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Short communication

Visual health assessments for palms

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ABSTRACT

Palms (family *Arecaceae*) can make up a significant portion of the urban forest in the climates where they are viable. Despite this, they are rarely included in the urban forest growth and longevity literature. One difficulty associated with including palms in research is an absence of a standard means for characterizing tree health or condition. Whether used as a measured response of its own or incorporated as a predictor of future mortality, standardized and meaningful health ratings are needed to advance the care and management of palms in urban areas. In this short communication, we investigate some of the rating systems used in past palm research. We then propose an adaptation of existing tree health rating processes based on insights from these past attempts and our own experience in qualifying palm health.

1. Introduction

In the regions where they are a viable plant selection, palms (family *Arecaceae*) have long been considered a unique and recognizable component of the urban forest. Prized for both their appearance and utility as sources of edible fruit, palms were installed as plantings in ancient Egyptian gardens (Hauer et al., 2017). Similarly, groves of date palms are noted in depictions and descriptions of ancient Mesopotamian gardens similar to the famed Hanging Gardens of Babylon (Wiseman, 1983). In the United States, palms are culturally significant in southern California and elsewhere, symbolizing leisure and glamour (Farmer, 2013). Though palms have more in common biologically with grasses than they do with conifers and broadleaved woody plants, they are typically managed as trees in horticulture and urban forestry contexts (Ali and Burkhart, 2017). As long-lived, woody perennials with a dominant trunk and an elevated crown, palms match many of the defining attributes commonly ascribed to trees (Hirons and Thomas, 2018; International Society of Arboriculture (ISA), 2011; Shigo, 2008).

Palms are primarily planted for aesthetic and cultural value in today's urban context (Farmer, 2013) as they provide fewer ecosystem services than deciduous and conifer trees over their functional lifespans (Peper et al., 2010). Palms can persist in spaces which would be considered limiting for other large woody plants and do so without causing damage to nearby infrastructure. Readily transplanted as large, mature specimens, palms can provide an immediate visual impact on the urban landscape (Hodel et al., 2005). However, this flexibility, along with a general lack of knowledge of palm biology, can lead ill-informed maintenance practices and an overconfidence in the ability of landscape palms to survive abuses such as deep planting (Broschat, 1995) or other adverse conditions.

Despite their prevalence across the tropics and sub-tropics, palms have received little attention in the urban forestry growth and longevity literature which has historically been dominated by studies originating from temperate North America and Europe (Hilbert et al., 2018, in press). Appraised values of urban trees are affected by health condition and perceived aesthetic value in most appraisal methods, but both metrics are prone to assessor subjectivity (Watson, 2002). Given the high cost associated with planting mature palms, homeowners, landscape contractors, and other stakeholders presumably have an interest in the health and long-term survival of transplanted specimens. While mortality is often a measured response in urban forest research (Elmes et al., 2018; Koeser et al., 2014; Roman et al., 2016), assessing tree and palm health before death occurs would be preferential from a management perspective. Past research has shown that a lower health rating

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in an initial inventory was found to be a significant predictor of future mortality (Koeser et al., 2013; Roman et al., 2014) and reductions in growth (van Doorn and McPherson, 2018). Visual urban tree health assessments can also enable detection of species-specific stress response following disturbance events, such as storms (Hallett et al., 2018).

The potential utility of assessing tree health has not gone unnoticed among practitioners. In a survey of 45 urban tree monitoring programs, health condition ratings were more widely recorded (89%) than observations of height (71%) and mortality status (76%) (Roman et al., 2013). Likewise, for urban tree inventories in Sweden, vitality was recorded more often (74%) than diameter at breast height (57%) (Östberg et al., 2018). Currently, methods for assessing tree health vary from qualitative visual protocols (Bond, 2010; Pontius and Hallett, 2014) to instrument- or lab-intensive procedures for quantifying plant stress (Percival et al., 2008; Percival, 2005; Rosenfield, 2009). In practice, the former approach, if sufficiently efficient and consistent, can be incorporated into tree inventories to track the health of individuals as well as the overall population.

Health ratings can be conducted in the weeks following planting as an early indication of transplant success, or to identify critical species-specific health thresholds when attempting to increase urban forest canopy coverage (Bond, 2012). Additionally, health ratings applied to woody plants that were subjected to past tree maintenance or construction activities, or ecological disturbances, could be used to inform future management decisions, advance research, and improve ecosystem service projections (Hallett et al., 2018; Martin et al., 2016). Martin et al. (2016) argues that tree survival percentages and projections may be inaccurate without first considering health. In addition to influencing survival, growth assessments require two field visits or a planting size specification (which may not reflect true size) for measurements such as height or diameter, whereas accurately assessed health can offer past and future insights with one visit. In attempting to increase consistency among assessors, the use of established protocols can reduce subjectivity and alleviate the pressure placed on the assessor and his or her abilities (Bond, 2012).

Although multiple health assessment procedures exist to assess woody plants, these procedures have been primarily developed for deciduous and coniferous tree species. Because of anatomical differences between palms and other trees, typical health observations that include branches and twigs do not translate to useful health information in palm assessments (Hosek and Roloff, 2016). The objective of this short communication is to build on past procedures used to visually assess palm health in the field and in research. In doing so, we propose a similar method to one that we used to assess large populations of palms planted along highways in Florida, United States (Blair et al., submitted). Although we believe this method has the potential to balance efficiency and resolution capable of detecting visible differences in palm condition, it is best practice and recommended to pursue further testing (Hallet and Hallet, 2018).

2. Palm health assessments used in past research

Visual health assessments have served as response variables in past research on the effects of management practices (Broschat, 1991, 1994, 1995; Hosek and Roloff, 2015) or environmental conditions (Duryea et al., 2007; Hosek and Roloff, 2016) on palm performance (Table 1). Although Rosenfield (2009) provides a thorough review of pruning and palm health response, it is excluded from this discussion because the research techniques noted utilized actual measurements of health (i.e., foliar nutrient analysis, fruit yield, frond length, etc.) rather than visual assessments.

Aside from utilizing different rating scales and parameters, language used can be inconsistent. For example, Broschat (1994) defines "quality" as living frond count, while Broschat (1995) defines living frond count as the name suggests – the number of living fronds. While appropriate for assessing individual palms, counting fronds in the field may prove inefficient. Terminology such as "appearance"," quality", and "color" may sound as though they can be used interchangeably, but lack of standardized definitions make it inappropriate to do so unless directing others to a past published health assessment method or defining what an adopted term is intended to describe within the text.

Hosek and Roloff (2016) provide the most detailed parameters and corresponding definitions for rating palm health. In their paper, a final health rating score was determined by rating frond discoloration, leaf/leaflet damage, symmetry, and fullness separately and reporting the lowest observed parameter score. Hosek and Roloff (2015) also tailor their size assessments to account for common, species-dependent palm pruning shapes (i.e., "10-2″ pruning – a reference to the numbers on a clock face). Their work is a departure from past size ratings where size has been rated on an undefined scale from zero to five (Broschat, 1991).

There are common themes in assessing palm health. Those are related to 1) color and 2) canopy size and shape (Table 1). In assessing palm color, we recommend using the "quality" visual assessment criteria proposed by Bond (2012). In this work, the author describes quality as a measure of the *percentage of the upper crown that is free from necrotic, chlorotic, or undersized foliage* (Bond, 2012). In rating quality by this definition, the assessor has one of six options: 0 – no live crown; 1 – < 20% live crown; 2 – 21–40% live crown; 3 – 41–60% live crown; 4 – 61–80% live crown; 5 – 81–100% live crown; or 6 – Quality cannot be determined (Bond, 2012).

Similarly, we recommend a substitution of the "ratio" measure from Bond (2012) as a measure of size. In his guide, Bond (2012) draws on the United States Department of Agriculture Forest Service's Forest Inventory and Assessment definition, stating that ratio *is the ratio of the*

Table 1
Overview of research projects that have utilized a palm health assessment. Parameter terms listed follow the language used in each publication.

Reference	Topic	Species	Parameters	Parameter Definitions	Notes
Broschat (1991)	responses to pruning/ tying at transplant	*Sabal palmetto*	appearance size	Six-point scale ranging from 0 = dead (size) 5 = full (size)	size and mortality not independent of each other
Broschat (1994)	responses to pruning/ tying at transplant	*Phoenix roebelenii*	quality	living frond count	
Broschat (1995)	nutrient deficiencies v. planting depth	*Phoenix roebelenii*	living frond count color	Six-point scale ranging from 0 = dead to 3 = moderately deficient to 5 = symptom free	high health rating generally = more fronds
Hosek and Roloff (2015)	pruning practices	*Arecaceae*	over-pruned not over-pruned	Pruning intensity categories based on the hands of a clock. Either 10:2 shape or 8:4 shape	pruning/canopy size directly related to palm health
Hosek and Roloff (2016)	site selection	*Arecaceae*	discoloration damage symmetry fullness	Five-point scale ranging from 1 = very good To 4 = very poor	well-defined scale for each parameter; excludes senescing fronds; overall score based on lowest parameter score
Duryea et al. (2007)	hurricane damage	various Fl palms	"percent leaf loss"	Visual assessment of percent leaf loss	

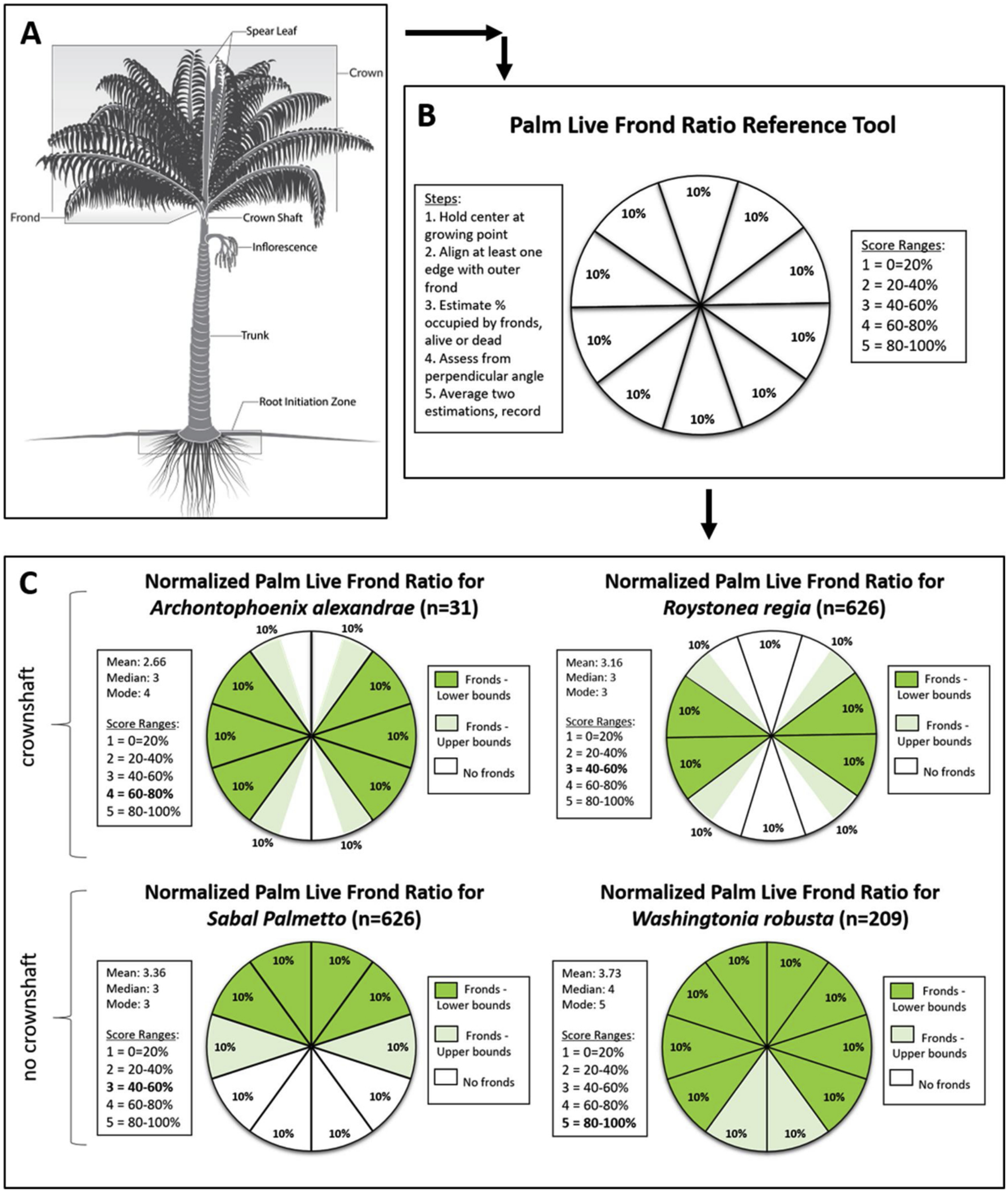

Fig. 1. (A) Diagram of a pinnately compound palm with a crownshaft; (B) Reference tool with brief guidelines for assessing palm live frond ratio; (C) Examples of data derived from canopy size estimations and corresponding summary statistics for four palm species observed in a roadside palm survey (unpublished data). Palms ranged between 8 and 58 months after planting (Blair et al., submitted).

live crown height to the total live tree height, expressed as a percentage. Bond acknowledges in this work that live crown ratio, as defined, is not an appropriate measure of palm health. However, we propose the following substitution for palms: palm live frond ratio *is the proportion of an imaginary circle imposed on the canopy of a palm that would be filled with live fronds* (Fig. 1). As with quality, our proposed ratio measure is divided into 20% increments (Fig. 1).

When working with a single specimen, both health ratings are compared against what the user perceives as the normal for the species given their professional experience in the area. When inventory data is available, ratings can actually be calibrated at a species or cultivar level to reflect what is normal for the region. The definition of “normal” has differed. For example, Bond (2012) considers normal for a given parameter to be the range of values typical for a given individual – factoring in species/cultivar, life-stage, phenology, and region. Pontius and Hallett (2014) calibrate normal as the mean rating of the sample. Using ordinal data, we recommend calibrating normal based on the mode rating of the sample. In work currently submitted, we rated the mode rating as “normal”, one deviation above the mode as “excellent”, one deviation below the mode as “fair”, two deviations below the mode a “poor”, and three deviations below the mode as “critical” (Blair et al., submitted). In assessing multiple species with this technique, the data was always skewed towards decline (Blair et al., submitted).

When assessing palm quality, an assessor should not consider senescing fronds in the lower canopy (Hosek and Roloff, 2016). Deficient fronds may be discolored (and misshapen) and upright/horizontal in the upper portions of the canopy. In contrast, naturally senescing fronds (typically seen in fuller, unpruned crowns) may be discolored but hanging down with a bent petiole. After assessing palm live frond ratio in the field, one should consider the normal fullness for the species as opposed to the most common pruning aesthetic found in the landscape, as over-pruning may be rampant in some regions. However, various palm species produce a different number of live fronds, and retain different numbers of senescing, deficient, and dead fronds for various lengths of time. In pruning, recommendations are to remove only completely brown fronds (Broschat et al., 2000). Over-pruning in nutrient-limited sites can lead to deficiencies and reduced growth. An assessment of health based on binary responses of crown shape (over-pruned versus not over-pruned) may only be appropriate when assessing pruning practices (Hosek and Roloff, 2015). However, estimates of canopy size may be appropriate regardless of whether the crown is diminished by some malady or by an ill-informed arborist.

Our palm live frond ratio measure accounts for differences in canopy shape, which can vary significantly by species (not accounting for clustering or single-trunked specimens). Much like categorizing trees as having excurrent or decurrent forms, palms can be categorized with or without a crownshaft (Fig. 1). A crownshaft is a neck-like structure at the top of the woody trunk that is formed by tightly-rolled leaf bases. Palms with a crownshaft often have pinnate fronds (i.e., *Roystonea regia*), while those without often have costapalmate fronds (i.e., *Sabal palmetto*) or palmate fronds (i.e., *Washingtonia robusta*). Palms with crownshafts tend to be "self-pruning" – shedding lower fronds which would typically be retained by a palm without this trait.

When used together (Appendix A), measures of palm quality and palm live frond ratio may be able to detect symptoms such as epinasty (stem twisting from boron deficiency), shrunken new growth, folded young leaves, leaf tip necrosis, and necrotic inflorescence (Broschat, 2017). Because nutrient deficiencies present themselves differently in various locations of the canopy, protocols should guide assessors in distinguishing aging fronds from symptomatic fronds. Protocols should help to identify palms in reduced health that may require further inspection and management interventions.

For canopy size assessments to be effective and useful in projecting ecosystem services and estimating health, it may prove helpful to understand typical relationships between height, crown width, age, and typical frond counts. Because there is no relationship between palm trunk diameter and crown dimensions, many inferences of palm size come from information provided by regional palm experts and growers (McPherson et al., 2016). Previously collected iTree data may provide insight into normal palm canopy sizes under a variety of environmental conditions and allow programs such as Urban FIA to begin incorporating palms in future regional analyses. Also highlighting challenges for incorporating palms in research studies, Blood et al. (2016) excluded palms from growth projection analyses, while van Doorn and McPherson (2018) and Roman et al. (2014) excluded palms from analyses of growth, health, and survival.

Health assessments are not without issues (i.e., subjectivity), emphasizing the need for collaboration and testing among researchers, especially those working with palms. Because palms must be transplanted when biologically mature (Broschat and Donselman, 1990; Pittenger et al., 2005), associated costs may be high. Researchers and urban forest managers want to ensure that this money is someday recovered. Therefore, any improvements made regarding palm management should be researched and implemented. This short communication aims to encourage researchers and managers to embrace palms as a major component of their urban forests, while also demonstrating the need for well-defined palm health assessment protocols.

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Appendix A

Palm Health Assessments Used in Practice – A Florida Case Study

In our Florida case study, one objective was to determine influential factors of palm health as they related to site conditions and management practices. Using a similar methodology to the one outlined below, visual health assessments were made to 1326 palms recently installed along Florida highways (Blair et al., submitted). The assessor evaluated both quality and live frond ratio in twenty percent scoring classes. From an analysis perspective, the methodology was adapted largely from Bond (2012) where final assigned health ratings are normalized by species. Results were fit to an ordinal logistic regression based on deviations below the normalized health rating for that species. It is recommended to use health score deviations but doing so requires a large sample size or regional knowledge of species characteristics. From a practical standpoint, a blend of Bond (2012) and Hosek and Roloff (2016) provide an efficient framework for palm inventories. The sample protocol outlined in Appendix A will hopefully provide researchers and practitioners confidence to include palm health assessments in their inventory and monitoring studies.

1. *Palm Health Assessment Protocol (Adapted from Bond, 2012)*

Assessing Palm Quality

1 If there is no live crown, enter 0.
2 Assess fronds in the upper portion of the canopy – paying attention to upright and straight fronds regardless of color.
3 Avoid naturally senescing fronds (i.e., brown or chlorotic fronds in the lower canopy which may have a bent petiole) and completely dead fronds.
4 Determine the overall percentage of upper canopy that is free of discoloration, in steps of 20%.
5 If quality cannot be determined, enter 6 for data filtering purposes.

Assessing Palm Live Frond Ratio

1 If there is no live crown, enter 0.
2 Visualize the center of the circle over the spear leaf base, which is the growth point of the palm (see Fig. 1).
3 Visualize the edge of the circle extending to the frond tips.
4 Attempt to assess palms from the same distance, if possible.
5 Estimate percent of circle occupied by live fronds, regardless of deficiency or senescence.
6 If quality cannot be determined, enter 6 for data filtering purposes.

Table A1 shows a potential means of using these two ratings to produce a final score based on the most limiting rating. Table A2 shows suggested qualitative ratings associated with deviations from the calibrated (mode) normal condition.

Table A1
Rapid visual palm canopy condition assessment sheet adapted from works by Bond (2012) and Hosek and Roloff (2016).

ID:		Species:	
Location:			
Score	% free of discoloration (quality)	% of circle filled with live fronds (live frond ratio)	(lower of two categories)
6	NA	NA	
5	81-100	81-100	
4	61-80	61-80	
3	41-60	41-60	
2	21-40	21-40	
1	1-20	1-20	
0	No live crown	No live crown	

Quality notes:
Live frond ratio notes:
If clustering, number of stems represented by this score (i.e., 1/7):

Table A2
Suggested qualitative ratings associated with deviations from the calibrated (mode) normal condition.

Health Rating	Description
Dead	Rating of 0
Critical	3 deviations below the normalized value
Poor	2 deviations below the normalized value
Fair	1 deviation below the normalized value
Normal	The normalized value
Excellent	1 deviation above the normalize value

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