No Longer "Confined to the Lower Keys of Florida": Mainland United States Cultivation of Breadfruit (*Artocarpus altilis*) in a Changing Climate

Russell Fielding[*] and Jorge Julian Zaldivar[†]

[*]*HTC Honors College, Coastal Carolina University, USA*
[†]*Guavonia Guava Grove & Tropication Rare Plants, USA*

Breadfruit (*Artocarpus altilis*) is a domesticated tree crop found throughout the insular Pacific and in other tropical regions of the world where it has been introduced, most notably in the Caribbean. Although breadfruit thrives in Hawai'i, as it has since before European contact, efforts to introduce breadfruit to the mainland United States have been challenged by the tree's intolerance for even mildly cold temperatures. Historically, only extreme southern Florida has been consistently warm enough to support breadfruit cultivation. Today, however, likely owing to warming temperatures associated with global climate change, but possibly also the selection of breadfruit varieties with improved cold tolerance, an increasing number of growers based throughout Florida are finding success cultivating breadfruit trees and producing fruit. Using a mixed-methods approach including interviews and surveys among forty-three Florida-based breadfruit growers, this article investigates the current status and geographical range of breadfruit in the mainland United States and considers both the sustainability implications and the remaining environmental challenges regarding its cultivation. *Key Words: agriculture, breadfruit, climate change, Florida, tropicalization.*

Geographers have long been interested in the spatial distribution of particular food crops. Although some writings, such as Sauer's (1993) *Historical Geography of Crop Plants*, have become academic classics, other such research, producing ever more precise maps of crop ranges, has been dismissed as mere "cabbage counting" and deemed overly quantitative at the expense of the advancement of any broader application or theory (McBryde 1947, 1). Yet, when the ranges of particular species are not viewed as static, but as being in dynamic response to external human and environmental factors, the detailed, geographical analysis of the past and present ranges of both crops and wild plants can yield important data toward our understanding of such concepts as cultural diffusion (Zerega, Ragone, and Motley 2004; Montenegro, Avis, and Weaver 2008), paleoclimatic reconstructions (Parry 1981; Davis and Shaw 2001; Mann 2002; Moriondo, Stefanini, and Bindi 2008), and evidence for ongoing climate change (Chen et al. 2011; Sloat et al. 2020; Wallingford et al. 2020).

On this last front, recent collaborative research by agronomists, climatologists, geographers, and wildlife biologists has shown empirical evidence for the "tropicalization" of temperate North American ecosystems—largely by the northward expansion of the ranges of tropical faunal and floral species in response to more frequent mild winters and fewer extreme cold events per year (Osland et al. 2021). This study reveals and analyzes data related to the expanded range of breadfruit (*Artocarpus altilis*) within Florida since the mid-twentieth century. Breadfruit is a particularly cold-intolerant tree species, said to thrive in temperatures between 21 °C and 32 °C, or about 70 °F to 90 °F (Ragone 1997; Jones et al. 2011; National Tropical Botanical Garden [NTBG] 2019b). As such, the northward expansion of its suitability range is interpreted as being made possible by the warmer conditions and fewer extreme cold events that result from global climate change, possibly aided by the selection of particular varieties with relatively higher tolerance for low temperatures.

Annals of the American Association of Geographers, 0(0) 2022, pp. 1–20 © 2022 by American Association of Geographers
Initial submission, January 2022; revised submissions, May and June 2022; final acceptance, July 2022
Published by Taylor & Francis, LLC.

Figure 1. Left: A small breadfruit tree (approximate height 3.5 m or 12 feet), growing outdoors at Fairchild Tropical Botanic Garden in Coral Gables, Florida. Right: Breadfruits growing on a tree near Miami. *Photos:* R. Fielding and J. J. Zaldivar.

Breadfruit is a fruit tree descended from wild ancestors native to Borneo that were naturally dispersed to New Guinea, the site of its original domestication and point of origin for its human-facilitated broader dispersal (Zerega, Ragone, and Motley 2006; Williams et al. 2017). As one of the "canoe plants" carried along by the Lapita people on their voyages of discovery and settlement throughout the Pacific, breadfruit was widely distributed across tropical Oceania between 4,000 and 2,000 years ago (Zerega, Ragone, and Motley 2004; Kirch 2019). This evergreen, monoecious tree is noted for its large, lobed leaves and cantaloupe-sized (12–20-cm diameter; Ragone 2007), oblong-to-round starchy fruits (Figure 1). In many Pacific cultures, breadfruit has long been a staple food, prepared in a variety of traditional ways. As breadfruit spread, it diversified through natural and artificial selection, resulting today in a remarkable number of varieties found across the Pacific (Ragone 2007).

The first known written description of breadfruit was by Pedro Fernandes de Queirós, navigator aboard Mendaña's 1595–1596 voyage to the South Pacific (Markham 1904). Europeans became more broadly aware of breadfruit during the seventeenth and eighteenth centuries: the English name of the fruit was bestowed in Guam by the pirate and explorer William Dampier (1697), who likened its staple role in the Chamorro diet to that of "a Penny Loaf" in his own country (296). After the publication of several glowing accounts of its nutritional value and ease of cultivation (e.g., Ellis 1775; Banks 1896), breadfruit became highly sought after and was further distributed, first to European colonies in Latin America and the Caribbean, where it was intended to serve as an easy source of food for enslaved plantation laborers, then more broadly throughout low-latitude regions of Africa and Asia (Mackay 1974; DeLoughrey 2007; Newell 2010; Braun 2019; Lincoln, Ragone, et al. 2019).

Breadfruit can be a key component for sustainable, regenerative agroforestry (Jones et al. 2011). The trees grow fast (0.5–1.5m/year) and can live for fifty to eighty years, sequestering atmospheric carbon, stabilizing soil, and providing shade and habitat, all while reliably and abundantly producing food that is high in carbohydrates and certain other vitamins and nutrients (Ragone and Cavaletto 2006; Badrie and Broomes 2010; Lincoln and Ladefoged 2014; Liu, Ragone, and Murch 2015; Turi et al. 2015; Needham, Jha, and Lincoln 2020). Although quantitative data on the amount of carbon sequestered by breadfruit trees is unavailable, comparable data for the closely related jackfruit tree (*Artocarpus heterophyllus*) is both instructive and encouraging. A study of trees representing forty-five species growing

in the Western Ghats region of India found that jackfruit sequestered more carbon (33,709 kg/year) than any other species included in the study (Jithila and Prasadan 2018).

Breadfruit trees usually begin fruiting three to six years after planting and the yield varies by variety, generally ranging from dozens to hundreds of fruits per year (Ragone 1997; Lincoln, Cho, et al. 2019). Commercial utilization of fresh breadfruit is limited, however, by the fruit's short shelf life. Within three days of harvesting, breadfruits have often deteriorated beyond the point of usability (Ragone 1997). As such, the most practical use for breadfruit is for fresh fruits to be consumed locally or to be converted into a shelf-stable product such as flour for later local use or for export (Liu et al. 2020).

Although breadfruit is most culturally meaningful throughout its prehistorical range in the Pacific (Ragone 1991; Meilleur et al. 2004; Taylor and Tuia 2007; Langston and Lincoln 2018), it has come to play a role in the cuisines, sustainable development initiatives, and indeed the cultural heritage of many regions to which it was introduced (e.g., Gamedoagbao and Bennett-Lartey 2007; Goebel 2007; Maerere and Mgembe 2007; Medagoda 2007; Moustache and Moustache 2007; Roberts-Nkrumah 2007; Omobuwajo 2007a, 2007b). Breadfruit, however, remains a "neglected and underutilized species" (Padulosi, Thompson, and Rudebjer 2013, 9; see also Ragone 1997), meaning that it is not among the major staple crops of the world but has unrealized potential to contribute to global food security and sustainable development initiatives. Breadfruit is also one of thirty-five crops listed in the International Treaty on Plant Genetic Resources for Food and Agriculture's Annex I, a compilation meant to include only those species "most important for food security" (Food and Agricultural Organization of the United Nations 2021). The promotion of neglected and underutilized food crops can reduce the risk exposure that results from an overreliance on a very narrow base of crops—namely rice, wheat, maize, and potatoes—that account for 60 percent of the human energy supply (Padulosi, Thompson, and Rudebjer 2013).

Recent modeling shows that the potential range of breadfruit is likely to expand as global climate change continues to trend toward warmer conditions throughout most of the world in response to the burning of fossil fuels and other human activities (Mausio, Miura, and Lincoln 2020). Although the direct and indirect effects of climate change are likely to be overwhelmingly negative to most of the world's human population (Intergovernmental Panel on Climate Change 2018), the expanded potential range for certain neglected and underutilized tropical crop species might represent one small positive effect of climate change. Because the planting of breadfruit trees—like most agroforestry and other forms of perennial agriculture—can contribute to climate change mitigation (Toensmeier 2016, 2017; Aba et al. 2017), any expansion of the potential range of breadfruit might serve to encourage more breadfruit cultivation, which would in turn contribute to the sequestration of additional atmospheric carbon. An expansion of breadfruit's potential range due to climate change, then, could make possible an increase in breadfruit's impacts on both global food security and, paradoxically, the mitigation of climate change.

Historical Background

Efforts to cultivate breadfruit in the mainland United States have a long history (Braun 2019). During his second term as president, George Washington received a letter from Fairlie Christie, a member of the Jamaican House of Assembly, promising to send "3 Bread fruit plants in Baskets for your Excellency." Christie, knowing of "your Excellency's Wish to have a Bread fruit plant," added that, "if it will thrive in the Southern parts of America it will be a great Aquisition, but I doubt it; it is however well worth the Tryal" (Christie 1795). The "Bread fruit plant" had been introduced to Jamaica just two years earlier, the culmination of many years' effort by the British government to bring the tree from the Pacific islands to their Caribbean colonies, where it was to serve as a reliable and low-maintenance source of food for their enslaved African laborers. British efforts to transplant breadfruit had been delayed by the mutiny aboard the *Bounty*, probably now the most famous breadfruit-related tale in the English-speaking world. After deposing Captain William Bligh, the mutineers are said to have tossed all 1,015 potted breadfruit saplings into the sea, well within view of Bligh and his loyalists, who had been set adrift in a meagerly provisioned longboat (Newell 2010).

Bligh, remarkably, survived his abandonment at sea by navigating the twenty-three-foot open boat to Timor, where he and the surviving crewmembers

found passage to England on a series of ships via Batavia and the Cape of Good Hope (Dening 1992). A year after arriving back in England, Bligh received orders to return to Tahiti, this time in command of the *Providence* accompanied by the heavily armed and aptly named *Assistant*, to make another attempt at importing breadfruit, said to be "of infinite importance" to the Caribbean colonies (Mackay 1974, 63). Britain's second breadfruit voyage would prove successful; the *Providence*, still under guard of the *Assistant*, entered the harbor at Jamaica's Port Royal in February, 1793, bedecked with potted trees for delivery, having previously made stops to deposit trees at the islands of St. Helena in the South Atlantic and St. Vincent in the Lesser Antilles (Newell 2010).

The introduction of breadfruit had long been a goal of Caribbean sugar planters, who had first learned about the tree from narratives of Pacific exploration written by men such as Dampier, Cook, and, especially, Sir Joseph Banks. Banks had described breadfruit not merely as a foodstuff but as the key to escaping the biblical curse that compelled humans to labor for their food. "Scarcely can it be said," wrote Banks (1896) of the Tahitian people, "that they earn their bread with the sweat of their brow when their chiefest substance Breadfruit is procur'd with no more trouble than that of climbing a tree and pulling it down" (134–35). To the Caribbean planters, who grudgingly allowed their enslaved laborers to "have Saturdays in the Afternoon, and Sundays, to feed themselves," breadfruit promised greater efficiency, allowing them to compel more time in the profit-making labor of sugar production because less would be needed for tending to "provision grounds" (Pulsipher 1990, 24, 28).

As the Caribbean islands were converted more and more to sugar cultivation, at the expense of acreage that might otherwise have been used for food production, planters came to rely increasingly on imports to feed both themselves and their enslaved workforces (Mulcahy 2014). Much of this imported food came from the mainland North American colonies and as independence loomed during the mid- to late eighteenth century, some planters were justifiably worried about blockades and their attendant food shortages. Valentine Morris, then Governor of St. Vincent, spoke for many of his fellow colonists when he wrote to Banks in 1772, asking "whether there was no possibility of procuring the bread tree … so as to introduce that most valuable tree into our American Islands" (Newell 2010, 148). If an introduction were possible, Morris continued, he was "certain it would be the greatest blessing to the inhabitants."

Caribbean planters were not the only ones interested in breadfruit, nor was the idea of bringing the crop to the United States presented only to President Washington. Thomas Jefferson was enchanted by the vision painted for him by Alexandre Giroud, of Saint-Domingue's Société Libre des Sciences et des Arts (Free Society of Sciences and Arts), who predicted that Jefferson's own Monticello might be "in 10 years, covered with the beautiful shade and the nourishing fruits of this precious tree" (Oberg 2002, 347–48). Giroud's letter accompanied a small packet of what he called "quelques Graines du … Arbre à Pain" (some seeds of the … Bread Tree), although the existence of seeds hints strongly that what Giroud actually sent Jefferson was from the closely related breadnut (*Artocarpus camansi*) rather than true breadfruit, which is mainly seedless and is propagated vegetatively through root cuttings, shoots, or air layers, rather than seeds (Aurore et al. 2014). Still, Giroud believed he was sending Jefferson breadfruit and, based on his observation that it "succeeds perfectly" in Saint-Domingue, wrote that he hoped "it will also be successful in the Southern States of your Republic." Jefferson may have had doubts. Years earlier, when Benjamin Vaughan of Jamaica had promised to send Jefferson samples of rice and breadfruit seeds as soon as the *Bounty* arrived with its cargo,[1] Jefferson responded to ask, "Will any of our climates admit the cultivation of the latter? I am too little acquainted with it to judge" (Boyd 1958, 133–34).

Jefferson's question was prescient. Today, breadfruit is considered an "ultra-tropical" plant, notoriously intolerant of cold weather (Morton 1987). The Hawai'i-based NTBG, which houses the Breadfruit Institute—a research unit formed in 2003 and dedicated "to promoting the conservation, study, and use of breadfruit for food and reforestation" (NTBG 2019c)—advises that breadfruit grows best in climates that range between 21 and 32 °C (about 70–90 °F) and that temperatures below 5 °C (41 °F) can damage the leaves, causing them to discolor, curl, and drop, depriving the trees of photosynthesized energy and eventually killing the tree (NTBG

2019b). Within the contiguous United States, the only place where breadfruit horticulture was even attempted has long been Florida, and even there, it has been challenging.

A late nineteenth-century U.S. government agricultural report noted that "the Bread Fruit tree is very rarely seen in Florida," but that there had been "one or two cases" in which "specimens have passed the winter safely as far north as Manatee," a former town now part of Bradenton (Reasoner and Klee 1888, 51). Frank Bidwell, a late-nineteenth-century plant enthusiast, imported breadfruit and other tropical fruit trees from Jamaica to his heated, Jacksonville-area greenhouse beginning at least as early as 1880 ("Bidwell's Nursery" 1880). In 1888, a newspaper reported that one of Bidwell's trees was "about ten feet in height and blooming," and the journalist mentioned that the resulting fruit, "so rare in Florida," would be "watched with great interest" as it developed ("Bread Fruit Tree" 1888, 4). A nursery catalogue from 1890 offered breadfruit trees for sale to Florida growers for prices ranging from three to five dollars (approximately $95–160 today), along with a warning that, "north of Charlotte Harbor it should have winter protection" (Hoyt 1890a, 4). Another catalogue warned starkly that breadfruit "will always be confined to the lower Keys of Florida" (Reasoner and Reasoner 1892, 7).

At the 1890 meeting of the Florida Horticultural Society, held in May of that year, Robert D. Hoyt, owner of a Pinellas County nursery, reported on the effects of a freeze that had occurred just two months earlier. Hoyt (1890b) stated that the unusually cold weather, "although a most unwelcome visitor," had given Florida horticulturists "the opportunity of testing the relative hardiness of the different species now growing here" (19). Importantly, Hoyt provided the latitude of his site, "27 degrees 57′" (27.95°N), and noted that he recorded a low temperature of 36 °F (2 °C) on the night of 17 March. A 1906 U.S. Department of Agriculture [USDA] report corroborates Hoyt's records, including the weather of 14 March through 17 March as among "the more important cold waves" of the decade and notes the extensive damage done to citrus and other crops in Florida (USDA 1906, 16). Accompanying weather charts show the temperature near Hoyt's nursery dropping from about 70 °F (21 °C) to 40 °F (4.5 °C) in three days. This rare weather proved intolerable for Hoyt's "famous breadfruit tree," which "wilted and died at a temperature of 45 degrees" Fahrenheit (7 °C; Hoyt 1890b, 20). Hoyt (1890b) noted that the breadfruit, along with other "very tender plants," had been kept in a greenhouse, "where frost was not allowed to come in direct contact with them," but that even these precautions were insufficient to protect the tree (20).

Julia Morton (1987), the celebrated University of Miami botanist, noted that the USDA had imported breadfruit from the Panama Canal Zone in 1906[2] and, at the time of her writing in the late 1980s, trees could be found growing and fruiting throughout Key West and "at least one on Vaca Key about 50 miles to the northeast" (52). Morton hinted that Vaca Key might represent breadfruit's northernmost limit as she continued:

> On the mainland of Florida, the tree can be maintained outdoors for a few years with mild winters but, unless protected with plastic covering to prevent dehydration, it ultimately succumbs. A few have been kept alive in greenhouses or conservatories. (52)

Breadfruit's sentence of confinement "to the lower Keys of Florida" seems to have been accepted widely within Florida horticultural circles for many years. One exception in proof of this rule is the case of H. Wallace Johnston, whose profile in an early-twentieth-century magazine called him "a Plant Wizard" (Dacy 1926, 36). Johnston grew tropical fruits at his forty-acre tract near Homestead and might have been one of the first to attempt to grow breadfruit outdoors north of the Florida Keys. According to the article, Johnson had "for many years … been trying to raise specimens of the South Sea Island breadfruit trees in southern Florida," but "time and again his importations, from one cause or another, have died" (Dacy 1926, 38). The article went on to detail Johnston's attempts to create suitable microclimates for his breadfruit trees, although, curiously, his focus seems to have been on the soil rather than the temperature. "Ultimately," the article continued, "success crowned his persistency and patience," and, in February 1926, the journalist declared that "today, the only bread-fruit tree growing outdoors in this country is a masterpiece of agricultural care at [Johnston's] gardens" (Dacy 1926, 38).

A Miami newspaper a few years later remarked that "almost everybody is interested in [Johnston's] Breadfruit tree" ("Suggests pulp tree for Dade area industry" 1929, 14). The article explained that David Fairchild, the botanist credited with importing

thousands of plant species into the United States during his tenure at the USDA's Office of Seed and Plant Introduction, which he established in 1898 (Stone 2018), had, a few years earlier, sent Johnston a breadfruit sapling, but that Johnston had refused it because "for seven years [he had] tried unsuccessfully to raise them." Fairchild had become enamored with breadfruit in Samoa and seems to have attempted to grow breadfruit in Florida himself. Fairchild's tree, or trees, however, did not survive long. His property, which he called "the Kampong," because "it suggested a little village—a Javanese Kampong" (Fairchild 1947, 39), is now a part of the NTBG and features at least fourteen breadfruit trees—several of which have fruited in recent years. The presence of these trees, however, is discontinuous from Fairchild's efforts; they were brought from Hawai'i as a gift from another NTBG site around 2009 (Craig Morell, Director of the Kampong, personal communication, October 5, 2021). After too many failed attempts to grow breadfruit, Fairchild (1947) would later declare that "it is too tender for Florida, except in Key West" (16), perhaps considering Johnston's tree to be exceptional.

Fairchild's estimation was shared by many who came after him. Herbert S. Wolfe, a University of Florida horticulturist, wrote in his fifty-year retrospective on tropical fruit cultivation in Florida that "only the leader of a forlorn hope" would continue to plant breadfruit in the state. Climatic lessons, it seemed, had been learned and Florida horticulturists, perhaps giving in to a spirit of environmental determinism, were increasingly aware of "what species are not suited to our conditions" (Wolfe 1937, 76).

Throughout the twentieth century, however, some growers in South Florida were successful in establishing breadfruit trees. These often experienced the cycle described by Morton (1987), in which "the tree can be maintained outdoors for a few years with mild winters but … it ultimately succumbs" (52). Fruiting also appears to have been rare. A 1946 "Points of Interest" list in the *Key West Citizen* newspaper includes "the only bearing breadfruit tree in the country" ("Points of Interest" 1946, 4). The *Citizen*'s exaggeration is perhaps forgivable, in keeping with the long tradition of luring tourists to Florida through overstatement. Other successful breadfruit growers during this time included Johan Petersen, whose home and garden in Redland, called Bonita Groves, was an early twentieth-century tourist attraction, and Frank Rimoldi, a University of Miami botanist and cofounder of the institution's Gifford Arboretum. The arboretum now features a fruiting breadfruit tree, yet stated, in a recent issue of its own newsletter, "Miami is generally considered to be too cold for breadfruit" (Gifford Arboretum 2014, 6). Petersen was featured in a 1929 Miami newspaper for the tropical flowers and fruits he brought to a popular fruit festival in Homestead. His display, which included breadfruit he had grown at Bonita Groves, was said to have caused "many favorable comments by tourists and homefolks" ("Fruit Festival" 1929, 6).

William "Bill" Whitman (1972), the mid-twentieth-century amateur horticulturist credited with introducing many novel species to the United States through his garden in Bal Harbour—a favorable location on a narrow isthmus between Biscayne Bay and the Atlantic Ocean—wrote that he "considers the breadfruit to be the most cold intolerant of all his introductions" (282). Whitman introduced a particular variety of breadfruit to Florida (Puero, from Tahiti), but he acknowledged that his accomplishment had predecessors with regard to both growing and fruiting of other breadfruit varieties, writing that breadfruit trees were already growing in Key West when he first planted one in Bal Harbour and, when Whitman's tree bore fruit in 1954, his report to the Florida State Horticultural Society mentioned that a tree planted by a grower named Duffield Matson had already fruited on Key Biscayne (Whitman, Mauro, and Younghans 1956). During the mid-twentieth century, breadfruit trees were indeed rare north of the Florida Keys; those that produced fruit were even more so.

Bruce Ledin, a horticulturist at the University of Florida's Subtropical Experiment Station in Redland during the 1950s (now the Tropical Research and Education Center of the University of Florida's Institute of Food and Agricultural Sciences), called breadfruit "one of the most cold sensitive plants thus far grown in Florida," and said that, "for this reason it is a rare tree and seldom seen." Ledin (1957) went on to point out that breadfruit, "is grown successfully only on the Florida Keys, especially in Key West, or in protected areas along Biscayne Bay where the temperature rarely falls below 40 degrees F" (356). This geographical limitation was long accepted as a natural, and immutable, factor for breadfruit cultivation in Florida: certainly possible in the Keys, maybe

in a few specific microclimates around Miami, but nowhere else. Even then, the soft wood of the breadfruit tree was known to be susceptible to breakage in strong winds, a fact counter to the Caribbean planters' argument that breadfruit would weather the region's seasonal hurricanes better than existing local food crops, most notably plantain (*Musa* spp.), as literary scholar Elizabeth DeLoughrey (2007) has pointed out. Indeed, Bill Whitman (1972) wrote presciently about environmental factors challenging tropical fruit horticulture in South Florida and noted that, "hurricanes, not the occasional winter cold front, are responsible for the loss or greatly delayed fruiting of certain plants" (286–87). As some models predict that tropical cyclone frequency and intensity will both increase due to climate change, Whitman's warning continues to be relevant for Florida's breadfruit growers today, even as cold weather remains a chief concern (Knutson et al. 2020).

Two important considerations, however, might persuade twenty-first-century breadfruit growers to reconsider the crop's supposed geographical limitation. The first is concerned with the actual cold tolerance of breadfruit itself, especially with regard to the possibility of differential hardiness among the many extant varieties. In 1976, the British botanist Colin Leakey (1977) undertook what he called a "breadfruit reconnaissance tour" throughout the Caribbean and reported that, "clearly, within the genetic range of the breadfruit, there is a much greater potential for adaptation to different climatic conditions than is indicated in the standard textbook accounts" (11). Researchers in Hawai'i are currently conducting trials to test differential resilience to a range of environmental conditions, including temperature, across several breadfruit varieties (Lincoln, Cho, et al. 2019). This point is especially salient when one considers how few breadfruit varieties have been introduced to the mainland United States (likely fewer than ten), relative to the diversity that exists within the Caribbean (tens of varieties) and, to a greater extent, in the Pacific, where hundreds of varieties are found (Ragone 2007; Roberts-Nkrumah 2018; Daley, Roberts-Nkrumah, and Alleyne 2020).

The second consideration is that the climate is changing, and most U.S.-based agriculturalists and gardeners derive their assumptions on the suitability of various plants in specific places from the Plant Hardiness Zone Map (USDA, Agricultural Research Service 2012; Figure 2). This map charts thirteen separate planting zones across the United States, based on average low temperatures. Each zone is divided into two subzones, a and b, so in practice there are twenty-six zones altogether, each representing a temperature band of 5 °F (a range of about 2.8 °C). The coldest zone, 1a, is in northern Alaska and the warmest, 13b, is in Puerto Rico. Puerto Rico is the only United States territory included on the map. The other inhabited U.S. territories—American Samoa, Guam, the Northern Mariana Islands, and the U.S. Virgin Islands—are not shown. According to individual data on each of these territories, however, all have climates similar to Zone 13 except American Samoa, which is more comparable to Zone 11.

Within the continental United States, the southern tip of Florida rates the warmest, with zones from 10a to 11b represented. According to data from the Breadfruit Institute at the NTBG, the only zones in which breadfruit should be expected to grow are 11b and higher (NTBG 2019b). The Plant Hardiness Zone Map, however, is based on temperatures recorded from 1976 to 2005 and, according to a 2021 U.S. government report, the seven hottest years on record were the immediately previous seven years: 2014 through 2020 (Blunden and Boyer 2021). As a result, the map and the data it charts are quickly becoming outdated. Florida-based breadfruit growers are taking note of these considerations and anecdotal reports of successful breadfruit cultivation throughout the state have become increasingly frequent in recent years (Leonard-Mularz et al. 2021). To us, these anecdotes seemed to call out for a more rigorous geographical analysis.

Materials and Methods

To investigate current trends of breadfruit cultivation in Florida, we employed a mixed-methods approach. Modeled to some degree on the work of Blaire Langston and Noa Kekuewa Lincoln (2018) in Hawai'i, the methods included site visits to breadfruit growing operations, semistructured interviews with growers, and an online survey sent to growers. During April 2021, we conducted site visits and interviews with fifteen breadfruit growers in South Florida.

After the fieldwork, we created an online survey to gather information from other breadfruit growers that we had not met in person. Survey questions were determined in part by considering themes that

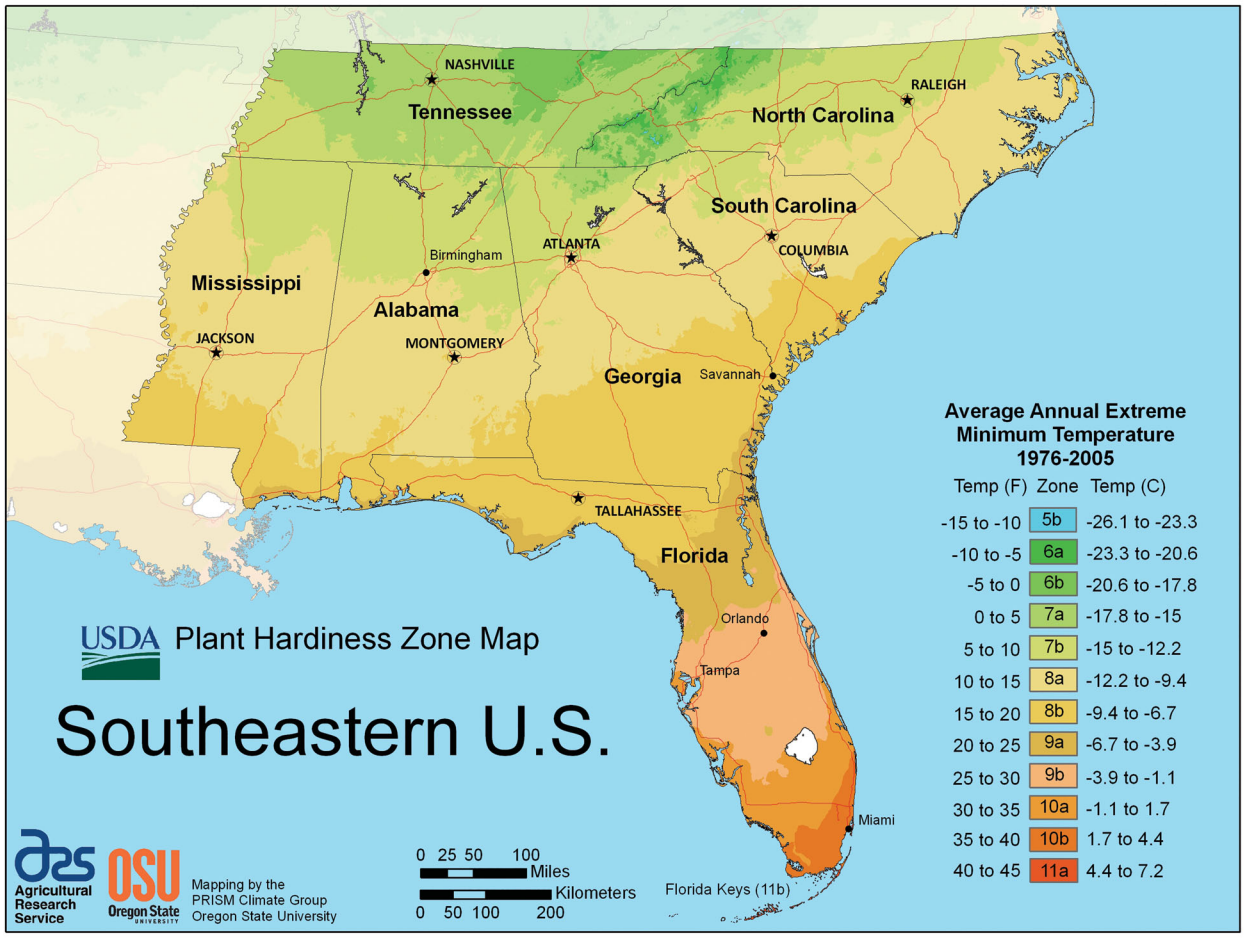

Figure 2. The current U.S. Department of Agriculture Plant Hardiness Zone Map for the Southeastern United States. Maps of other U.S. regions and of the entire country are available at planthardiness.ars.usda.gov. *Source:* Prism Climate Group and United States Agricultural Research Service (2012).

had arisen during on-site interviews. The survey was distributed through official channels including county extension offices and interest groups for tropical fruit enthusiasts, as well as through more informal means such as social media posts and word of mouth. It was open for responses from 21 June 2021 to 23 August 2021.

All human-subject research for this study was approved by the Institutional Review Board at Coastal Carolina University (protocol number 2021.69 initially approved on 12 February 2021, with updates approved on 23 February 2021, and 26 April 2021).

Site Visits and Interviews

Before field work commenced, one author, Fielding, reached out to breadfruit growers through two online message boards: the Tropical Fruit Forum (tropicalfruitforum.com) and the International Palm Society's "Palm Talk" forum (palmtalk.org/forum). The former includes discussions of many kinds of tropical fruits, including breadfruit, and the latter, although focused on palms as the name suggests, also hosts a so-called Off Topic Forum in which "tropical-looking plants other than palms" are discussed. In each post, the author introduced himself as a South Carolina–based researcher and Florida native,[3] with interest in breadfruit as a component of sustainable development. He stated that he was interested in learning about efforts to grow breadfruit outside of its known hardiness zones, particularly in Florida, and invited forum participants to contact him through the message boards or by e-mail if they would be interested in sharing their own experiences with breadfruit. Both posts resulted in many responses from breadfruit growers in Florida and elsewhere. In the correspondence that followed, several

Figure 3. A breadfruit tree, growing outdoors at the Harry S. Truman Little White House in Key West, Florida. *Photo:* R. Fielding.

Florida-based growers invited us to come see their breadfruit trees. Some growers referred us to others and, through a snowball sampling method, we were able to build a list of sites that we would visit and growers we would interview. This list included eight private individuals, four botanical gardens or similar institutions, and three other sites: a public park, a presidential museum (Figure 3, see Parks 1991), and a hotel. The site visits and interviews for this study are listed in Table 1, along with information specific to each.

During site visits, we engaged the growers in semi-structured interviews. These lasted from just a few minutes to several hours. The shortest visits consisted of simply observing and photographing a tree from the edge of a property for which we had not been able to make contact with the grower. We were unable to visit one site altogether but we spoke extensively by telephone with the grower, who sent photographs of the tree. Thirteen breadfruit growers were interviewed and topics similar to those raised in the online survey, detailed in what follows, were discussed. Specifically, each interview covered the grower's own history of—and motivation for—growing breadfruit, the provenance of each tree (i.e., whether it was planted from a seed, a root cutting, or an air layer, and whether the variety was known), the grower's experience with climatic and other environmental challenges, and the benefits they have seen from growing breadfruit in Florida.

Online Survey

The online survey, made available in both English and Spanish, included sixteen core questions, with an additional nine or ten questions (depending on the specific responses) that were repeated based on the number of trees that a person was growing. The

Table 1. Summary of site visits and interviews, ordered from north to south

Site name or type	Location	Method(s) of contact	No. of trees
Private home	Loxahatchee Groves	Interview	1
Private home	Davie	Interview, site visit, survey	1
Private home	Davie	Interview, site visit	1
Fairchild Tropical Botanic Garden	Coral Gables	Interview, site visit	2
The Kampong	Coconut Grove	Interview, site visit, survey	14
Private farm	Redland	Interview, site visit	2
Fruit & Spice Park	Redland	Interview, site visit	2
Private home/farm	Redland	Interview, site visit	1
Private home	Homestead	Interview, site visit	1
Grimal Grove	Big Pine Key	Interview, site visit	26
Private home	Key West	Interview, site visit	1
Private home	Key West	Site visit	1
Truman Little White House	Key West	Interview, site visit	1
Truman Waterfront Park	Key West	Site visit	1
Southernmost Point Guest House	Key West	Interview, site visit	1

survey was administered via the Snap Surveys account licensed to Coastal Carolina University. Prior to seeing the first survey question, respondents were given a choice of languages (English or Spanish) and presented with a brief paragraph of introductory text. Respondents were then asked to read a standard piece of informed-consent text and to type their name and the date as confirmation of their consent to participate in the survey.

Results

Based on both survey responses and site visits, this study has identified forty-three Florida-based breadfruit growers with a combined total of more than 121 breadfruit trees. The locations of all breadfruit trees represented in this study are mapped in Figure 4. Because results from the interviews and site visits can serve to clarify and refine trends identified through the survey, we shall discuss the results from the survey first and then results from the interviews and site visits below.

Online Survey

The survey yielded forty-one responses, thirty of which were from individuals currently growing breadfruit in Florida. Five respondents were identified as nongrowers and six as non-Florida growers; these were removed from the results for analysis. Two of the survey respondents were also growers that had been interviewed during the site visits. All but one respondent opted to complete the survey in English. Any extracts from the single Spanish response are presented here in English and the translations are our own.

Qualitative or otherwise open-ended survey responses were coded into an appropriate number of categories, based on the range of responses. Quantitative responses were grouped into ranges with natural breaks when necessary or analyzed statistically without grouping.

Survey responses are summarized by grower in Table 2 and by tree in Table 3. Cumulatively, the thirty Florida-based growers who responded to the survey reported having more than eighty breadfruit trees. Twenty-seven unique ZIP codes across eight counties were represented, with no more than two growers per ZIP code.

Four growers (13 percent) had been growing breadfruit for less than a year, ten (33 percent) had been growing between one and five years, six (20 percent) between six and ten years, and eight (27 percent) for more than ten years. The length of time spent growing breadfruit in Florida is especially relevant, owing to the number of cold winters that the older trees would have experienced.

In response to Question 5 ("Why do you grow breadfruit?"), the majority of respondents (15 growers, or 50 percent) reported that food production was their motivation. The second most common reason (eight growers, 27 percent) was the beauty of the tree. Thirteen percent of respondents (four growers) reported that growing breadfruit is a way

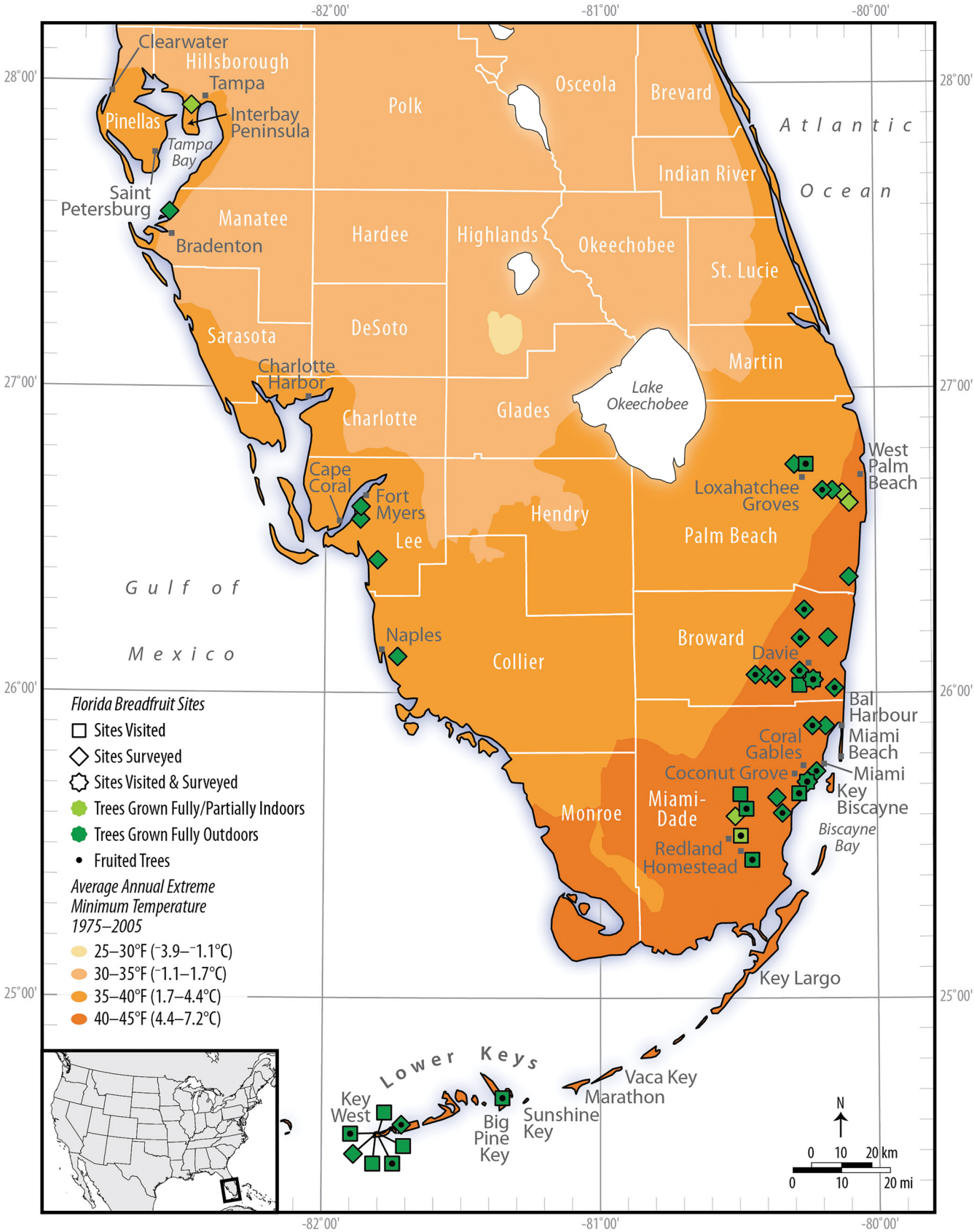

Figure 4. Map showing locations of breadfruit sites discussed in this study. Temperature data are derived from U.S. Department of Agriculture Plant Hardiness Zone Map (see Figure 2). *Cartography:* A.D. Ollivierre, Tombolo Maps & Design.

Table 2. Data on Florida breadfruit growers, summarized from survey responses

	No.	Percentage
Location, by county		
Broward	9	30
Collier	1	3
Hillsborough	1	3
Lee	3	10
Manatee	1	3
Miami-Dade	7	23
Monroe	2	7
Palm Beach	6	20
Type of growing operation		
Residential/home	22	73
Agricultural/farm	2	7
Botanical garden	2	7
Plant nursery	3	10
Length of time spent growing breadfruit in Florida		
< 1 year	4	13
1–5 years	10	33
6–10 years	6	20
> 10 years	8	27
No response	5	17
Number of trees currently growing		
1	23	73
2–5	5	17
6–10	1	3
11–25	1	3
25 or more	1	3
Motivation for growing breadfruit		
Beauty of tree	8	27
Food production	15	50
Challenge	4	13
Cultural or historical heritage	4	13
Other	5	17
No response	2	7
Experience with environmental hazards		
Protect against cold	13	43
Protect against wind	4	13
Problems due to saltwater	1	3
Membership in horticultural organizations		
Calusa Rare Fruit Exchange, Fort Myers	2	7
Florida Nursery, Growers and Landscape Association	1	3
International Palm Society	1	3
Rare Fruit & Vegetable Council of Broward	2	7
Rare Fruit Council International	4	13
Rare Fruit Society of Florida	2	7
Tropical Flowering Tree Society	1	3
Tropical Fruit & Vegetable Society of Redland	2	7
Tropical Fruit Growers of South Florida	1	3
Not a member of any horticultural organization	19	63
No response	9	30

Note: Only responses from current Florida-based breadfruit growers are included here ($n = 30$). The sum of percentages for some categories (e.g., motivation for growing breadfruit) add up to more than 100% because participants were allowed to provide more than one response.

that they connect to their own cultural heritage or to the history of the property on which the trees grow. Statements that were coded as cultural heritage refer to the grower's own personal history and include, "I am from Puerto Rico and grew up eating it all the time," and "It's my favorite tree. I

Table 3. Data on breadfruit trees currently growing in Florida, summarized from survey responses

	Number	Percentage
Variety		
'Ma'afala'	16	41
Unknown	23	59
Age of tree		
< 1 year	4	10
1–5 years	15	38
6–10 years	11	28
> 10 years	9	23
Height of tree		
< 2 feet (< 0.6 m)	1	3
2–5 feet (0.6–1.5m)	5	13
6–10 feet (1.8–3.0 m)	10	26
11–20 feet (3.6–6.1m)	17	44
21–30 feet (6.4–9.1m)	3	8
> 30 feet (9.1 m)	3	8
Propagation method		
Air layer	13	33
Root cutting	13	33
Seed[a]	2	5
Other	7	18
Unknown	16	41
Type of planting		
In the ground	33	85
In a container	5	13
No response	1	3
Location of planting		
Fully outdoors	33	85
Fully indoors (including greenhouses)	2	5
Partially sheltered	2	5
No response	2	5
Fruiting history		
Has produced fruit	19	49
Has not produced fruit	19	49
No response	1	3
Presence or absence of seeds in fruit[b]		
Seeds present	4	21
Seeds absent	9	47
Seeds inconsistent	1	5
No response	5	26

Note: Only trees for which complete, or nearly complete, responses were provided through the survey are included here ($n = 39$). Responses that were largely incomplete (i.e., with vital information such as number of trees or ZIP code missing) have been eliminated from this analysis.
[a]The trees propagated by seed may have been breadnut (*A. camansi*) rather than true breadfruit (see Aurore et al. 2014 and NTBG 2019a).
[b]Percentages given for this category are only of those trees that have produced fruit ($n = 28$).

had one in my backyard growing up in Haiti, but after moving to America, I found it hard to get the fruit, so eventually I decided to grow my own." Statements coded as historical heritage refer to the history of the property, as opposed to the grower's own personal history, and include this example from a representative of the Edison and Ford Winter Estates in Fort Myers (see Cosden, Newman, and Pendleton [2015] for more information):

> Breadfruit has both botanical and historical importance to the property here at the estates. Our geography and climate allow us to grow the specimens as part of our botanical collection. But breadfruit is also historically important because it is in the Mulberry family, which Edison was studying for a source of latex in the 1920s.

Another example of a historical heritage statement, which also mentions the changing climate, came from a representative of the Kampong:

> Our trees are part of the legacy of fruit crops collections of Dr. David Fairchild. … Breadfruit have been grown here with marginal success for about 25 years, but only in the last 5 years or so have the winters been warm enough to allow the trees any significant growth.

Four growers (13 percent) referenced being motivated by the challenge of attempting to grow breadfruit outside of its native habitat. An exemplary response for this category of motivation was, "Because when I moved to Miami I was told that it would not grow here." The particular grower who made that statement was proud of his twenty-five-foot, twenty-one-year-old breadfruit tree, which he said, "produces a large amount of fruit every year."

The majority of growers reported that they do not take precautions to protect their trees against cold weather, strong wind, or saltwater exposure (50 percent, 83 percent, and 90 percent, respectively). We coded the open-ended responses to the questions about the specific kinds of damage that occurs from cold weather, strong wind, and saltwater exposure; these responses are summarized in Table 4.

Although we relied heavily on the networks established by various horticultural enthusiast groups based in South Florida to distribute the survey, only eleven respondents (37 percent) reported being members of any such group. Membership was dispersed across nine separate groups, with four growers (13 percent) being members of more than one group.

Of the eighty trees identified in the survey results, thirty-nine (49 percent) had complete or nearly complete data (i.e., responses to the subsections of Question 11). Of these thirty-nine trees, the oldest was reported as having been planted thirty years ago and the newest was reported as having been acquired

Table 4. Reported damage to breadfruit trees from environmental conditions—cold, wind, and saltwater—ordered from least to most severe

	Due to cold weather		Due to strong wind		Due to saltwater	
Type of damage	No. of growers reporting	Percentage of growers reporting	No. of growers reporting	Percentage of growers reporting	No. of growers reporting	Percentage of growers reporting
None	10	33	12	40	0	0
Leaves smaller than normal	1	3	0	0	0	0
Fruit yield less than normal	0	0	1	3	0	0
Leaf discoloration or "burn"	9	30	2	7	0	0
Defoliation	9	30	3	10	0	0
Dehydration	0	0	1	3	0	0
Physical damage to leaves (i.e., tearing)	0	0	3	10	0	0
Branch tip damage	1	3	0	0	1	3
Branches drop	3	10	4	13	0	0
Tree stops growing	2	7	0	0	0	0
Tree dies back to roots	1	3	0	0	0	0
Tree falls down	0	0	1	3	0	0
Tree dies	3	10	0	0	1	3

Note: Percentages are based on the number of growers ($n = 30$) who responded to the survey.

only forty-five days prior to the completion of the survey. The average tree age reported was six years, ten months.

Survey respondents were asked to report the heights of their trees. Acknowledging misestimation as a possibility, we report here the specific heights given by the growers uncritically, as we have no practical way to verify the heights of trees we have not seen. The smallest tree reported was sixteen inches (40.6 cm) in height and the tallest was forty feet (12 m). The average height was fifteen feet (4.5 m). In terms of growth rate, then, the average as calculated from these data would be about four feet, three inches (1.3 m) per year. This average growth rate is near the top end of the range (0.5–1.5m/year) said to be expected for breadfruit trees growing "in favorable conditions" and might support our assumption that some overestimation of tree height by the survey respondents occurred (Lincoln, Ragone, et al. 2019, 330). Half of the trees (49 percent) had fruited and half had not.

Thirty-three trees (85 percent) were planted in the ground and five (13 percent) in containers. Two trees (5 percent) were reported as being kept "fully indoors" and two were "partially sheltered." The grower of one "partially sheltered" tree explained that the container-grown tree was left outside when the weather was warm and brought inside when it was cold. The other "partially sheltered" tree was planted outdoors with other, taller trees nearby as windbreaks. In all, thirty-two trees (40 percent of the total) were reported as being planted both in the ground and fully outdoors. This combination of criteria represents the most exposure to environmental conditions that a breadfruit tree would experience in Florida and was reported in six counties: Broward, Lee, Manatee, Miami-Dade, Monroe, and Palm Beach. Survey respondents reported that, of these thirty-two trees, only fifteen (42 percent) are given any form of protection from the cold. Methods of cold protection include erecting temporary shelters over the trees, placing heat lamps at the trees' bases, and adjusting irrigation protocols in anticipation of cold weather. One grower reported "string[ing] Christmas lights onto the tree" as the only method of cold protection practiced. Nineteen of these "outdoors, in-the-ground" trees (53 percent) have fruited.

Site Visits and Interviews

The information gathered during site visits and interviews serves to clarify some of the data collected through the survey. For example, one grower in Redland explained that he planted a single small breadfruit tree in a field mainly planted with palms because "I love a good challenge." He had planted the tree in January, 2021, and it had survived several nights below 50 °F (10 °C). When asked what he did

to protect his tree during winter, this grower said simply, "Nothing. It's a warrior!" Another grower, the Director of Collections for the Center for Tropical Plant Conservation at Fairchild Tropical Botanic Garden in Coral Gables, explained that the duration of cold weather can be just as important, or more so, than the absolute lowest temperature experienced. With a well-timed regimen of watering in the days leading up to a forecasted cold front, this grower is able to protect his outdoor breadfruit tree, which he described as "hearty and adaptable." Another botanical garden-based grower, a horticulturist at the Preston B. Bird and Mary Heinlein Fruit & Spice Park in Redland (Rollins 1987), discussed the relationship between watering and cold weather. She described how the Park's two breadfruit trees, which are planted in large box-like containers under the cover of a greenhouse, had never fruited while previously planted directly in the ground, but when the trees were dug up and replanted in the containers, they began to fruit. The horticulturist explained that the reason was likely related to the type of soil in the containers and its drainability. She specifically pointed out that the temperature range inside the greenhouse was similar to that of the Florida Keys and that the soil in the containers was similar to soils found in the Keys.

One grower, a Jamaican immigrant based in Homestead, maintained an impressive tropical garden in the backyard of her very suburban home. The centerpiece in this garden was a large breadfruit tree, which she had planted as an air layer taken off a tree that had stood in its place but was blown down during Hurricane Irma, which struck Florida in September 2017. This grower's tree produces fruit prolifically and also sends up many root suckers, which she cuts and pots to sell. The fruits, however, are not for sale. "I try to eat everything I grow," she said. Another grower, who immigrated to the town of Davie from Guyana, planted a single breadfruit tree in her suburban front yard because she missed the fruit that was plentiful in her home country. This tree defoliates in winter and has not borne fruit, despite being sixteen years old at the time of this study. The grower diligently prunes the tree and picks off insects because, in her words, "I really want breadfruit."

The largest breadfruit operation visited for this study was Grimal Grove on Big Pine Key. This two-acre site was established by amateur horticulturist Adolf Grimal in 1955 but fell into disrepair after his death in 1997. Grimal hewed his grove out of the limestone rock that underlies much of the land in the Florida Keys and filled the excavations with soil brought in from mainland Florida (Garvey 2016). The Grove's present owner took over in 2013, initiating a community-based restoration campaign that culminated in the Grove's reopening in 2016, just prior to its devastation in Hurricane Irma the following year. After the hurricane, Grimal Grove was restored once again, having "lost 85 percent of our trees [with] three feet of saltwater over the whole grove" as the grower described to local media (Duong 2019). Twenty-six breadfruit trees now grow at Grimal Grove, most of them—eighteen—of the 'Ma'afala' variety, with five that the grower called "white variety," (a Caribbean designation for which the analogous Pacific variety is not certain; see Daley, Roberts-Nkrumah, and Alleyne [2020] and Roberts-Nkrumah [2018]) and one each of 'Piipiia,' 'Puaa,' and a suspected 'Ma'afala' hybrid. Grimal Grove sells air layers from breadfruit trees, as well as the fruits themselves. Having witnessed the resilience with which the breadfruit trees grew back after Hurricane Irma, the grower at Grimal Grove stated that he was "done planting anything but breadfruit."

Discussion

This study identified forty-three breadfruit growers in Florida, with a total of more than 121 individual breadfruit trees. We say "more than 121" because one survey respondent indicated that they currently grow more than twenty-five breadfruit trees but did not provide the exact number. The figure of 121 and all the calculations in our analysis assume exactly twenty-five trees from this grower. Thirty-five of the growers (81 percent) are based north of the Florida Keys, with the absolute northernmost breadfruit tree identified by this study at latitude 27.9°N on Tampa's Interbay Peninsula in Hillsborough County. This tree, however, is planted in a container and is moved indoors during cold weather—a practice that could, conceivably, allow for breadfruit to be grown much farther north than Tampa. The northernmost tree planted outdoors, in the ground, and without cold protection identified by this study grows on Terra Ceia Island in Manatee County at latitude 27.6°N, but at only six months old (at the time of the survey), it has not yet proven whether it can produce fruit. The northernmost

breadfruit tree in Florida that has fruited, according to this study, grows at latitude 26.7°N in Loxahatchee Groves. All the fruiting trees identified by this study are in the Florida Keys or in the counties of Miami-Dade, Broward, or Palm Beach—all southeastern counties. The location of the northernmost fruiting tree identified in this study might approximate the current northern environmental limit to breadfruit fruit production in the mainland United States.

Here, it must be acknowledged that growing breadfruit trees as a horticultural exercise is interesting for the growers (and the geographers who study their spatial distribution), but rather inconsequential in terms of food production: an outcome of agroforestry for which fruiting is the *sine qua non*. Practitioners of sustainable development tout breadfruit's high yield of nutritious fruit in terms of its potential to contribute to global food security (Jones et al. 2011). For this contribution to be realized in novel environmental settings, breadfruit trees must do more than survive outside their prescribed hardiness zones—they must yield fruit. Fruit produced by Florida-grown breadfruit trees is sold at local farmer's markets and fruit stands and is especially popular among members of Florida's Caribbean immigrant communities. Among survey respondents, "food production" was the most frequently given reason for growing breadfruit.

The northernmost fruit-producing breadfruit tree found in this study was planted in Loxahatchee Groves during the winter of 2018–2019 and has survived its fourth winter at the time of writing. It has produced fruit during the past two years. The map in Figure 4, which shows the locations of all breadfruit trees identified by this study, indicates a likely expansion of breadfruit's actual hardiness zone well beyond what has been historically assumed to be its natural limit of cultivation "only on the Florida Keys, especially in Key West, or in protected areas along Biscayne Bay" (Ledin 1957, 356).

As global temperatures continue to rise in response to anthropogenic greenhouse gas emissions, it is likely that the areas of Florida where breadfruit is currently being grown will become even more suitable to this "ultra-tropical" crop. It is also likely that more areas in Florida and perhaps even in other U.S. states will become suitable for breadfruit as modeling by Mausio et al. (2020) predicts. Bill Whitman, the twentieth-century amateur horticulturist, seems to have predicted this moment in a 1991 article on the technical methods of cold protection for what he referred to as "cold-tender fruit trees," highlighting breadfruit as among the most "cold-tender" of all. Whitman (1991) wrote:

> If our planet continues to heat up, as some scientists predict, possibly our descendants will face a climatically changed environment. This could mean the Greater Miami area would possibly experience minimum temperatures similar to that of Key West and cold protection would no longer be required. (5)

This study, although certainly not inclusive of every breadfruit grower in the mainland United States, has shown that Whitman's "possibility" is now, in some parts of Florida, a reality. Breadfruit currently grows, outdoors and without cold protection, in at least six Florida counties. That geographical range is likely to expand both northward and inland as average temperatures rise and extreme cold events become less frequent, causing the temperate zones of Florida to "tropicalize" (Osland et al. 2021). Perhaps, then, the ecosystem services, contributions to food security and biocultural restoration, and value to sustainable development that Hawai'i-based scholarship has identified with regard to breadfruit (Langston and Lincoln 2018) might be further realized throughout the mainland United States.

Acknowledgments

The authors wish to thank all the Florida-based breadfruit growers who responded to our online survey and who welcomed us to their homes, farms, gardens, and nurseries for site visits. We are grateful to Bárbara Gasquet Carrera and Maria T. Zaldivar for their assistance in creating the Spanish version of the survey, and to Molly French for its development and administration. Mike Opgenorth of the National Tropical Botanical Garden and Noa Kekuewa Lincoln of the University of Hawai'i-Manoa provided valuable background information on breadfruit (or *'ulu* as it is rightly called in Hawai'i). Crafton Clift, Arturo Gonzalez, Chris Rollins, and Larry Wiggins shared their knowledge and experience of tropical horticulture in Florida. Jonathan Crane of Tropical Research and Education Center and Michelle Leonard-Mularz of the University of Florida Extension office in Monroe County offered insight and assistance. Fieldwork for

this project was supported by internal funding through the HTC Honors College at Coastal Carolina University.

Supplemental Material

The specific questions included in the online survey, along with notes on the design and structure of the survey itself, are available as an online supplement to this article. This supplemental information can be accessed on the publisher's site at: https://doi.org/10.1080/24694452.2022.2107986

ORCID

Russell Fielding http://orcid.org/0000-0002-5401-2141

Notes

1. Vaughan's letter, dated 17 March 1789, would have been written while Bligh was still overseeing final efforts to load the *Bounty* with potted breadfruit saplings at Tahiti's Matavai Bay; in another letter the following year, Vaughan would break the news of the mutiny to Jefferson.
2. Morton cites USDA SPI #19228 as the record of the 1906 importation. A cross-check of the USDA's Bureau of Plant Industry bulletins from the time reveals that Seed and Plant Introduction number 19228 did indeed occur on 27 September 1906, and involved an unstated number of breadfruit plants (given the then-current scientific name *Artocarpus incisa*) that were brought from Ancon, in Panama, and received by one Henry F. Schultz (USDA 1908, 18).
3. Both authors are Florida natives. Based on the frequency with which our birthplaces came up in discussions with Florida-based breadfruit growers, and the positive manner in which this information was received, we believe that mentioning this fact in initial communications was instrumental in gaining access to some of the sites we visited.

References

Aba, S. C., O. O. Ndukwe, C. J. Amu, and K. P. Baiyeri. 2017. The role of trees and plantation agriculture in mitigating global climate change. *African Journal of Food, Agriculture, Nutrition and Development* 17 (4):12691–12707. doi: 10.18697/ajfand.80.15500.

Aurore, G., J. Nacitas, B. Parfait, and L. Fahrasmane. 2014. Seeded breadfruit naturalized in the Caribbean is not a seeded variety of *Artocarpus altilis*. *Genetic Resources and Crop Evolution* 61 (5):901–07. doi: 10.1007/s10722-014-0119-0.

Badrie, N., and J. Broomes. 2010. Beneficial uses of breadfruit (*Artocarpus altilis*): Nutritional, medicinal and other uses. In *Bioactive foods in promoting health*, ed. R. R. Watson and V. R. Preedy, 491–505. London: Academic Press.

Banks, J. 1896. *Journal of the Right Hon. Sir Joseph Banks*, ed. J. D. Hooker. London: Macmillan.

Bidwell's nursery. 1880. *Florida Agriculturalist*, December 8.

Blunden, J., and T. Boyer, eds. 2021. State of the climate in 2020. *Bulletin of the American Meteorological Society* 102 (8):Si–S475. doi:10.1175/2021BAMSStateoftheClimate.1.

Boyd, J. P., ed. 1958. *The papers of Thomas Jefferson*, Vol. *15: 27 March 1789–30 November 1789*. Princeton, NJ: Princeton University Press.

Braun, J. 2019. Bioprospecting breadfruit: Imperial botany, transoceanic relations, and the politics of translation. *Early American Literature* 54 (3):643–71. doi: 10.1353/eal.2019.0062.

Bread fruit tree. 1888. *Palatka Daily News*, January 31.

Chen, I.-C., J. K. Hill, R. Ohlemüller, D. B. Roy, and C. D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. *Science* 333 (6045):1024–26.

Christie, F. 1795. To George Washington from Fairlie Christie, *Founders Online*, National Archives, 25 March 1795. Accessed May 7, 2021. https://founders.archives.gov/documents/Washington/05-17-02-0457-0001.

Cosden, M., B. Newman, and C. Pendleton. 2015. *Edison and Ford in Florida*. Charleston, SC: Arcadia.

Dacy, G. H. 1926. Florida's Burbank. *South* 2 (4):36–38, 66–68, 74.

Daley, O. O., L. B. Roberts-Nkrumah, and A. T. Alleyne. 2020. Morphological diversity of breadfruit [*Artocarpus altilis* (Parkinson) Fosberg] in the Caribbean. *Scientia Horticulturae* 266:109278. doi: 10.1016/j.scienta.2020.109278.

Dampier, W. 1697. *A new voyage round the world*. London: Knapton.

Davis, M. B., and R. G. Shaw. 2001. Range shifts and adaptive responses to Quaternary climate change. *Science* 292 (5517):673–79. doi: 10.1126/science.292.5517.673.

DeLoughrey, E. 2007. Globalizing the routes of breadfruit and other bounties. *Journal of Colonialism and Colonial History* 8 (3). doi: 10.1353/cch.2008.0003.

Dening, G. 1992. *Mr. Bligh's bad language: Passion, power and theatre on the Bounty*. Cambridge, UK: Cambridge University Press.

Duong, T. 2019. Growing hope—Historic Grimal Grove re-opening, becoming "Grove of the Future." *Keys Weekly*, November 8. Accessed August 18, 2022. https://keysweekly.com/42/growing-hope-historic-grimal-grove-re-opening-becoming-grove-of-the-future/.

Ellis, J. 1775. *A description of the mangostan and the breadfruit: The first, esteemed one of the most delicious; the other, the most useful of all the fruits in the East Indies*. London: Dilly.

Fairchild, D. 1947. *The world grows round my door: The story of the Kampong, a home on the edge of the tropics*. New York: Charles Scribner's Sons.

Food and Agricultural Organization of the United Nations. 2021. Annex I: List of crops covered under the Multilateral System. International Treaty on Plant Genetic Resources for Food and Agriculture: The Multilateral System. Accessed August 18, 2022. http://www.fao.org/plant-treaty/areas-of-work/the-multilateral-system/annex1/en/.

Fruit festival at Homestead draws crowds. 1929. *Miami Daily News and Metropolis*, February 19.

Gamedoagbao, D. K., and S. O. Bennett-Lartey. 2007. Conservation and use of breadfruit: Ghanaian perspective. *Acta Horticulturae* 757:125–27. doi: 10.17660/ActaHortic.2007.757.16.

Garvey, P. 2016. Saving the Grimal Grove, restoring a legendary tropical fruit collection and establishing Grimal Grove as the southernmost tropical fruit park. *Proceedings of the Florida Horticultural Society* 129:35–36.

Gifford Arboretum. 2014. Gifford Arboretum Horticultural News. *Gifford Arboretum Newsletter* 10 (1):6.

Goebel, R. 2007. Breadfruit—The Australian scene. *Acta Horticulturae* 757:141–48. doi: 10.17660/ActaHortic.2007.757.19.

Hoyt, R. D. 1890a. *Descriptive catalogue and price list of tropical and semi-tropical fruit trees, vines, shrubs, and greenhouse plants grown at the Seven Oaks Nurseries, Bay View, Florida, U.S.A.* Harrisburg, PA: McFarland.

Hoyt, R. D. 1890b. Tropical fruits. In *Proceedings of the Third Annual Meeting of the Florida Horticultural Society*, ed. I. K. Cresap, 19–21.

Intergovernmental Panel on Climate Change. 2018. *Global warming of 1.5 °C: An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, ed. V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, et al. Geneva, Switzerland: World Meteorological Organization.

Jithila, P. J., and P. K. Prasadan. 2018. Carbon sequestration by trees—A study in the Western Ghats, Wayanad Region. *Indian Journal of Ecology* 45 (3):479–82.

Jones, A. M. P., D. Ragone, N. G. Tavana, D. W. Bernotas, and S. J. Murch. 2011. Beyond the bounty: Breadfruit (*Artocarpus altilis*) for food security and novel foods in the 21st century. *Ethnobotany Research and Applications* 9:129–49. doi: 10.17348/era.9.0.129-149.

Kirch, P. V. 2019. *A shark going inland is my chief: The island civilization of ancient Hawai'i*. Berkeley: University of California Press.

Knutson, T., S. J. Camargo, J. C. L. Chan, K. Emanuel, C.-H. Ho, J. Kossin, M. Mohapatra, M. Satoh, M. Sugi, K. Walsh, and L. Wu. 2020. Tropical cyclones and climate change assessment: Part II: Projected response to anthropogenic warming. *Bulletin of the American Meteorological Society* 101 (3):E303–22. https://doi.org/10.1175/BAMS-D-18-0194.1

Langston, B. J., and N. K. Lincoln. 2018. *The role of breadfruit in biocultural restoration and sustainability in* Hawai'i. *Sustainability* 10:3965.

Leakey, C. L. 1977. *Breadfruit reconnaissance study in the Caribbean region*. Cali, Colombia: CIAT.

Ledin, R. B. 1957. Tropical and subtropical fruits in Florida (other than citrus). *Economic Botany* 11 (4):349–76. doi: 10.1007/BF02903817.

Leonard-Mularz, M., R. Fielding, and P. Garvey. 2021. An introduction to a breadfruit grove in Big Pine Key, Florida. *Proceedings of the Florida State Horticultural Society* 134:39. https://fshs.org/book/proceedings-of-the-134th-annual-meeting-2021/.

Lincoln, N. K., and T. Ladefoged. 2014. Agroecology of pre-contact Hawaiian dryland farming: The spatial extent, yield and social impact of Hawaiian breadfruit groves in Kona, Hawai'i. *Journal of Archaeological Science* 49:192–202. doi: 10.1016/j.jas.2014.05.008.

Lincoln, N. K., A. Cho, G. Dow, and T. Radovich. 2019. Early growth of breadfruit in a variety × environment trial. *Agronomy Journal* 111 (6):3020–27. doi: 10.2134/agronj2019.02.0068.

Lincoln, N. K., D. Ragone, N. J. Zerega, L. B. Roberts-Nkrumah, M. Merlin, and A. M. P. Jones. 2019. Grow us our daily bread: A review of breadfruit cultivation in traditional and contemporary systems. *Horticultural Reviews* 46:299–384.

Liu, Y., P. N. Brown, D. Ragone, D. L. Gibson, and S. J. Murch. 2020. Breadfruit flour is a healthy option for modern foods and food security. *PLoS ONE* 15 (7):e0236300. doi: 10.1371/journal.pone.0236300.

Liu, Y., D. Ragone, and S. J. Murch. 2015. Breadfruit (*Artocarpus altilis*): A source of high-quality protein for food security and novel food products. *Amino Acids*.47 (4):847–56. doi: 10.1007/s00726-015-1914-4.

Mackay, D. 1974. Banks, Bligh, and breadfruit. *New Zealand Journal of History* 8 (1):61–77.

Maerere, A. P., and E. R. Mgembe. 2007. Breadfruit production in Tanzania: Current status and potential. *Acta Horticulturae* 757:129–34. doi: 10.17660/ActaHortic.2007.757.17.

Mann, M. E. 2002. Medieval climatic optimum. In *The Earth system: Physical and chemical dimensions of global environmental change*, vol. 1 of *Encyclopedia of global environmental change*, ed. M. C. MacCracken and J. S. Perry, 514–16. Chichester, UK: Wiley.

Markham, C. 1904. *The voyages of Pedro Fernandez de Quiros, 1595 to 1606*. London: Hakluyt Society.

Mausio, K., T. Miura, and N. K. Lincoln. 2020. Cultivation potential projections of breadfruit (*Artocarpus altilis*) under climate change scenarios using an empirically validated suitability model calibrated in Hawai'i. *PLoS ONE* 15 (5):e0228552. doi: 10.1371/journal.pone.0228552.

McBryde, F. W. 1947. *Cultural and historical geography of southwest Guatemala*. Washington, DC: Smithsonian Institution.

Medagoda, I. 2007. Breadfruit in the Asian region—Focus on Sri Lanka. *Acta Horticulturae* 757:65–69. doi: 10.17660/ActaHortic.2007.757.7.

Meilleur, B. A., R. R. Jones, C. A. Titchenal, and A. S. Huang. 2004. *Hawaiian breadfruit: Ethnobotany, nutrition, and human ecology*. Honolulu: College of Tropical Agriculture and Human Resources, University of Hawai'i at Mānoa.

Montenegro, A., C. Avis, and A. Weaver. 2008. Modeling the prehistoric arrival of the sweet potato in Polynesia. *Journal of Archaeological Science* 35 (2):355–67. doi: 10.1016/j.jas.2007.04.004.

Moriondo, M., F. M. Stefanini, and M. Bindi. 2008. Reproduction of olive tree habitat suitability for global change impact assessment. *Ecological Modelling* 218 (1–2):95–109. doi: 10.1016/j.ecolmodel.2008.06.024.

Morton, J. F. 1987. *Fruits of warm climates*. Miami, FL: Author.

Moustache, A.-M., and M. Moustache. 2007. History and use of breadfruit in the Seychelles. *Acta Horticulturae* 757:135–40.

Mulcahy, M. 2014. *Hubs of empire: The southeastern lowcountry and British Caribbean*. Baltimore, MD: Johns Hopkins University Press.

National Tropical Botanical Garden (NTBG). 2019a. Breadfruit species. The Breadfruit Institute. Accessed September 1, 2021. https://ntbg.org/breadfruit/about/species/.

National Tropical Botanical Garden (NTBG). 2019b. Growing regions. The Breadfruit Institute. Accessed August 26, 2021. https://ntbg.org/breadfruit/care/regions/.

National Tropical Botanical Garden (NTBG). 2019c. Our work. The Breadfruit Institute. Accessed September 13, 2021.https://ntbg.org/breadfruit/work/.

Needham, A., R. Jha, and N. K. Lincoln. 2020. The response of breadfruit nutrition to local climate and soil: A review. *Journal of Food Composition and Analysis* 88:103451. doi: 10.1016/j.jfca.2020.103451.

Newell, J. 2010. *Trading nature: Tahitians, Europeans, and ecological exchange*. Honolulu: University of Hawai'i Press.

Oberg, B. B., ed. 2002. *The papers of Thomas Jefferson, Vol. 29: 1 March 1796 to 31 December 1797*. Princeton, NJ: Princeton University Press.

Omobuwajo, T. O. 2007a. Breadfruit as a key component of sustainable livelihoods in Nigeria: Prospects, opportunities and challenges. *Acta Horticulturae* 757:121–24.

Omobuwajo, T. O. 2007b. Overview of the status of breadfruit in Africa. *Acta Horticulturae* 757:61–63. doi: 10.17660/ActaHortic.2007.757.6.

Osland, M. J., P. W. Stevens, M. M. Lamont, R. C. Brusca, K. M. Hart, J. H. Waddle, C. A. Langtimm, C. M. Williams, B. D. Keim, A. J. Terando, et al. 2021. Tropicalization of temperate ecosystems in North America: The northward range expansion of tropical organisms in response to warming winter temperatures. *Global Change Biology* 27 (13):3009–34. doi: 10.1111/gcb.15563.

Padulosi, S., J. Thompson, and P. Rudebjer. 2013. *Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): Needs, challenges and the way forward*. Rome: Bioversity International.

Parks, A. M. 1991. *Harry Truman and the Little White House in Key West*. Milwaukee, WI: Centennial Press.

Parry, M. L. 1981. Climatic change and the agricultural frontier: A research strategy. In *Climate and history: Studies in past climates and their impact on man*, ed. T. M. L. Wigley, M. J. Ingram, and G. Farmer, 319–36. Cambridge, UK: Cambridge University Press.

Points of interest. 1946. *Key West Citizen*, March 23.

Prism Climate Group and United States Agricultural Research Service. 2012. *USDA plant hardiness zone map: Southeastern U.S.* Washington, DC: U.S. Department of Agriculture, Agricultural Research Service; Corvallis: Oregon State University. Accessed May 25, 2022. https://planthardiness.ars.usda.gov/.

Pulsipher, L. M. 1990. They have Saturdays and Sundays to feed themselves. *Expedition* 32 (2):24–33.

Ragone, D. 1991. Ethnobotany of breadfruit in Polynesia. In *Islands, plants, and Polynesians: An introduction to Polynesian ethnobotany*, ed. P. A. Cox and S. A. Banack, 203–20. Portland, OR: Dioscorides Press.

Ragone, D. 1997. *Breadfruit—Artocarpus altilis (Parkinson) Fosberg: Promoting the conservation and use of underutilized and neglected crops 10*. Rome: International Plant Genetic Resources Institute.

Ragone, D. 2007. Breadfruit: Diversity, conservation and potential. *Acta Horticulturae* 757:19–29.

Ragone, D., and C. G. Cavaletto. 2006. Sensory evaluation of fruit quality and nutritional composition of 20 breadfruit (*Artocarpus*, Moraceae) cultivars. *Economic Botany* 60 (4):335–46. doi: 10.1663/0013-0001(2006)60[335:SEOFQA.2.0.CO;2]

Reasoner, P., and W. G. Klee. 1888. *U.S. Department of Agriculture, Division of Pomology Bulletin no.1*. Washington, DC: U.S. Government Printing Office.

Reasoner, P., and E. Reasoner. 1892. *Descriptive and illustrated catalogue and manual of Royal Palm Nurseries, Oneco, Florida, U.S.A.* Harrisburg, PA: McFarland.

Roberts-Nkrumah, L. B. 2007. An overview of breadfruit (*Artocarpus altilis*) in the Caribbean. *Acta Horticulturae* 757:51–60.

Roberts-Nkrumah, L. B. 2018. *The breadfruit germplasm collection at the University of the West Indies, St Augustine Campus*. Mona, Jamaica: University Press of the West Indies.

Rollins, C. B. 1987. The role of the Fruit & Spice Park in popularization and dissemination of tropical fruit in South Florida. *Proceedings of the Florida Horticultural Society* 100:323–27.

Sauer, J. D. 1993. *Historical geography of crop plants: A select roster*. Boca Raton, FL: CRC Press.

Sloat, L. L., S. J. Davis, J. S. Gerber, F. C. Moore, D. K. Ray, P. C. West, and N. D. Mueller. 2020. Climate adaptation by crop migration. *Nature Communications* 11 (1):1243. doi: 10.1038/s41467-020-15076-4.

Stone, D. E. 2018. *The food explorer: The true adventures of the globe-trotting botanist who transformed what America eats*. New York: Penguin.

Suggests pulp tree for Dade area industry. 1929. *Miami Daily News*, August 4.

Taylor, M. B., and V. S. Tuia. 2007. Breadfruit in the Pacific region. *Acta Horticulturae* 757:43–50.

Toensmeier, E. 2016. *The carbon farming solution: A global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security*. White River Junction, VT: Chelsea Green.

Toensmeier, E. 2017. Perennial staple crops and agroforestry for climate change mitigation. In *Integrating landscapes: Agroforestry for biodiversity conservation and food sovereignty*, ed. F. Montagnini, 439–51. Cham, Switzerland: Springer.

Turi, C. E., Y. Liu, D. Ragone, and S. J. Murch. 2015. Breadfruit (*Artocarpus altilis* and hybrids): A traditional crop with the potential to prevent hunger and mitigate diabetes in Oceania. *Trends in Food Science & Technology* 45 (2):264–72. doi: 10.1016/j.tifs.2015.07.014.

U.S. Department of Agriculture (USDA). 1906. *Weather Bureau bulletin P*. Washington, DC: Weather Bureau.

U.S. Department of Agriculture (USDA). 1908. *Seeds and plants imported during the period from July, 1906, to December 31, 1907*. Bureau of Plant Industry Bulletin No. 132. Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture, Agricultural Research Service. 2012. USDA Plant Hardiness Zone Map. Accessed February 17, 2021. https://planthardiness.ars.usda.gov/.

Wallingford, P. D., T. L. Morelli, J. M. Allen, E. M. Beaury, D. M. Blumenthal, B. A. Bradley, J. S. Dukes, R. Early, E. J. Fusco, D. E. Goldberg, et al. 2020. Adjusting the lens of invasion biology to focus on the impacts of climate-driven range shifts. *Nature Climate Change* 10 (5):398–405. doi: 10.1038/s41558-020-0768-2.

Whitman, W. F. 1972. Two decades of tropical fruit introduction. *Proceedings of the Florida State Horticultural Society* 85: 280–87.

Whitman, W. F. 1991. Cold protection for ultra tropicals in a sub tropical climate. *Tropical Fruit News* 25 (11):4–5.

Whitman, W. F., S. Mauro, and S. W. Younghans. 1956. Rare Fruit Council activities 1955–1956. *Proceedings of the Florida State Horticultural Society* 69:297–303.

Williams, E. W., E. M. Gardner, R. Harris, III, A. Chaveerach, J. T. Pereira, and N. J. Zerega. 2017. Out of Borneo: Biogeography, phylogeny and divergence date estimates of *Artocarpus* (Moracae). *Annals of Botany* 119:611–27.

Wolfe, H. S. 1937. Fifty years of tropical fruit culture. *Proceedings of the Florida State Horticultural Society* 50:72–78.

Zerega, N., D. Ragone, and T. J. Motley. 2004. Complex origins of breadfruit (*Artocarpus altilis*, Moraceae): Implications for human migration in Oceania. *American Journal of Botany* 91 (5):760–66. doi: 10.3732/ajb.91.5.760.

Zerega, N., D. Ragone, and T. J. Motley. 2006. Breadfruit origins, diversity, and human-facilitated distribution. In *Darwin's harvest: New approaches to the origins, evolution, and conservation of crops*, ed. T. J. Motley, N. Zerega, and H. Cross, 213–38. New York: Columbia University Press.

RUSSELL FIELDING is an Assistant Professor in the HTC Honors College, Coastal Carolina University, Conway, SC 29528. E-mail: rfielding@coastal.edu. His research addresses issues related to food security and sustainability in the Caribbean and other tropical and semitropical regions of the world.

JORGE JULIAN ZALDIVAR is a tropical fruit farmer in Guavonia Guava Grove & Tropication Rare Plants, Homestead, FL 33031. E-mail: jzald001@fiu.edu. His research interests include prerevolutionary Cuba, Floridiana, guava, Florida agriculture, and historical anecdotes surrounding Miami, Florida.