

**Pleistocene Plant Diversity at the Warm Mineral Springs  
Locality, Sarasota County, Florida and Comparison with the  
Modern Local Flora**

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## **Abstract**

A study of charcoaled floral remains from the late Pleistocene at Warm Mineral Springs (WMS), Florida was done to examine the environmental conditions at that time. Most research on WMS has focused on the extinct megafauna fossils and human remains that were found, but there is a superficial understanding of the plant material that were present. To gain an understanding of the plant biodiversity at WMS and what it signifies for the climate at that time, fruit, seed, and leaf fossils were identified based on their morphological characteristics. The Shannon-Wiener diversity index is used to measure the biodiversity of the area. Fruits and seeds found include those of *Vitis* sp., *Quercus* sp., *Sabal* sp., and *Phytolacca americana*. The absence of aquatic plant species and the fact that these fossils are charcoaled support the idea that WMS had a drier climate at the time. The presence of this type of plant remains suggests a transition from a drier habitat type (such as pine scrub) to a wet habitat as water level in the cenote rose after the Wisconsinan glaciation.

## **Introduction**

Warm Mineral Springs (WMS) is a spring located in Sarasota County, FL (Fig. 1) [1]. Accounts on this site dated back to 1875, but did not gain attention from the science community until one hundred years later. In the late 1950s Colonel William Royal began scuba diving in WMS and discovered human remains that were very well preserved [2]. This attracted the interest of marine biologist Eugenie Clark as well as University of Florida geologist H. K. Brooks to the site [2, 3]. Clark and Royal's excavation in 1959 led to discovery of human remains that are estimated to be 10,000 years old. Faunal remains of extinct animals such as *Smilodon fatalis* (saber-tooth cat) and the giant ground sloth (*Megalonyx jeffersonii*) were also found [4].



**Figure 1** Warm Mineral Springs (WMS) is located in the southern part of Sarasota County, FL from The Springs.

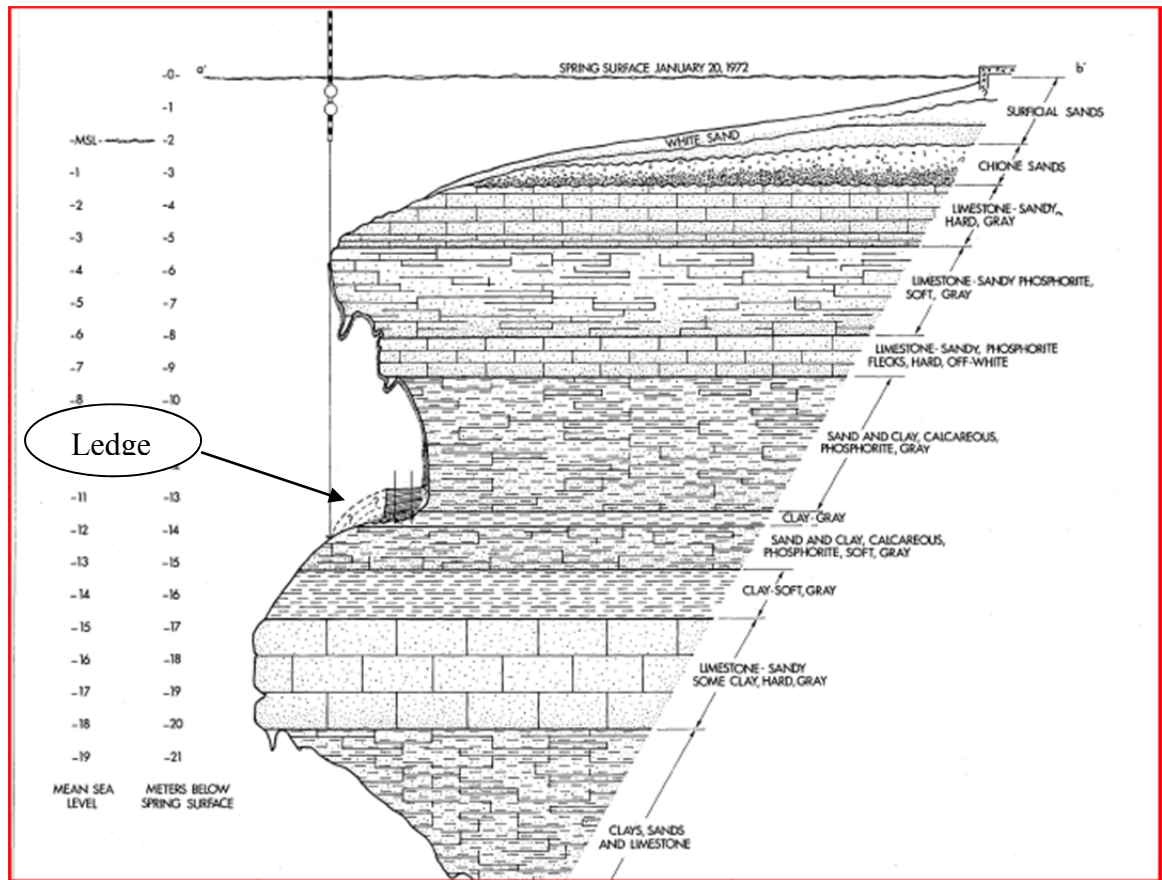
[16]

In 1961, H. K. Brooks collected charcoaled plant remains from WMS [1]. This collection was later transferred to the Paleobotany Collection at the Florida Museum of Natural History in 2009. So far, there has been one attempt to identify these remains by Clausen et al. in 1975 [3]. Only a list of the plant species was given and no method of identification or evidence had been presented to support the identity of these fossils. In this project, the charcoaled fruits, seeds, and leaves found in Zone 3 (see next section for further explanation) were identified and will be discussed later in this paper their significance in WMS during the late Pleistocene.

### **Geology and Environment**

WMS is a sinkhole that is located in North Port, Sarasota County, Florida. It is an artesian spring whose source of mineral-rich waters flows through sandy limestone from the Floridan Aquifer [4, 5]. The surface of the spring is round with a diameter of 73 m and 70 m deep [3, 4]. The pond slopes around 0.15 m below the surface (Fig. 2) to form roughly an hourglass-shaped sinkhole [3]. There are two ledges going down the sinkhole with one being about 3 m below spring surface and the second ledge being 13.40 m

below spring surface [3]. It is this 13 m ledge that has been the focus of excavation and study by scuba diver William Royal and scientists including Clark, Cockrell, Brooks, and Clausen.



**Figure 2 Stratigraphic sections of the upper part of WMS.**

An illustration of the ledge where the plant remains were collected [3].

This ledge was divided into three zones by H. K. Brooks when collections were made based on trends in sediment composition. Organization of the zones started from top down with Zone 1 being the more superficial layer and Zone 3 being the lowest layer [3]. Zone 1 is mainly composed of algal ooze and shells of snails that still exist in the spring [3]. Zone 2 contains calcitic silt, *tufa*, and some plant debris [3]. Zone 3 contains charcoaled plant remains and that is where research was most extensively done by Clausen et al. in 1975. According to them, the diversity of plant specimens included *Pinus elliotii*, *Quercus virginiana*, *Quercus laurifolia*, *Ampelopsis arborea*, *Carya* sp.,

*Phytolacca rigida*, and *Thelypteris normalis* [3]. Brooks also organized this zone into subzones a, b, and c to further partition the remains. This partitioning is necessary due to the large variation of bands in that level; this is affirmed by the radiocarbon dating of these sub-strata ranging from about 9,370 to 9,870 years old top to bottom [3]. Based on previous top-down organization of strata, I extended this pattern of organizing to that of the subzones with Zone 3a as the top layer and Zone 3c as bottom layer.

The climate during the late Pleistocene was inferred to be drier, more arid, and with a lower water level in WMS than today based on observations of the formation of tufa crust in various strata and stalactites [3, 4]. Both Cockrell [4] and Clausen [3] believed that the rise in water level in the spring was in response to the end of the Wisconsinan glaciation and rise in mean sea level. There is, however, debate on the water level of when sediments in Zone 3 were deposited. Cockrell [4] believed that the ledge was still dry and that the human remains were intentionally buried there while Clausen et al. [3] argued that the ledge was already submerged and it was more likely that humans, animals, and plant debris had fallen in the sinkhole.

### **Material and Methods**

A dissecting microscope was used to initially sort out plant remains. Fruits or seeds that were different from one another were placed in separate plastic containers. A count of the total amount of fruits or seeds in each sub-zone was measured. References from sources who have studied morphological characters of the species of interest include Chen and Manchester [6], Caulkins and Wyatt [7], and Borgardt and Pigg [13].

The specimens were photographed using a Nikon D100 digital camera. Scale bars were also set next to the specimens to help illustrate the actual size of each fruit or seed. The photos were edited with Photoshop.

The Shannon-Wiener diversity index was used to calculate the species diversity in each sub-zone and compare how those numbers vary from subzone to subzone. The index is often used to measure and compare areas for two reasons: species diversity and species evenness. The diversity of species explains whether or not there is a large variety of plants present; evenness explains the numbers of each species that is present and how these numbers compare to each other. To find a number for the index, first, the relative abundance ( $p_i$ ) of each species in each zone was calculated:  $p_i = n_i/N$  where  $n_i$  is the number of individuals in that species and  $N$  is the total number of individuals in that subzone.  $P_i$  was then multiplied by the log of itself:  $p_i * (\log(p_i))$ . The index number is then calculated as the negative sum of all the species:  $-\sum(p_i * (\log(p_i)))$ .

### **Systematics**

The diverse and complex history of plants calls for an understanding of their evolution and a method in which to organize the information. Systematics is a way of naming plants and placing them into groups such as genera and families. Each group of plants have shared derived characters that help systematists and botanists to identify plants. Here, the specimens are identified by family, genus, and if possible, by species. A description of the morphology of these specimens are provided along with particular features that justify its taxonomic placement.

*Vitis* sp.

Family: Vitaceae

Description: The seeds are pyriform (Fig. 3) with a prominent hilum that is about 0.75 mm wide. The length of the seed ranges from 2.25 mm to 5.75 mm. It is widest near the apex ranging from 2.25 mm to 4 mm wide. There is a pair of short ventral infolds in the center that are separated by a raphal ridge. On the dorsal side there is a rounded chalaza

in which ruga lines are sometimes present. The seeds are smooth and rounded although sometimes they can be flat ventrally.



**Figure 3**

**A: Ventral view of *Vitis* sp. from specimen 53370b.**

Note the short ventral infolds and pyriform shape.

**B: Dorsal view of the chalaza.**

It is connected to a long groove leading to a prominent apex. Scale bars = 1 mm.

Specimen count: 70.

Specimens examined: 053370a, 053370b, and 053370c.

Discussion: In the literature Clausen et al. [3] identified a vitaceous plant remain as *Ampelopsis arborea*. Although *Vitis* and *Ampelopsis* (Fig. 4) do have very similar features [6], there are characters differences that separate the two genera. For one, these seeds have prominent apical notches which are characteristic of *Vitis* [6]. The short ventral infolds of these seeds generally are not divergent like those of *Ampelopsis*. Finally, the chalazas of these seeds are not very close to the apical notch as seen by the long groove that goes down the dorsal side making them more *Vitis*-like than *Ampelopsis* which do not have grooves visible on the dorsal side [6].



**Figure 4 The anatomy of *Ampelopsis*.**

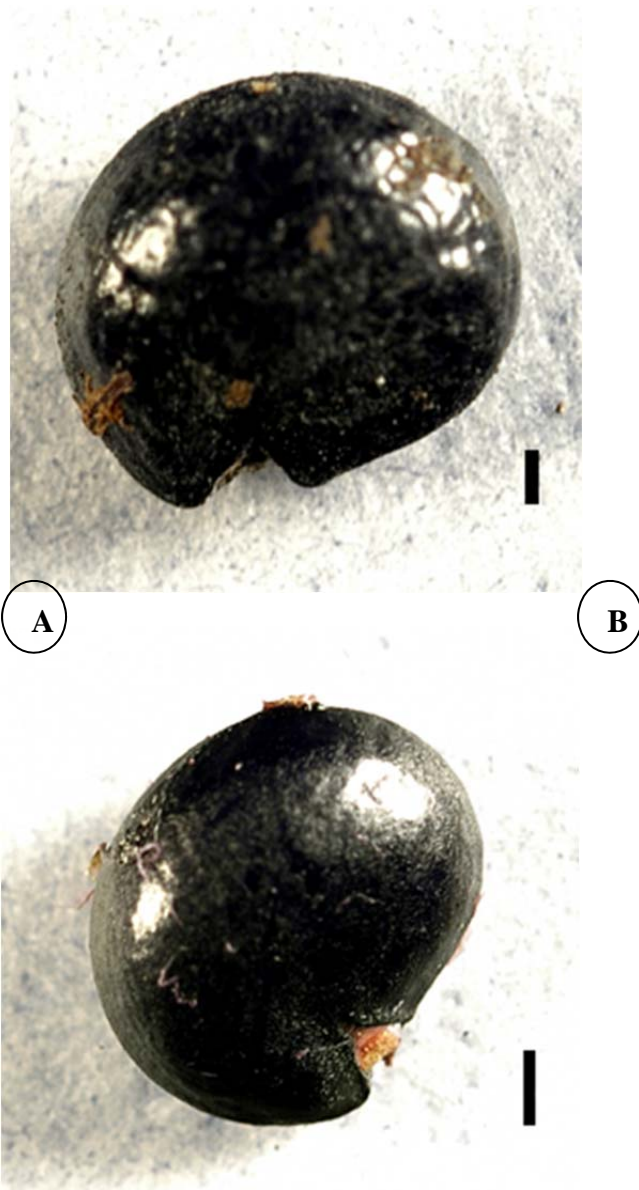
No prominent groove is seen at the apex. The ventral infolds are also divergent, by Chen and Manchester [6].

*Phytolacca americana* Linnaeus var. *rigida* (Small)

Family: Phytolaccaceae

Description: The seeds are flattened and lenticular (Fig. 5). They have a mean width of about 2.0 mm and mean length of 2.5 mm.





**Figure 5. A: Specimen 53357 of the charcoalized *Phytolacca americana*.**

**B: A modern *Phytolacca americana* seed.**

In both images, the seed has a flattened, lenticular shape. Scale bars= 0.5 mm

Specimen count: 11.

Specimen examined: 053357.

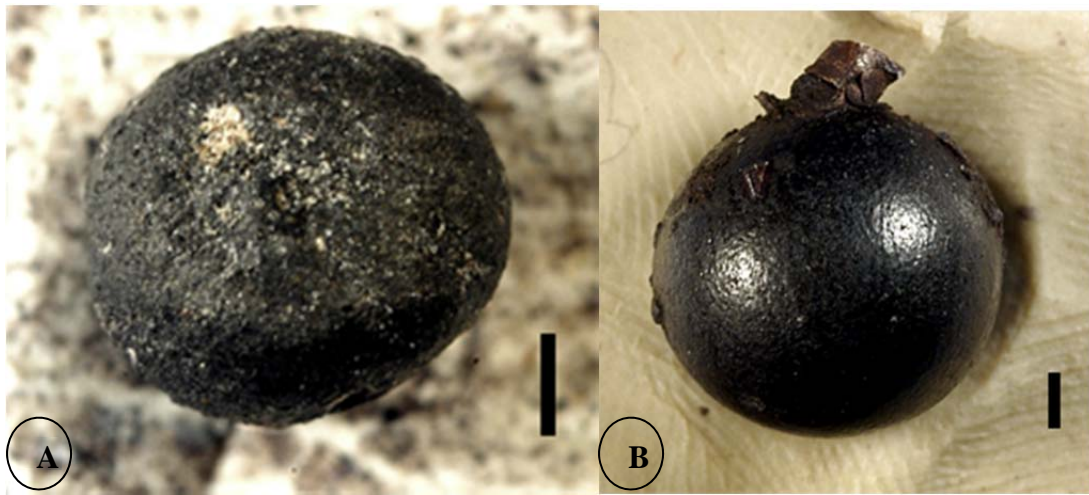
Discussion: Clausen et al. [3] had classified this as *Phytollaca rigida* which has now been changed to *Phytolacca americana* Linnaeus var. *rigida* (Small) [7]. Even though the full plant is not available to see whether the stems are drooping or erect, this is the correct

name because the other variety, *Phytolacca americana* var. *americana* does not occur in Florida [7].

*Sabal* sp.

Family: Arecaceae

Description: The fruits are globose drupes (Fig. 6) and the epicarp is smooth and shiny black if it was not burned off. Diameter ranges from 3.0 to 5.0 mm.



**Figure 6 A: Globose drupe of Specimen 53368d**

Scale bar = 1 mm.

**B: A modern *Sabal palmetto* fruit.**

Scale bar = 1 mm

Specimen count: 42.

Specimens examined: 53368a, 53368b, 53368c, 53368d.

Discussion: It is likely that these are fruits and not seeds because no germination valves can be seen. The diameters of these specimens range from 3.0 mm to 5.0 mm. This range of size matches that of the range of *Sabal minor* more than that of *Sabal palmetto* [8].

The fruits of *S. palmetto* are larger in diameter ranging from 5.4 to 9.7 mm [9]. The possibility of these drupes being *S. etonia*, *S. miamiensis*, or *S. mexicana* are also not likely because *S. etonia* appears only in pine scrub communities and the other two are not present in the central part of Florida [10-12]. Fruits cannot be those of *Serenoa repens*

because the fruits of saw palmetto are larger (length about 2.5 cm) and can be more elliptical in shape [17].

*Serenoa repens*

Family: Arecaceae.

Description: This leaf petiole shows a short, blunt hastula that does not go very far into the leaf blade (Fig. 7)



**Figure 7 A: Abaxial view of *S. repens* with a blunt hastula that does not extend deep into the leaf blade.**

**B: Adaxial view of petiole.**

Scale bars = 5 mm.

Specimen count: 1.

Specimen examined: 53374.

Discussion: Even though drupes of *S. palmetto* were identified, it is not probable that this leaf petiole belongs to it. The fronds of *S. palmetto* usually have a very long midrib that extends far into the leaves but that is not the case in this specimen. *Serenoa repens* is known to have a blunt hastula, and also sharp teeth on the petiole but this petiole is not long enough to determine whether or not there are teeth [17].

*Quercus* sp.

Family: Fagaceae

Description: Fruits are acorns which consist of the nut and the cupule. The cupule is scaly (Fig. 8), goblet-shaped or hemispheric, and varies very much in size depending on the maturity of the fruit. The cupules were mostly found separated from the nuts. The nut is often barrel-shaped and sometimes ovoid; size can range from 5 x 10 mm to 8 x 13 mm. It has a raised hilar scar at the base which varies from 1.5 mm to 3.0 mm wide. The apex of the fruit shows a prominent umbo which also varies from 0.25 mm to 1.0 mm long. The body of the fruit can be smooth but is seen here with bifurcating longitudinal ridges (Fig. 9).



**Figure 8 Acorn with a deep goblet-shaped cupule.**  
Scale bar = 1 mm.



**Figure 9 Lateral views of Specimens 53372A and 53372B.**  
Note the bifurcating, longitudinal ridges. Scale bars = 3 mm.

Specimen count: 280.

Specimens examined: 53371, 53372a, 53372b, 53372c, 53372d.

Discussion: Plants with inferior ovaries have umbos or persistent styles on fruits. The presence of an umbo and other characters support that these fruits are acorns [13]. One possible reason that these nuts have longitudinal ridges that are not normally seen may be due to the degree in which the fruits were burned. According to Soepadmo [14], a mature fruit wall contains 5 distinct layers; there is also mention that the central outer parenchymatous layer becomes sclerified. To test this, some modern acorns of *Quercus virginiana* were taken and with their outer epidermis layer peeled off, baked in an oven at 400° F for 15 minutes. The resulting appearance is shown below (Fig. 10).



**Figure 10 A modern *Q. virginiana* fruit with outer epidermis peeled off.**  
Scale bar = 2 mm

Clausen has identified two oaks, *Q. virginiana* (live oak) and *Q. laurifolia* (diamond leaf oak). However, only one type of acorn was observed. It is not likely that these acorns belonged to *Q. laurifolia* because the shape of the cupules and shape of the nut is different from that of *Q. virginiana*. The depth of the cupules of *Q. laurifolia* is usually shallower than that of live oaks [18, 19]. The shape of the nut is also different; diamond leaf oak acorns are often globose or sometimes ovoid with a wide scar diameter between 6.5 to 11.5 mm [18]. The scar diameters measured ranged only from 1.5 to 3.0 mm.

## **Results**

A Shannon-Wiener index of below 1.5 indicates low biodiversity and low species evenness. All three zones indicate very low plant diversity and evenness at the time (Table 1). It is also interesting to note that traveling through time from Zone 3C to Zone 3A there is a decrease in biodiversity.

**Table 1 A count of the number of individuals of each species in each subzone.**

	Species count		
	Zone 3a	Zone 3b	Zone 3c
<i>Quercus</i> sp.	85	77	118
<i>Vitis</i> sp.	15	18	37
<i>Sabal</i> sp.	0	15	27
<i>Phytolacca americana</i>	0	0	11
<b>Total count</b>	100	110	193
<b>Shannon-Wiener index</b>	0.184	0.355	0.46

The Shannon-Wiener index is calculated from these numbers based on the formulae mentioned in Material and Methods.

In comparison of modern freshwater wetlands flora with the flora that was present at WMS, it is found that none of these charcoaled species are plants characteristic of freshwater wetlands.

### **Analysis and Conclusions**

There is evidence that the vegetation at WMS during the late Pleistocene was undergoing a transition from drier habitat to wetter habitat. First, the fact that these plant remains were charcoaled indicates the presence of fire at that time. In Florida, fires usually take place in dry habitats such as sandhills and sand pine scrubs. This is in agreement with Cockrell's suggestion that WMS was more arid and dry. However, the plant species that were present were not ones who had any fire-adapted anatomical features. Both *Q. virginiana* and *Q. laurifolia* have thin bark and branches that grow very close to ground which are not adaptations to fire.

The Shannon-Wiener index results (Table 1) support the theory that WMS flora was undergoing a transition from one ecosystem type to another in that the index number decreases going from Zone 3C to Zone 3A. As time progresses, fewer of these species are present. However, there are problems with the analysis. These samples were collected only from a small area that may not represent all of the plants in the area. It is also possible that some of the specimens have been lost from transportation. Clausen et al. had

mentioned the remains of species including hickory, fern, and pine, but no such specimens were found in the collection.

Besides the sampling area being too small, it is also curious that plant remains are not found above Zone 3. If there is indeed a transition from drier to wetter environment, the levels higher up should contain more aquatic plant remains. It is unlikely that the entire flora in that area had died out after that because modern plants are still seen surrounding the spring. The abrupt absence of flora in Zones 1 and 2 suggest that not enough excavating was done.

It is likely that the remains in Zone 3 are not accurate representations of the flora from WMS. It is possible that this ledge had been larger previously and contained samples of other plants but had broken and fallen deeper down into the cenote. More sampling should be done at the site to see whether more fossils can be recovered. Another useful tool to measure biodiversity there is pollen analysis. As pollen is more abundant and generally dispersed across a larger area, it would be possible to gather more information from examining the variety of pollen grains present.

Another reason that WMS was not previously that wet is because of the type of specimens that were collected. Although these plants do occur in moist environments such as mesic hammocks, they are not really characteristic plants of freshwater swamps or springs. Common plants that are present in springs currently include aquatic plants such as tapegrass and wild rice, bald cypress and red maples, sweet gum, and other plants that may have special adaptations to aquatic environments [20].

Although collecting more samples from the site would be very helpful, it may be difficult to do now as WMS has been converted into a health spa and is no longer a site for research. One site that is available for study is Little Salt Springs (LSS) which is also



a cenote located only two miles away from WMS [2]. Clausen et al. have also done research at LSS in 1979 [15] and had discovered that plant diversity there at around the same time (9572 years ago) was also very low; they found wood stakes made from pine, hickory nuts, and a pollen analysis revealed the presence of wax myrtle and oaks as well. In their research, they also noticed the absence of pollen of aquatic plants. As the history of the formation of both WMS and LSS are so similar, more information could be gathered if both sites were studied in conjunction.

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## References

1. Rupert, F.R., *The geology of Warm Mineral Springs, Sarasota County, Florida*. 1994, Florida Geological Survey.
2. Koski, S.H. and J.A. Gifford, *Warm Mineral Springs and Little Salt Spring*. 2009.
3. Clausen, C.J., H.K. Brooks, and A.B. Wesolowski, *The Early Man Site at Warm Mineral Springs, Florida*. *Journal of Field Archaeology*, 1975. 2(3): p. 191-213.
4. Cockrell, W.A., *The Warm Mineral Springs Archaeological Research Project: Current Research and Technological Applications*. American Academy of Underwater Sciences, 1987.
5. Rosenau, J.C., *Springs of Florida*. 1977, Florida Bureau of Geology.
6. Chen, I. and S.R. Manchester, *Seed Morphology of Vitaceae*. *International Journal of Plant Sciences*, 2010. 172(1): p. 1-35.
7. Caulkins, D.B. and R. Wyatt, *Variation and Taxonomy of Phytolacca americana and P. rigida in the southeastern United States*. *Bulletin of the Torrey Botanical Club*, 1990. 117(4): p. 357-367.
8. Ramp, P.F., *Natural History of Sabal minor: Demography, Population Genetics and Reproductive Ecology*. 1989, Tulane University.
9. Brown, K.E., *Ecological studies of the cabbage palm, Sabal palmetto*. *Principes*, 1976. 20: p. 3--10, 49--56, 98--115, 148--157.
10. Zona, S. and W.S. Judd, *Sabal etonia (Palmae): Systematics, distribution, ecology, and comparisons to other Florida scrub endemics*. *Sida*, 1986. 11: p. 417--427.
11. Lockett, L., *Native Texas palms north of the lower Rio Grande Valley: recent discoveries*. *Principes*, 1991. 35(2): p. 64-71.
12. Zona, S., *A new species of Sabal (Palmae) from Florida*. *Brittonia*, 1985. 37: p. 366-368.
13. Borgardt, S.J. and K.B. Pigg, *Anatomical and Developmental Study of Petrified Quercus (Fagaceae) Fruits From the Middle Eocene, Yakima Canyon, Washington, USA*. *American Journal of Botany*, 1999. 86(3): p. 307-325.
14. Soepadmo, E., *A revision of the genus Quercus L. subgen. Cyclobalanopsis (Oersted) Shneider in Malesia*. *Gardeners' Bulletin, Singapore*, 1968. 22: p. 355-427.
15. Clausen, C. J., A. D. Cohen, C. Emiliani, J. A. Holman, and J. J. Stipp, *Little Salt Spring, Florida: A Unique Underwater Site*. *Science*, 1979. 203 : p. 609-613.
16. Warm Mineral Springs. North Port, FL  
<http://www.mcdougalldigital.com/warm/index.html>
17. Anderson, P., *Identifying Commonly Cultivated Palms—Fact Sheet: Serenoa repens*. *Identifying Commonly Cultivated Palms*, 2011.  
[http://itp.lucidcentral.org/id/palms/palm-id/Serenoa\\_repens.htm](http://itp.lucidcentral.org/id/palms/palm-id/Serenoa_repens.htm)
18. Hurst, S., *PLANTS Profile for Quercus laurifolia (laurel oak)*. USDA Plants, 2011. <http://plants.usda.gov/java/nameSearch>
19. Hurst, S., *PLANTS Profile for Quercus virginiana (live oak)*. USDA Plants, 2011. [http://plants.usda.gov/java/profile?symbol=QUVI&photoID=quvi\\_005\\_ahp.tif](http://plants.usda.gov/java/profile?symbol=QUVI&photoID=quvi_005_ahp.tif)
20. Birmingham-Hague, N., Bowers, A., Engle, J., Fluchel, T., Johnson, H., Korhnek, L., Long, A., Monroe, M., Seitz, J., Smith, J., and Wood, W., *Plants of Florida Swamps*. Florida 4-H Forest Ecology.  
[http://www.sfrc.ufl.edu/4h/Other\\_Resources/Contest/Highlighted\\_Ecosystem/swplants.htm](http://www.sfrc.ufl.edu/4h/Other_Resources/Contest/Highlighted_Ecosystem/swplants.htm)