Palm Conservation at a Botanic Garden: a Case Study of the Keys Thatch Palm

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Botanic garden palm collections are among the world's best examples of *ex situ* plant conservation. Palm conservation collections are central to two botanic gardens in South Florida. Recent research funded by the International Palm Society sought to evaluate the effectiveness of garden collections in maintaining the genetic diversity of palms. Studies focused on *Leucothrinax morrisii* are reviewed here. For these botanic garden collections, maintaining more individual plants per population results in greater capture of genetic diversity. As the number of plants increases, the genetic diversity captured increases more slowly. Maintaining multiple accessions (i.e., progeny from more than one mother plant) helps to capture greater diversity, but for this case, the effect was much less significant than simply increasing the number of plants. Balancing genetic capture with efficiency of the garden operation is challenging, but best accomplished with specific data. *Ex situ* conservation remains an expedient and feasible strategy to ensure against extinction of palm species.

Palm collections have long been a beloved and celebrated part of botanic gardens worldwide (Fig. 1). In the Victorian period, major gardens invested heavily in the acquisition and care of palm collections. This is exemplified by the great Palm House, a central feature at gardens in Belfast, Brooklyn, Edinburgh, Frankfurt, Glasnevin and Kew. In frost-free parts of the world, outdoor palm collections are central to the visitor experience at Bogor Botanic Garden

(Indonesia), the Huntington Botanical Gardens, the Harold L. Lyon Arboretum and the Singapore Botanic Gardens. Palms reach a singular focus in the Palmetum of Santa Cruz de Tenerife (Canary Islands) and Palmetum of Townsville (Australia).

Traditionally for purposes of research, education and display, botanic gardens have greatly expanded their scope of work. One primary enlargement of the botanical mission is the work of plant conservation, especially since the late 20th century. To advance conservation goals, botanic gardens have worked in policy development, scarcity assessment, land stewardship, public outreach, climate change research and advocacy, student engagement initiatives, among many other areas. Recent calls for further broadening the scope of garden conservation have also been made (Dunn 2008, Chen et al. 2009, Donaldson 2009). All of these are important objectives.

Yet, a central and fundamental contribution of a botanic garden remains in the living collection of plants around which the institution has grown. For gardens, horticulture and botany are the areas of deep institutional skill, real physical capacity and authentic staff expertise. *Ex situ* (off-site) conservation is the area of conservation work that is both uniquely rooted in the garden tradition and is a unique conservation activity not served by most other organizations. Therefore, *ex situ* conservation is the modern, relevant, undiluted purview of botanic gardens and is a clear path forward for the 21th century.

Palm collections show many straightforward examples of the value of *ex situ* conservation. A leading example, *Hyophorbe amaricaulis*, survives as a single individual in Curepipe Botanic Gardens (Ludwig et al. 2010) and is thus extinct in the wild, (although the IUCN lists this species as Critically Endangered). *Corypha taliera*, also potentially extinct in the wild (Basu 1987, Dhar 1996, Maunder et al. 2001a), is maintained in four botanical gardens, with perhaps as few as 20 individuals left. Two individuals of *Pritchardia aylmer-robinsonii* remain in the wild, but at least 30 botanical gardens cultivate documented collections (Chapin et al. 2004). *Hemithrinax ekmaniana*, found on just two hilltops in central Cuba (Morici 2000), is now established and reproducing at Montgomery Botanical Center (MBC). These are just four readily recalled examples, and many others are provided by the IUCN Palm Specialist Group (IUCN 2010). Botanic garden collections are critical to species conservation efforts for most imperiled palm species. For this reason, we sought to assess and explore the effectiveness of this collection-focused conservation work.

1. The Montgomery Palmetum at Fairchild Tropical Botanic Garden. Colonel Robert Montgomery established the Coconut Grove Palmetum in 1932 and Fairchild Tropical Garden in 1938 (the two gardens are now known as Montgomery Botanical Center and Fairchild Tropical Botanic Garden). The first palm collection planted at FTBG, named in honor of Colonel Montgomery, sought to display the palm family's great diversity of form, texture, and color, and thus comprised great taxonomic breadth.

2. *Leucothrinax morrisii* living collections at MBC. Sandra Namoff (FTBG) and Sandra Rigotti-Santos (MBC) collected DNA samples from each plant in the living collection in August 2007. Adequate investment in mapping, labeling, and data tracking for each living collection ensures utility for *ex situ* conservation and for research purposes.

Two Gardens for Palm Conservation

Colonel Robert Montgomery worked with some of the world's most talented botanists and conservationists to establish two important palm collections in South Florida. From 1932 forward, the Colonel developed a leading palmetum, now known as MBC, and from 1936 forward developed a leading public garden, now known as Fairchild Tropical Botanic Garden (FTBG). Located less than one mile apart, these two botanical institutions together may represent the world's densest concentration of cultivated palm diversity, with over 500 palm taxa on 200 acres. Since the 1930s, these gardens have grown to emphasize complementary areas of work.

Recently, the authors assessed the specific assets and needs of both gardens with regard to *ex situ* conservation. Specifically, we aimed to leverage the conservation protocols and collections management of MBC palm collections and the laboratory expertise and infrastructure of the joint molecular systematic laboratory of Florida International University (FIU) and FTBG in order to explore a fundamental question for gardens: How many plants should a garden maintain, if the collection is designated for conservation purposes?

Designing a model system

By carefully considering this question, we determined that prior work placed the authors

Table 1: *Leucothrinax morrisii* accessions from Big Pine Key, Florida.

MBC Accession	Number of plants
951261	8
951262	11
951263	3
951264	1
951266	6
951268	3
951269	14
951270	3
951456	1
951457	4
951459	5
Total	**59**

in a favorable position to explore strategies for *ex situ* palm conservation. There was one model group available which was an exceptionally good fit for the question. *Leucothrinax morrisii* is a familiar palm species from the Caribbean that occurs over many island groups (Zona et al. 2007). Yet, in Florida the species is found in a limited geographic range and is considered Endangered within the state (Coile & Garland 2003). Further review of the biology of this species showed some other advantages for our study. *Leucothrinax* is a long-lived perennial plant, pollinated by wind, monoecious and pleonanthic. So, it is very generalized in its biology, making the data generalizable to a broader group of other species that are of conservation interest – all traits of a good model system.

As part of MBC's renewed collections development work beginning in the 1990s, extensive living palm collections were developed (Zuckerman 1997). Montgomery Botanical Center maintains a robust living collection of *L. morrisii* from a single collecting event at a single locally abundant population. While performing research fieldwork in October 1995, Larry Noblick, Bill Hahn and Laurie Danielson collected seeds of *L. morrisii* in the Florida Keys, Monroe County, Florida (*Noblick 5075*, *5077* and *5078*, FTG). The team collected seeds from 11 different mother plants and accessioned them separately. Those seeds germinated and grew, and the majority of the resulting palms left the nursery to be planted on the grounds in 2000 and 2001, with a few others planted in 2004. Currently, 59 plants are maintained in the living collection at MBC from that fieldwork (Fig. 2), and the plants can be traced back to their respective half-sibling groups, through independent accession numbers (Table 1). So, these plants comprise a well-documented, robust number of living ex situ palm collections from a single collecting event from one population, making an ideal test case for the research.

In the last decade, research developments at FIU and FTBG positioned the team to bring new tools and techniques to bear on this question (Francisco-Ortega 2003). Recent focus on the conservation mission between FIU and FTBG directed the team to augment strengths in plant molecular systematics with population-level genetic approaches (e,g, Cariaga et al. 2005). With a robust tradition in palm research, this approach was leveraged for research in Arecaceae (e.g., Roncal et al. 2007). One ongoing project at that time looked at genetic diversity within *Coccothrinax argentata* in South Florida using Inter Simple Sequence Repeat (ISSR) markers (Davis et al. 2007). Other molecular analysis showed a close relationship between *Coccothrinax* and *Leucothrinax* (Lewis & Zona 2008), so the team saw potential in adapting these population genetic approaches to answer our *ex situ* conservation question.

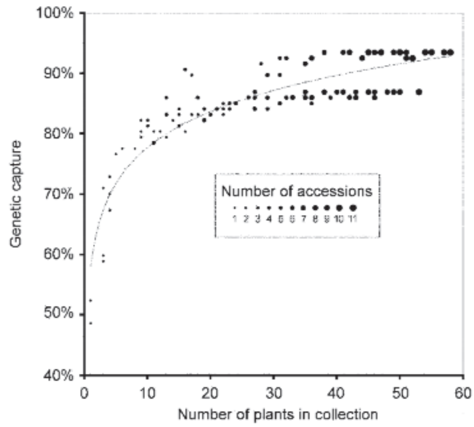
Having determined a suitable test case and an assessment tool – *Leucothrinax* and ISSR DNA

Table 2: Definition of terms used for groups of plants in this case study.

Accession An individual or group of plants from the same collecting event, assigned a unique number for tracking purposes. MBC accessions are from the same mother plant. Therefore, this represents a group of siblings or half-siblings. Accessions at MBC can be of variable size (see Table 1.).

Collection A group of plants brought together for a purpose, or an individual plant in such a group, or the act of bringing an individual into such a group, for example, the *L. morrisii* plants cultivated in the garden that were used for the DNA study (n = 59).

Population A group of individual plants of the same species inhabiting a certain area, for example, the *L. morrisii* plants growing on Big Pine Key used in the DNA study (n = 100).



3. Genetic capture for collections of various sizes (adapted from Namoff et al. 2010). The x-axis shows the number of palms in each resample, and the y-axis shows the observed genetic capture for that re-sample. The size of the points represents the number of accessions (see Table 2) in each re-sample. As the collection size increases, the rate of increase in genetic capture diminishes. The curve represents the logarithmic fit of the points (R = 0.83).

microsatellite data – the team designed a way to approach the question. We proposed a fairly simple data gathering strategy: revisit the original field site, collect 100 DNA samples from the parent population, collect DNA samples from the garden collection at MBC and gather data with the ISSR techniques used by Davis et al. (2007). We would then compare the collection to the population to see how effective the MBC *ex situ* conservation protocol is at conserving genetic diversity.

Exploring the Question: How many plants to grow?

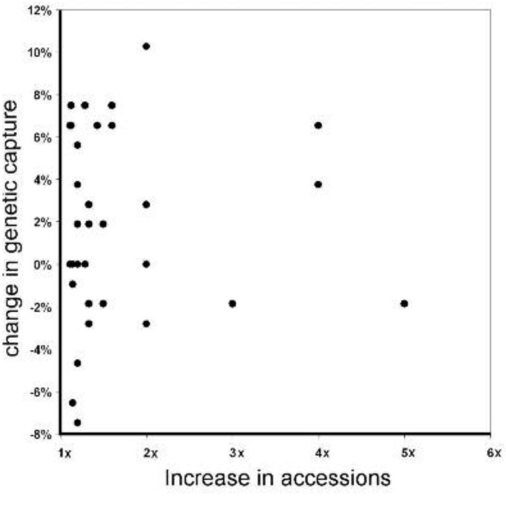
The methods and results of this investigation (Griffith & Husby 2010, Namoff et al. 2010) can illustrate some principles for managing palm conservation collections, and these findings could potentially be generalized more broadly. The results have a specific bearing on the work of MBC and allow for an assessment of current practice. The results are detailed below within the context of general principles and recommendations. To clarify terms used in this case study, please see Table 2.

Single individuals and multiple plants capture genetic diversity.

Many garden collections are designed for taxonomic breadth (Dosmann 2006). These synoptic collections are essential educational and outreach resources. The fundamental method of developing such collections has been to fill in taxonomic gaps, often with single specimens. Ever since studies for crop resource planning have employed models based on maximizing genetic diversity (Gale & Lawrence 1984), garden conservation collections have been more often structured to include representative population samples. Recommendations on sample size are especially well developed for seedbank work (Guerrant et al. 2004), yet are lacking for the typical botanic garden flora. For plants with recalcitrant seeds, like most palms, garden cultivation is essential. Given the much larger amount of space needed for mature plants, maintaining viable population sizes in cultivation requires significant resources.

We examined the relationship of sample size and genetic capture through random re-samples of the collection (composed of entire half-sibling groups) compared to the wild population. In our case study, the following principle holds true: more individual plants maintained gave a higher percent of genetic capture (Fig. 3). Importantly, though, a single-specimen collection recovered about half of the alleles that we found in the wild population – going from no specimens to a single specimen gave the single biggest

4. Effect of collecting seed from multiple mother plants (adapted from Namoff et al. 2010). To investigate the effect of accessions breadth, we compared re-samples with the same number of plants but with different numbers of accessions represented. The average effect of increased accessions breadth was positive: the 95% confidence interval for increased accession breath did not include zero (0.45%, 3.11%). The overall contribution of increased accession breadth is less significant than increased collection size.



increase in genetic capture. So, objectively reading the numbers, even a synoptic collection is better than no collection, where conservation is concerned. Increasing from a single specimen to more than one gave the next biggest increase in genetic capture.

The basic parameter we sought to evaluate here: how many plants should we maintain per population to capture adequate diversity? The MBC collections policy has long recommended maintaining a collection of 15 palms to represent each population, with at least 3 accessions represented. In this case study, the current protocol would capture around 83% of the genetic diversity of the population. This finding has direct bearing on our work. MBC seeks to preserve a high proportion of population genetic diversity, so these data confirm that we should continue to maintain collections of at least 15 plants per population or perhaps more if resources allow. As shown in Figure 2, the rate of increase in genetic capture slows as the number of plants maintained increases. This is discussed further below.

Multiple accessions may not be as important as number of plants.

For this case study, we structured the random re-samples to be composed of entire half-sibling cohorts (i.e., accessions, or seeds collected from the same mother plant); the half-sibling groups were not split up, regardless of the number of individuals in each group. This gave the data set an additional parameter to explore: does collecting seed from multiple plants give better genetic capture than collecting seed from one plant? This can be explored by examining paired comparisons of re-samples that have the same number of plants, but different numbers of accessions (Fig. 4). Our finding here was that on average, increasing the representation of different half-sibling groups gave a positive increase, but the increase was much less significant than simply increasing the number of plants in the collection. One inference here is that *L. morrisii* appears consistent with a panmictic mating system (no assortment of paternity), as expected for a wind-pollinated species.

For plants of different life histories and different biology, this relative unimportance of accession breadth may or may not hold true. Dioecious palms, plants with shorter life histories, palms with very limited numbers or insect-pollinated species may assort paternity to some degree, and therefore making collections from multiple accessions could be more important.

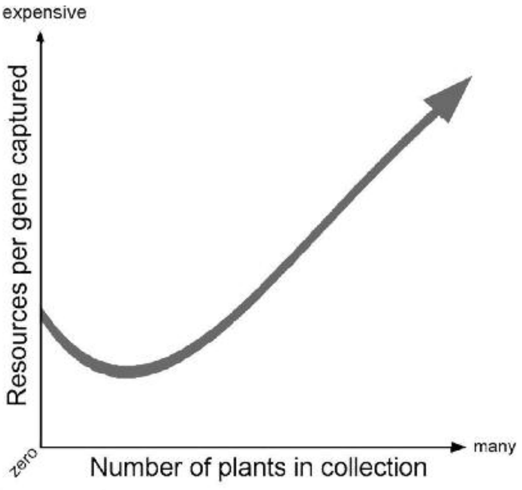
Garden conservation collections have a point of maximum efficiency.

Resources for accomplishing the work of botanic gardens are limited. Therefore, exploring these data in contrast with resource expenditures can help allocate work with greater efficiency. As noted above, the genetic capture increases at a slower rate as the number of plants in the collections is increased (cf. the "law of diminishing marginal returns"). A section of this study looked at the genetic capture curve (Fig. 3) and compared this to financial spending data from MBC over a ten year period (Griffith & Husby 2010). The cost of maintaining any individual plant at a botanic garden includes the initial costs of collecting fieldwork, followed by all direct horticultural and record keeping costs (including personnel), but not administration or overhead. We measured efficiency as the unit cost of genetic capture; i.e. for each collection of a certain size, the cost of maintaining that collection divided by the percent genetic capture (Figure 6). After the initial investment in bringing collections into the garden, there is a great increase in efficiency (lower unit cost), a most efficient collection size (lowest unit cost) and then a steady decrease in efficiency (higher unit cost), as the collection size increases. In the *Leucothrinax* study, the most efficient collection size was around 5 plants, and a collection of 20 plants was as efficient (same unit cost) as a single plant. This efficiency appears to be determined more by the population genetic side of the equation than the financial side.

Other circumstances can make a big difference.

By design, this case study is for a single population of a single palm. Great diversity of circumstance can make other strategies necessary. In one of the examples mentioned above, *Corypha taliera*, it may be wise to grow as many individuals of these as possible, given the great paucity of known plants and the current lack of genetic data. Additionally, genetic drift in small collections is a primary concern (Gale & Lawrence 1984). In the botanic garden, drift can occur with the unplanned loss of individuals and is one reason to build redundancy into *ex situ* collections.

At our gardens, the experience with hurricanes serves to underscore this need for redundancy



5. Behavior of the collections conservation efficiency curve (adapted from Griffith & Husby 2010). After the initial costs of bringing the collection into cultivation are expended (y-intercept), the resources used per gene captured goes down as the collection increases above zero. After reaching a point of maximum efficiency (lowest y-value) the resources needed for additional genetic capture increase steadily. In this case study, the collection size with greatest efficiency is around 5 individuals, and a collection of 20 individuals has the same unit cost as a single-specimen collection.

(Klein 1992, Griffith et al. 2008). Redundancy at multiple sites adds an additional layer of protection for very rare palms, as these can provide a range of environmental conditions and therefore increased likelihood of success. *Attalea crassispatha* provides a good example here (Timyan & Reep 1994). In its native range in southwest Haiti, this species survives with fewer than 30 individuals and is imperiled by habitat reduction and seed consumption. Significant living collections at MBC, FTBG and the Tropical Research and Education Center (Homestead) of the University of Florida ensure that this Critically Endangered species can survive in cultivation.

How effective is botanic garden conservation?

There are many examples of plant species that would simply be extinct were it not for garden collections. Yet, one thread in the literature debates the value of *ex situ* conservation, subordinates it to other work, or otherwise diminishes these efforts (Hamilton 1994, Aplin 2008). This critique is often rooted in philosophy (see Rolston 2004), but sometimes also in data (Clement et al. 2009). Conservation priority is sometimes determined through subjective means (see nic Lughadha et al. 2005 for discussion). The value of garden collections for conservation can sometimes be inflated (Aplin 2008), and this is often due to insufficient data (Maunder et al. 2001b).

The opposite of insufficient data, of course, is adequate, relevant data. Data appear to be the best way forward for rigorous assessment of conservation value. We propose that one strength of the current approach is that it represents direct assessment of an existing conservation collection with an objective and direct measure of "conservation value," genetic capture. Targeted study remains the most accurate way to make inferences and develop strategies. For conservation workers at botanic gardens, this approach may provide a starting point to adapt a potential evaluation method. This will depend on the specific case of the population in question. In the case study here, collaborative analysis and planning between gardens achieved the best results.

The straightforward expediency and established technical feasibility of *ex situ* work keep it relevant and vital (Li & Pritchard 2009, Calonje et al. 2010, Seaton et al. 2010; Vitt et al. 2010). The current work suggests that significant genetic diversity can be conserved with proper planning. Therefore, it is important to continue the work of *ex situ* conservation and to develop new data to assess effectiveness and plan future strategies.

Regardless of how one feels about the relative merits of *ex situ* or *in situ* conservation, or any other aspect of conservation work, the least effective plan is to do nothing. A statement by Dr. Margaret From expresses this truth best: "conservation must be more than conversation."

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