 long recurved leaves. Populations consist mainly of seedlings and juveniles; reproductive adults are uncommon (Stevenson 2004 and this study). Under field conditions, plant does regeneration and exhibit commonly vegetative branching (pers. obs.). Like all cycads, *Z. obliqua* is dioecious with male and female cones on separate plants. Between 3-6 male cones were found in three plants and 1-3 female cones in three plants, curiously all female plant were close. The female cones produced from 135 to 300 seeds (mean=241, n=8). During this study seed cones do occurred in larger (1.5 m) individual, but contrary to previous reports three male individuals and two female individuals were shorter than 1 m. Individuals with cones were only observed in gardens and backyards.

Study Area

The study was conducted in the Tribugá Gulf in the Chocó region of Colombia (figure 1). The Chocó region is one of the top biodiversity hotspots due to its levels of endemism, diversity, and biological complexity. Forests develop form the cost line up to the hills that can be 100 m high. The hills are small with smooth slopes and deep soils. Mangrove areas, flooded forests and non flooded forest can be found in level ground almost at sea level, and lowland Rain Forest is found in the slopes and top of the hills.

The study area is dominated by mountain forest, mangroves and “firme” forest. Elevation within the study area ranged from 0 to 100 m above sea level. Average annual rainfall is between 5500 and 9632 mm (El Amargal Meteorological station, IDEAM 1998-2003). The rainy season extends from August to October; dry months are from January to April. The area covers old growth forest with different levels of perturbation as consequence of extractive activities and patches of secondary vegetation can be observed. Three sites were visited during the field-work: “El Amargal” biological research station, Guachalito private reserve and Coquí surroundings (Afrocolombian communal land) (figure 1). The maximum distance between two sites was 11.5 km. Previous studies have shown that the best preserved forests are those located at “El Amargal” Biological Station, and the flora has been described in detail by Galeano *et. al* (1999?).

Field work

The sampling took place between September and October of 2007. One of the sites was at “El Amargal” biological research station, the selected area had a gradual slope having a high density of *Zamia obliqua* to establish a permanent rectangular 0.5 ha plot. Plot bisected *Zamia* population including the maximum number of individuals. Two contiguous quadrants of 50 X 50 m were established, each quadrant was subdivided into four sub-quadrants of 25 X 25 m. All *Zamia* individual was censured, permanent marked and referenced. Information of each individual found as number of leaves, caudex size, longitude of three new and two mature leaves and number of leaflets of these five leaves. Distance between individuals and percentage of leaflets missed by herbivory of the five selected leaves were recorded. Forest structure, canopy openness, conservation state was added.

In Guachalito and Coquí, field exploration included walks through paths. When an individual was sighted a circular plot of 25 m radius was established around it. Information of each individual found such as caudex size, number of leaves, longitude of longest leaf and number of leaflets, distance, and orientation between individuals was recorded. Percentage of leaflets missed by herbivory of longest leaf and report of the color of the new leaves was also included. Information about forest structure, canopy openness, and conservation state of the forest was added. If a *Zamia* individual was found outside the area another plot was placed contiguous to the previous one. Al the plots were geo-reference and its topographic position noted

Zamia individuals were assigned to different size class based on caudex size (seedling, presence of sarcotesta or/and one leaf, sapling 1-25 cm, juvenile 26- 99 cm, and > 1 m adult). Previous literature report *Z. obliqua* reproductive state to plant higher than 1 m (Stevenson 2001), nevertheless we have observed in backyard and garden shorter cone *Zamia* plants (Benavides A.M. & Zuluaga J.S., pers. obs). Despite this observation, we accord with the previous report because we do not have evidences for individuals into the forest). *Zamia* group or patch is defined in this study as a group of individual/s where each individual is far no more than 100 m.

During field exploration no reproductive individuals were sighted within the forest, nevertheless in gardens and backyards at Coquí and Guachalito beach, were founded individuals with female or male cones. Insect on male cone were collected. Additionally Lycaenidae caterpillars present in *Zamia* leaves were monitoring from pupa to adult state and butterflies preserved to entomological collection. Entomological and plants collections were deposited at CIB and Herbaria Universidad de Antioquia respectively.

Numerical analysis

Pearson correlation was used test the degree of relation between caudex size and morphological traits. To test for differences in forest and properties between forest age categories or sites, we used analysis of variance (ANOVA).

The response of *Zamia obliqua* to environmental variables was explored using indirect (Principal Component Analysis, PCA) and direct (Canonical Correspondence Analysis, CCA) multivariate gradient analysis. In these, *Zamia obliqua* values were present in the life-cycle stage abundance per group. In CCA, the independent variables were forest (ordinal, flatland or mountain), slope scale (ordinal 1=0^o , 2=1^o -15^o, 3=16 ^{o}-35^o, 4=>36^o) population size (nominal, number zamias), slope (nominal), forest stage (ordinal, secondary forest or primary forest), forest stage (nominal, ranked from 50 (secondary forest) to 100 (primary forest). For the numerical analyses were performed using MVSP (version 3.13) and CANOCO (version 4.0; ter Braak & Smilauer 1998). Multiple distances calculations among *Zamia* individuals were carried out, after compute geographic distances from latitude-longitude data, using the R package (Casgrain & Legendre 2001).

Results

General Pattern

Zamia obliqua individuals reached in this study a maximum height of 4.5 m and beared from 0 to 90 long recurved leaves (mean=7 n=836). Number of leaves, leaflest and longitude of longest leaf increase according with the caudex height (Pearson correlation 0.73, 0.65 and 0.59 respectively p<0.001). Five percentage of individuals present herbivory in its longest leaf. Butterflies were determined as *Eumaeus godortii* (Boisduval, 1870) Lycanidae.

Population distribution and structure

Zamia obliqua individuals tend to be aggregated; the 1010 individuals recorded in 107 plots (radius 25 m) were grouped in 26 patches or groups. The three larger groups compass 68% of the individuals found and half of the groups have less than 10 individuals. Isolated individuals were uncommon (4 individuals) and adult plants were more frequent in larger groups.

Population structure based on caudex size gave a reverse J-shaped curved for *Zamia obliqua* (figure 2). Seedling and juveniles with 768 individuals (92%) dominate the population profile adults (>1m caudex size) were uncommon.

Life cycle stages distribution related to environmental factors and distance

Zamia pattern show a shorter gradient length along first two PCA axes, indicating that groups share life cycle-stage. Nevertheless *Zamia* patches tend to aggregated according to the predominance of some of the life cycle-stages (figure 3A).

This pattern is more evident in CCA diagram, where each caudex size category is closer to its contiguous category. Indicating, as the factors affect in different way each caudex size category or each life cycle-stage. Analyzed by CCA, seedling was related to group size and primary forest, as well as to low slope. On the other hand, others life cycle stages could stand a more pronounced slope, less size group and secondary forests (Figure 3B).

The abundance of *Zamia* varies greatly across the landforms. Nevertheless, larger groups (177, 205 and 212 individual) were located in mature forest, no-flooded low-lying areas and elevated areas with moderate slope. No plants were located in mangroves and few individual were located close to a flooded area and elevated area with extreme slopes.

Distance among individual in the same caudex size category differ from seedling to juvenile and adult plants. (Table 1). Distance from seedling to juvenile increment to 11 m to 77-78 m and decrease to 25 m from juvenile to adult size class.

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community of Coquí. Dr Gerardo Lamas identified Lycanidae species (Director Museo de Historia Natural Universidad Nacional Mayor de San Marcos).

References

Casgrain,P. and Legendre,P. (2001). The R Package for Multivariate and Spatial Analysis. Département de sciences biologiques, Université de Montréal.

Figure 1. Map of Colombia showing the locations of the study sites at the Tribuga Gulf, Pacific Coast Chocó Colombia.

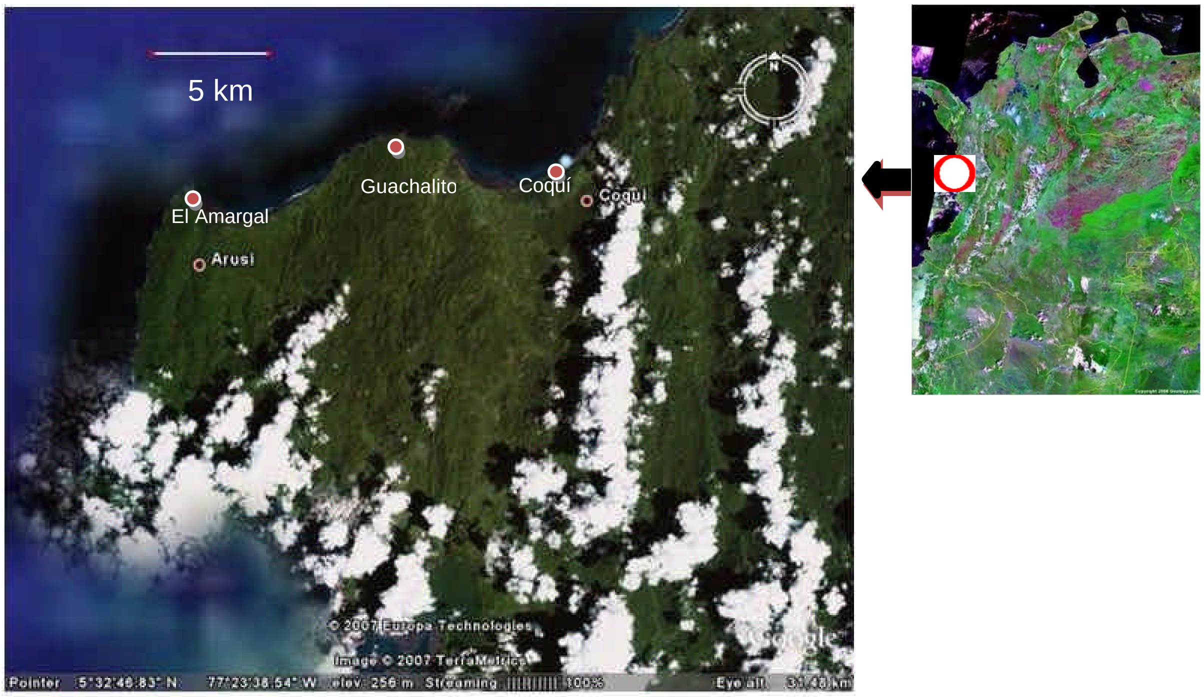

Figure 2. Population structure showing *Zamia obliqua* individuals per caudex size.

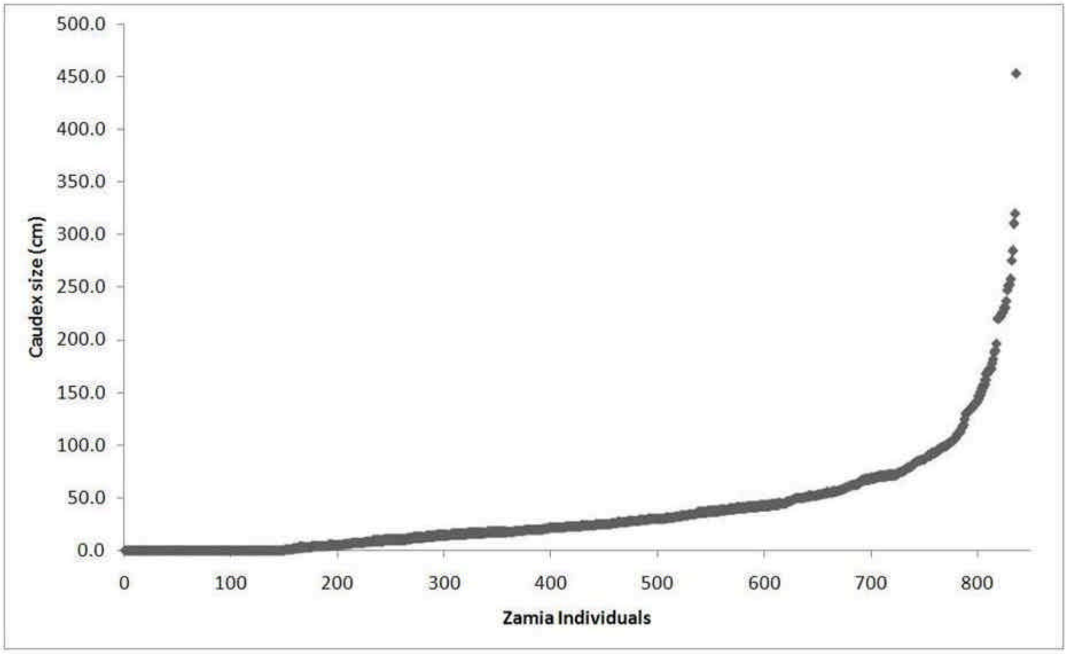

Figure 3A

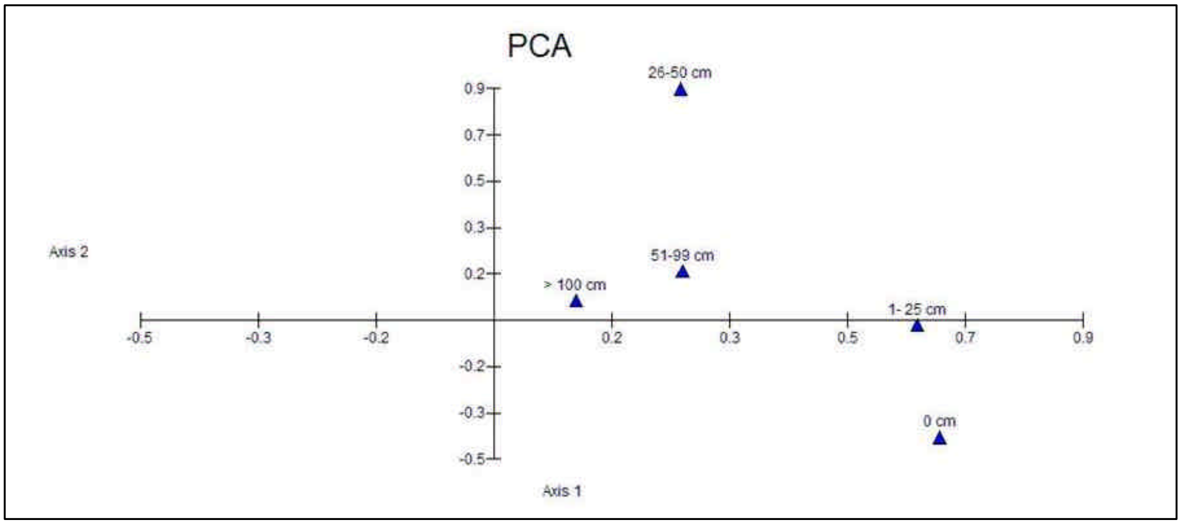

Figure 3B

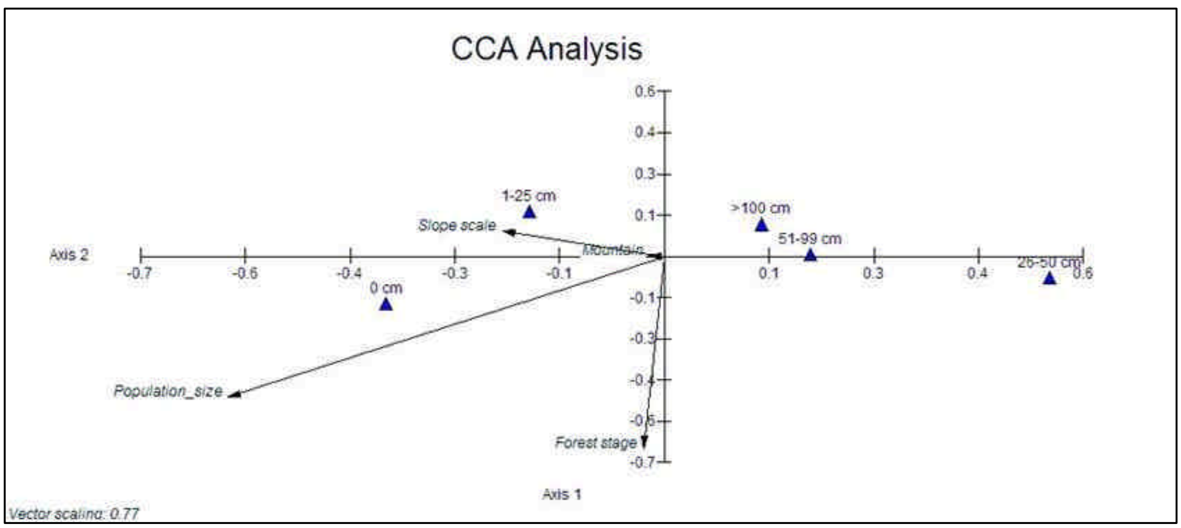

Table 1. Mean distance among *Zamia obliqua* individuals per each caudex size category.

Post Hoc Test

Tukey B[a,b]

catecaudex	N	Subset for alpha = .05		
		1	2	3
o cm	7720	12.0341		
51-99 cm	3502		52.2444	
> 100 cm	362		58.0768	
1-25 cm	5219			76.7662
26-50 cm	8776			77.4821

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 1435.515.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Appendix

Table present the *Zamia obliqua* individuals in each caudex size category per group

Group	0 cm	1-25 cm	26-55 cm	56-99 cm	> 99 cm
1	117	98	25	46	19
2	7	14	7	15	2
3	0	0	0	1	1
4	0	0	0	1	1
5	0	2	0	0	2
6	2	14	21	8	0
7	0	1	0	0	0
8	0	5	4	3	0
9	0	2	1	1	0
10	0	1	3	1	2
11	41	69	43	38	13
12	0	4	2	2	0
13	0	4	1	1	1
14	0	8	5	4	1
15	0	0	0	1	0
16	2	7	5	4	6
17	0	1	0	0	0
18	0	0	0	1	1
19	0	1	1	0	0
20	0	1	0	0	0
21	14	13	6	3	1
22	13	9	1	2	2
23	54	52	48	11	12
24	0	1	0	1	0
25	0	0	0	1	0
26	2	0	36	19	8