Interested in Contributing to Cycad Conservation? Guidelines for Establishing Your Own Population Monitoring Program

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As highlighted by the *IUCN Cycad Action Plan*, the demography of cycad populations is poorly understood (Donaldson 2003). The IUCN/SSC Cycad Specialist Group (CSG), in collaboration with researchers from around the world, has produced an impressive account of population sizes for many cycad taxa throughout the world. One of the next steps we need to follow in the action plan is to carry out population-level studies to evaluate population viability in the short- and the long-term. Here, I describe how demographic studies work and the benefits they can provide for cycad conservation, and present some guidelines for establishing monitoring programs. I hope to encourage people with access to natural populations of cycads to begin their own monitoring programs, so they can contribute valuable information to the CSG and to the global conservation of cycads.

Demographic studies can be used to assess population viability in cycad species. In such studies the main goal is to estimate the population growth rate (i.e. if the population is increasing or decreasing in size) or extinction probabilities (given some assumptions are met). Although demographic studies are time- and labor-intensive, they are relatively simple to implement and can be very powerful tools for conservation. The fundamental challenge is to maintain an adequate monitoring program, where many individuals within a population(s) can be followed in the long-term.

The information produced by demographic studies can address a variety of issues in conservation. The models can be used to identify factors affecting population decline, to predict the long-term persistence of small isolated populations, to evaluate alternative conservation scenarios (e.g. restoration strategies), and to design sustainable exploitation programs, among others. Below, I describe how demographic models work and propose some general guidelines for standardizing such studies in cycad populations.

How demographic studies work

The first step in building a demographic model is to define the stages in the life-cycle that will be assessed. For plants, these stages are usually defined using measures of size rather than age. In cycad populations, the most basic stages of the life-cycle are seedling, juvenile, non-reproductive adult, and reproductive adult. In cycads, these stages can be determined based on leaf number, leaflet number, and/or caudex size as suggested by several studies (e.g. Clark and Clark 1987; Negron-Ortiz and Gorchov 2000).

The estimation of the population growth rate involves two parameters: survival and fecundity. Survival is estimated as the probability of plants changing their stage, e.g. the probability of seedlings becoming juveniles, over a set time period. Fecundity is estimated as the contribution of the adults to the seedling stage. These parameters are then built into a matrix that can be used to calculate the rate of population growth and to perform other statistical analyses.

The population growth rate is usually the most important piece of information produced by the demographic model, but there are some other useful outputs. For example, some quantification of the relative importance of adult survival versus fecundity can be obtained, allowing for the identification of the stages in the life-cycle that are most critical for population growth. Another possibility is to use the demographic model to evaluate the effect of alternative management strategies. For example, it is possible to use the model to evaluate how different seed harvesting regimes will affect population growth (e.g. see Raimondo and Donaldson 2003).

Estimation of demographic parameters in cycad populations

Gathering the data for demographic analyses can be labor intensive, because the model needs accurate estimations of survival and fecundity. Estimating these rates is not a trivial matter in cycad populations, but it is not impractical. Several years of such estimations would be preferable, since it is likely that demographic rates vary between years, and an estimation of the inter-annual variability is fundamental to improve the predictions of the model.

The data required for the demographic model can be obtained in one or more permanent plots in one or more populations. Within plots, all seedlings, juveniles, and adult individuals should be permanently marked. These plots can differ in size, according to plant density, but it would be best to have at least 100 individuals per life-cycle stage within them. These plots need to be monitored in even intervals of time. Since most cycad populations will produce seeds every year, monitoring the plots once a year will be appropriate. The best time during the year for the census will be the time after seed dispersal when germination is mostly completed.

During the annual censuses, the proportions of seedlings, juveniles, and adults that have survived from the previous year need to be recorded. Adult survival is extremely high in most cycad species; therefore accurate estimations of the adult survival rate may be difficult. Perhaps estimations can be improved by monitoring a large quantity of adult individuals (outside the permanent plots), but undoubtedly only very long-term data sets will allow us to adequately evaluate this aspect of cycad demography.

Estimation of the fecundity rate can be done, in the simplest way, by counting how many seedlings have germinated and survived (by the time of the census) from the pool of seeds that was produced in the previous reproductive season. If more detailed monitoring is possible, then the fecundity estimation can be partitioned into several items: the proportion of females in the population producing seeds, the average number of seeds/female, and the germination rate. These other aspects of the population are more difficult to explore, but fortunately they are not required in a demographic model (although they can be included). *In-situ* or greenhouse experiments--that try to mimic natural conditions as much as possible--could be used to address some of these aspects, e.g. germination rate (e.g. see Negron-Ortiz and Gorchov 2000), and could provide additional and valuable information on cycad demography.

Once estimates of survival and fecundity are available, data analysis can be performed using statistical packages designed for demographic analysis. It is in this stage when the expertise from the members of the CSG could help--by gathering data from monitoring programs in the field and analyzing these data in a standardized framework. Standardized data analysis and comparative studies will be an invaluable source of information for designing conservation strategies for cycads.

Finally, not only can demographic studies provide useful information for conservation, but within these studies, many other aspects of cycad biology can be explored. The permanent plots and periodic censuses that demographic studies require could be used to gather additional data, as this may not significantly increase the effort in the field. For example, data

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on the growth of new leaves and even herbivory rates can be obtained from marked individuals, or plots established in habitats with differing disturbance regimes could help us understand the role of disturbance on cycad biology.

An invitation to start your own monitoring program!

I hope I have demonstrated here that producing good demographic datasets is worthwhile, not only to improve our knowledge of cycad life history, but also for cycad conservation efforts. New and ongoing monitoring programs for cycad populations will produce invaluable information for evaluating population viability, for understanding the factors that affect population decline, and for long-term population management. The more information we have on as many different species as possible, the more tools we will have to develop sound conservation programs for cycads. That is why we want to encourage members of the cycad societies and cycad enthusiasts who have access to a cycad population to establish their own monitoring programs, so we can have loads of available data to analyze and to use in conservation planning. If you are interested in setting up monitoring plots to study cycad demography, please contact me or a member of the CSG for assistance. We can all contribute to generate information for cycad conservation, and have fun along the way by studying field populations of the plants that we all love!

Literature cited

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Fig. 1. Tagged plants in a long-term monitoring program of a Zamia fairchildiana *population in Costa Rica. Above: adult plant; below: seedlings.*