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Title:

Ecological studies for *Zamia obliqua* in the Chocó region of Colombia for supporting conservation initiatives

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Zamia obliqua (Zamiaceae) is one of the most attractive cycads from the neotropics, with a tall slender trunk and shiny elliptic leaves, typical of the understory of lowland rainforest of the Darien and Choco regions of Panama and Colombia. The plants can be up to 5 m tall, with a smooth grayish trunk bearing up to 20 leaves. Leaves can reach 2.5 m, with 10-20 pairs of leaflets that are almost perfectly elliptic, dark-green with finely serrated margins towards de apex. Male cones are cream and shorter than 10 cm, while females cones can produce between 150-300 seeds ad reach 30 cm of length. *Zamia obliqua* plants appear as clusters of tens to a few hundred individuals in the understory of the forest, with clusters of individuals separated by hundred of meters or sometimes kilometers.

In the Choco region of Colombia *Z. obliqua* is relatively common with many populations distributed from the border with Panama and along the Pacific coast on very humid rainforest on the ´Serrania del Baudo´ (a small coastal mountain chain parallel to the west chain of the Colombian Andes, from which is separated by the large Atrato river). Towards its northern distribution range *Z. obliqua* localities can be in close proximity of localities for *Z. manicata*, while towards the middle of its range localities for *Z. chigua* can be found. Nevertheless, localities for *Z. manicata* and *Z. chigua* tend to be away from the coast, and the probability of real overlap in the distribution of this Chocoan species is not certain. Towards the southern Pacific coast of Colombia, where the topography is flat and the coast is dominated by mangroves, other two species with this coastal and more inland distribution are found: *Z. roezlii* and *Z. amplifolia*. This group of species from the Choco region seems to be somewhat diverse in morphology

and some ecological traits, and exploring their population biology and abundance/distribution patterns should be quite interesting.

Zamia obliqua exhibits a local distribution pattern and population structure that seems to be typical of understory-dwelling cycad species of rainforests, i.e. a highly aggregated distribution pattern and clusters of individuals composed mostly by seedlings and juveniles and a few adults. Some ecological studies in neotropical rainforest cycads and other cycads suggest that the population growth rate depends mostly on adult survival (and less on adult fecundity), given the great longevity of individuals that keep contributing to population recruitment. Nevertheless, there is very little information on the patterns of population regeneration for rainforest cycads, that is on the environmental conditions adequate for germination and seedling establishment, the effect of biotic and abiotic factors on seedling survival and growth rate, or the impact of variation in seedling recuitment on the dynamics of populations. We have established permanent plots for population monitoring of *Z. obliqua* in a couple of localities in the Cabo Corrientes region of the Colombian Choco, and we plan to generate detailed biological information about the recruitment patterns and other aspects of population dynamics of *Z. obliqua* in the long-term, thanks in part to the support from The Cycad Society.

During a first phase of this study, we have explored the population structure, i.e the distribution of abundances of different stages of the life-cycle: seedlings, juveniles, and adults, and the spatial distribution of life-cycle stages in relation to environmental variables of the understory of the rainforest. To achieve this, we sampled a little more than 1000 individuals of *Z. obliqua* in two localities that have a landscape mosaic, dominated by relatively undisturbed mature forest, but that includes some patches of secondary forests, mangroves, and open land used for agricultural activities. We classified individuals in life-cycle stages based on trunk height and the number of leaves/leaflets in the plant. Abundance for each life-cycle stage was obtained from individual counts in 107 small (25 m radius) circular plots in one locality, and a large (100 x 50 m) plot in the other locality. In addition, we estimated the conservation status of the surrounding forest for each plot, by classifying the forest as primary or secondary state, and described some topographic features of the site. All individuals are permanently marked for long-term monitoring. We then conducted statistical analyses

(canonical correspondence analysis) to explore potential environmental factors associated with the presence of each life-cycle stage, in an effort to identify key features associated with the success of germination and seedling establishment in the populations.

As mentioned before, *Z. obliqua* showed the typical population structure of many rainforest cycads and other long-lived plants of the understory, with less than 10% of the individuals being adults, and a very high proportion of seedlings and juveniles. Clusters of individuals were separated from each other by at leas 100 m, and they can have wide variation in size, with clusters composed by a few individuals to clusters with almost 200 plants. The average spatial distance between adult individuals is ca. 50 m, while the average distance among seedlings is only 10 m. This population structure and spatial distribution is probably the result of restricted seed dispersal, common in rainforest cycads, the consequent aggregation of the seedlings, and the high mortality of the early stages of the life cycle. This is a common pattern found in tropical rainforest long-lived plants that produce a large number of recruits and have a risk of mortality that decreases as plants get larger in size.

The distribution of the different life-cycle stages showed some interesting patterns, that have been less explored for rainforest cycads, and that could provide some useful information for understanding population dynamics and therefore for the conservation of cycad populations. In particular, the behavior of the seedling stage was contrastingly different from that of juvenile and adults, as the presence of seedlings was associated with particular factors. Larger clusters, or groups with a large amount of plants, had a higher probability of produce seedlings. In addition, the presence of seedlings was associated with the conservation status of the forest, with the probability of finding seedling being greater in primary forest in comparison to secondary forests. Rainforest *Zamia* species seem to increase their seed production under the higher lit conditions of secondary forests, but the germination and establishment success of seedlings in these type of habitas has not been evaluated. We do not have data on adult fecundity for *Z. obliqua* populations yet, but our data so far suggest that the success of seedlings might decrease under the environmental conditions of secondary forests. These are interesting hypotheses that we plan to address in the near future as we continue studying *Z. obliqua* populations, and hopefully other rainforest cycads, in the future.

In addition to characterizing population structure and spatial distribution, the establishment of permanent plots for the study of *Z. obliqua* populations has generated useful information about the life-history and other ecological aspects of these cycads. We performed a preliminary estimation of the extent of herbivore damage for clusters of individuals for example, and found that in average only 5% of the individuals are attacked by the herbivore (*Eumaeus godortii* Boisduval, 1870, Lycaenidae, distributed from Costa Rica to norther Peru). The potential beetle pollinators were also collected. We are now beginning a leaf phenology monitoring, where we will try to establish weather these *Zamia* populations from a rainforest that has a less marked dry season (compared to Central American and Amazonian forests) show less synchrony in leaf production. Finally, we are now designing a detailed study with genetic and ecological research tools to explore the relative contribution of adults to the regeneration of the populations, which could provide further invaluable information on factors associated with the successful recruitment of *Z. obliqua* populations in the study site. The continuation of the cycad population research is also being supported by The Cycad Society.

Detailed ecological studies, like the ones described here, about crucial aspects of cycad population biology affecting the viability of populations can be used to generate adequate recommendation for cycad conservation. Furthermore, detailed information on the population dynamics of cycads can be used to explore the impact of potential management and also extractive stratagies in the populations. The local communities in along the distribution range of *Z. obliqua* and other species of Chocoan *Zamia* species are among the most socially marginated in Colombia. The local afroamerican human communitites in the region of Cabo Corrientes are interested in exploring the possibility of a local community nursery to propagate *Zamia obliqua* for the ornamental trade. Alongside the research project with *Z. obliqua* in Cabo Corrientes, we have involved local people and have organized community meetings as a way to exchange our knowledge about the biology of the species, and for exploring the possibility of developing future project integrating research, conservation, and use goals. Our long-term goal is to keep monitoring populations of *Z. obliqua*, to generate relevant biological information for conservation and for the potential use of this forest resource, that we think could contribute to improving the standard of living of local human

communities and provide incentives for the conservation of cycad populations and the rainforest in general.