

**Four-petal pawpaw  
(*Asimina tetramera*)**

**5-Year Review:  
Summary and Evaluation**



Photo by Kim Alexander, Florida Natural Areas Inventory

**January 2022**

**U.S. Fish and Wildlife Service  
South Atlantic-Gulf Region  
Florida Ecological Services Field Office  
Vero Beach, Florida**

**5-YEAR REVIEW**  
**Four-petal Pawpaw (*Asimina tetramera*)**

**I. GENERAL INFORMATION**

**A. Methodology used to complete the review:** In conducting this 5-year review, we relied on the best available information pertaining to historical and contemporary distributions, life histories, genetics, habitats, and threats of this species. This review includes information from the previous 5-year review (U.S. Fish and Wildlife Service [Service] 2009) that is still applicable to the species, with updated or new information incorporated, as appropriate. We announced initiation of this review and requested information in a published *Federal Register* notice with a 60-day comment period in 2019 (84 FR 28850). We received one public comment during the open comment period. We evaluated and incorporated the comment as appropriate in this review. We used a variety of information resources, including monitoring reports, surveys, and other scientific and management information. Specific sources included: The final rule (51 FR 34415; Service 1986) listing this plant under the Endangered Species Act of 1973, as amended (ESA), the Recovery Plan (Service 1999), the last 5-year review (Service 2009), the recovery plan amendment (Service 2019), peer reviewed scientific publications, and unpublished field observations by Federal, State, and other experienced biologists. The Service contracted this review to a Florida Natural Areas Inventory (FNAI) botanist, and it was finalized by the lead recovery biologist for the four-petal pawpaw in the Florida Ecological Services Field Office (FESFO), Vero Beach. Literature and documents used for this 5-year review are on file at the FESFO. All recommendations resulting from this review are a result of thoroughly reviewing the best available information on the beautiful pawpaw. The Service did not seek additional peer review for this updated 5-year review.

**B. Reviewers**

**Lead Region:** South Atlantic-Gulf Region, Carrie Straight, (404) 679-7226

**Lead Field Office:** FESFO, Vero Beach, Heather Hitt, [Heather\\_Hitt@fws.gov](mailto:Heather_Hitt@fws.gov), (772) 469-4267

**C. Background**

**1. FR Notice citation announcing initiation of this review:** June 20, 2019, 84 FR 28850.

**2. Listing history**  
Original Listing

Federal Register Notice: 51 FR 34415

Federal Register Notice Date: September 26, 1986

Effective listing date: October 27, 1986

Entity listed: Species

Classification: Endangered

3. **Associated rulemakings:** There are no associated rulemakings for this species.
4. **Review History:** Each year, the Service reviews and updates listed species information to benefit the required Recovery Report to Congress. Through 2013, we performed a yearly recovery data call. The last review conducted in 2009 showed this species' status as uncertain with no change recommended to the species' status due to the lack of population monitoring and ongoing threats.

Recovery Plan: 1999

Recovery Plan Amendment: 2019

Previous Five-Year Reviews: 1991 and 2009, both reviews recommended no change in status for the species.

5. **Species' Recovery Priority Number at start of review (48 FR 43098):** 11  
Degree of Threat: Moderate  
Recovery Potential: Low  
Taxonomy: Species
6. **Recovery Plan**  
Name of plan: South Florida Multi-Species Recovery Plan (MSRP) (Service 1999)  
Date issued: May 18, 1999  
Date of recovery plan amendment: September 24, 2019 (Service 2019)  
Date of previous plan: April 5, 1988 (Recovery plan for three Florida pawpaws) (Service 1988)

## II. REVIEW ANALYSIS

### A. Application of the 1996 Distinct Population Segment (DPS) policy

1. **Is the species under review listed as a DPS?** No. The Endangered Species Act defines species as including any subspecies of fish, wildlife, or plant, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review is a plant, the DPS policy is not applicable.

### B. Recovery Criteria

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes.
2. **Adequacy of recovery criteria.**
  - a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** Yes.
  - b. **Are all of the 5 listing factors that are relevant to the species addressed in the**

**recovery criteria (and is there no new information to consider regarding existing or new threats)?** Yes.

**3. List the recovery criteria as they appear in the recovery plan and discuss how each criterion has or has not been met, citing information.**

The recovery criteria, as presented in the 2019 amendment to the 1999 recovery plan, are broken down into three criteria ([1-3] in bold below). These criteria address factors A) the present or threatened destruction, modification, or curtailment of its habitat or range; D) inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors affecting its survival. Factors B (overutilization) and C (disease or predation) are not considered relevant to this species.

**Four-petal pawpaw will be considered for delisting when:**

**[1] At least 25 populations exhibit a stable or increasing trend, evidenced by natural recruitment and multiple age classes. (Factors A, D, and E)**

This criterion has not been met. Currently there are only 9 extant or presumably extant populations on 14 different sites (i.e., sub-populations) remaining, a significant decrease since the previous review when there were 16 populations on 21 different sites (Service 2009; FNAI 2021; Table 1). Sub-populations at eight sites have been extirpated, in nearly every case due to development. At three separate sites, introduction/relocation attempts were ultimately unsuccessful as plants did not survive for more than a few years. Even at sites where populations remain, only half appear to be stable or increasing, with the rest decreasing or their status currently unknown. Based on the most recent and comprehensive data available, there are likely only 1,400 plants left in the wild with the largest populations occurring on public lands at Jonathan Dickson State Park (JDSP), Jupiter Ridge Natural Area (JRNA), Juno Dunes Natural Area (JDNA), Jupiter Inlet Lighthouse Outstanding Natural Area (JILONA), and Karen Marcus Ocean Park Preserve (Table 1). This represents a 22 percent decline from the 1,800 plants estimated in the previous review (Service 2009).

Cox and Shropshire (2006) developed a monitoring protocol and delineated six distinct life history stages of four-petal pawpaw from seedlings to senescing adults. However, only four natural populations/sub-populations have been closely monitored in this manner to be able to make determinations regarding survival rates, recruitment, and/or population structure, all of which are necessary to assess long-term population viability. Three of these populations/sub-populations, JDNA North, JDNA South, and Pawpaw Preserve, are stable, though very little recruitment has been observed and the fourth, Florida Power and Light (FPL) Juno Beach, seems to be declining (Table 1; Tolbert and Witmer 2014, 2015; Tolbert 2016; Richardson 2021). While four-petal pawpaw is a long-lived species and successful reproduction and recruitment is not necessary every year (Cox 1998), some amount of at least intermittent recruitment is ultimately necessary for long-term population viability.

## Four-petal Pawpaw 5-Year Review

Seven populations of the four-petal pawpaw can be classified as conservation translocations (International Union for Conservation of Nature Species Survival Commission 2013) and have been intermittently followed since the time of their initiation. Three of these were augmentations where plants and/or seeds were transplanted to a site where the species was already present but in low numbers: Savannah Preserves State Park (SPSP), JILONA, and a privately owned site. Two of the translocations were introductions where both plants and seeds were planted in areas where four-petal pawpaw had not ever been recorded, but suitable habitat (sand pine scrub habitat with appropriate soil type) was present: Rocky Point Hammock and Lake Park Scrub. One translocation was a relocation effort from a private site in Martin County where plants were in danger of imminent development to two city parks in Sewall Point (Cox and Shropshire 2019; Cox 2021a). The remaining translocation at Nathaniel P. Reed Hobe Sound National Wildlife Refuge (Hobe Sound NWR) was a reintroduction in which plants had historically existed on site (Moyroud 1985) but were no longer present. Only four of these populations are still extant (Table 1). Monitoring at each of these sites over several years revealed the highest success rates at the augmentation sites and with sown seeds compared to introductions and outplantings of seedlings/saplings respectively.

It is especially significant to note that no new populations have been discovered or documented over the last 12 years, despite field botanists and biologists surveying for listed plant species in the region during this time. This demonstrates what is perhaps low potential or likelihood that additional populations exist beyond what is currently known. Unless new populations are eventually discovered through additional surveys, this species will not meet the first delisting criteria without introductions. Therefore, four-petal pawpaw's specific ecological needs must be further investigated in order to choose highly suitable locations and establish viable introduced populations.

## Four-petal Pawpaw 5-Year Review

**Table 1:** Summary of the status of known four-petal pawpaw populations. Last observation date indicates when living plants at the site were last seen, although surveys may have been completed in a different year (see Population Estimates column). Population estimates, status, and notes are derived from Florida Natural Areas Inventory (FNAI) 2021 data unless otherwise indicated. Management actions listed may be for the management unit in which the four-petal pawpaw occurs but not concentrated at the exact four-petal pawpaw population location. EO = Element Occurrence

EO Number	Site Name	County	Ownership	Natural/ Introduced	Last Observation of Live Plants	Most Recent Population Estimates	Status	Notes
9	Savannas Preserve State Park Hawk's Bluff Trail	Martin	State	Natural (Augmented)	2018	25 in 2013 93 in 2018	Increasing	2001: 292 seeds planted <sup>1</sup> ; 2008: 52 naturally occurring plants, 251 from planted seeds; 2013: 25 total plants
	Sugar Hill	Martin	Private	Natural (Augmented)	2008	Present <sup>2</sup>	Unknown	2008: 3 naturally occurring plants, 30 seedlings planted
8	Jensen Beach Dunes	Martin	Private	Natural	2006	Unknown	Unknown	Scrub still appears intact, but site is inaccessible <sup>2</sup>
	Silver Maple Way Scrub	Martin	Private	Natural	2006	35	Unknown	Site not currently accessible, but is in a preserve <sup>2</sup>
5	Arch Street	Martin	Private	Natural	2021	22 in 2006 <sup>3</sup> 6 in 2021	Decreasing	1988: 33 plants; lot mowed and overgrown with non- native grasses but some oaks and hickory remain <sup>2</sup>
	Dolphin Motel	Martin	Private	Natural	1993	0	Extirpated	Developed in 2000 <sup>2</sup>
	Sago Drive	Martin	Private	Natural	2004	0	Extirpated	Lot entirely bulldozed in 2004, leaving 2 plants; mowed in 2007, 0 plants <sup>2</sup>
NA	Sewall's Point	Martin	City	Introduced (Translocated from natural population)	2005	0	Unsuccessful Translocation (Extirpated)	42 plants found on private land in 2002, relocated 13 to city park nearby but none survived due to herbicide use on weeds <sup>1</sup>
28	Rocky Point Hammock	Martin	County	Introduced	2006	0	Unsuccessful Introduction (Extirpated)	Both seedlings and seeds planted in 2005, none remaining by 2018 <sup>1</sup>

Four-petal Pawpaw 5-Year Review

EO Number	Site Name	County	Ownership	Natural/ Introduced	Last Observation of Live Plants	Most Recent Population Estimates	Status	Notes
30	Hobe Sound National Wildlife Refuge	Martin	Federal	Introduced (Reintroduced at extirpated natural site)	2010	0	Unsuccessful Reintroduction (Extirpated)	Plants originally onsite pre-1988; 11 plants and 67 seeds were planted in 2010 but none survived past 2012 <sup>1</sup>
3	Jonathan Dickinson State Park	Martin	State	Natural	2021	495 in 2006 <sup>3</sup> 100s in 2021 <sup>4</sup>	Stable	Area managed with prescribed fire periodically and invasive treatments <sup>4</sup>
21	Jupiter Inlet Lighthouse Outstanding Natural Area	Palm Beach	County	Natural (Augmented)	2021	81 in 2016 60 in 2018 78 in 2021 <sup>5</sup>	Decreasing to Stable	2008: 6 natural plants, 126 planted; 2011: 108 more planted; 2012: 160 total plants; 2014: 128 total plants
19	Carlin Park	Palm Beach	County	Natural	2006	0	Extirpated	Area cleared <sup>2</sup>
	Ocean Boulevard	Palm Beach	Private	Natural	2006	0	Extirpated	Developed <sup>2</sup>
13	Jupiter Ridge Natural Area	Palm Beach	County	Natural	2021	178 in 2006 <sup>3</sup> 150 in 2019 <sup>6</sup>	Stable	Area managed with prescribed fire every 7-8 years, mechanical fuel reduction, and yearly invasive treatments, 57 seeds planted in 2021 <sup>6</sup>
	Karen Marcus Ocean Park Preserve (formerly Radnor Park)	Palm Beach	County	Natural	2021	224 in 2006 <sup>3</sup> 100 in 2021 <sup>7</sup>	Stable	Encroaching vegetation cut back from pawpaws, further survey efforts will be made spring 2022, current estimate is a minimum <sup>7</sup>
	Bluffs Buffer Scrub	Palm Beach	Private	Natural	1988	0	Extirpated	Developed

Four-petal Pawpaw 5-Year Review

EO Number	Site Name	County	Ownership	Natural/ Introduced	Last Observation of Live Plants	Most Recent Population Estimates	Status	Notes
20	Juno Dunes Natural Area North	Palm Beach	County	Natural	2016	113 in 2006 302 in 2016 <sup>5</sup>	Stable to Increasing	Has been monitored every 1-4 years since 2001, prescribed fire and mowing both used for management <sup>8</sup>
12	Juno Dunes Natural Area South	Palm Beach	County	Natural	2021	202 in 2006 <sup>3</sup> 304 in 2015 335 in 2018/2021 <sup>5</sup>	Stable to Increasing	Has been monitored every 1-4 years since 2002, prescribed fire and mowing both used for management <sup>9</sup>
	Florida Power and Light Juno Beach	Palm Beach	Private	Natural	2021	61 in 2006 <sup>3</sup> 23 in 2021	Decreasing	Decline likely due to lack of fire or mechanical work, resulting in dense shading <sup>10</sup>
	Juno Park	Palm Beach	County	Natural	2006	5 in 2006 <sup>3</sup> 0 in 2011 <sup>2</sup>	Extirpated	Herbicide treatment killed about 40 plants prior to 2004 <sup>11</sup> , Searched 2011 and 2021, no plants found <sup>2</sup>
	Pawpaw Preserve	Palm Beach	County	Natural	2017	38 in 2014 <sup>12</sup> 44 in 2017 <sup>5</sup>	Stable	Monitored every 2-4 years from 2005 to 2014, usually between 37-39 plants <sup>12</sup>
7	None	Palm Beach	Private	Natural	1980	0	Extirpated	Developed
27	Lake Park Scrub	Palm Beach	County	Introduced	2020	28 in 2006 5 in 2018 <sup>1</sup> 5 in 2020 <sup>5</sup>	Decreasing to Stable	Planted 17 saplings and 198 seeds in 2005 <sup>1</sup>
2	None	Palm Beach	Private	Natural	1957	0	Extirpated	Developed

<sup>1</sup>Cox and Shropshire 2019; <sup>2</sup>Cox 2021a; <sup>3</sup>Peterson 2008; <sup>4</sup>Rossmannith 2021; <sup>5</sup>King 2021; <sup>6</sup>Black Finch 2021; <sup>7</sup>Farmer 2021; <sup>8</sup>Tolbert 2016; <sup>9</sup>Tolbert and Witmer 2015; <sup>10</sup>Richardson 2021; <sup>11</sup>Cox 2004; <sup>12</sup>Tolbert and Witmer 2014



**[2] Populations (meeting criterion 1) occur in coastal sand pine scrub and are distributed across the historical range of the species. (Factors A and E)**

Four-petal pawpaw has always had a limited range, occurring only in coastal sand pine scrub habitat on the Atlantic Coastal Ridge of Florida in Martin and Palm Beach Counties. Populations are extant in both these counties within this habitat, so this criterion has partially been fulfilled. However, the southern-most natural population (Element Occurrence 2; Table 1) has been extirpated since it was first observed which reduces the species' natural current range, shifting it north about 7.5 miles (mi) (12 kilometers [km]) (FNAI 2021). The Lake Park Scrub conservation translocation partially helped to negate this range reduction by introducing plants 3.5 mi (5.6 km) further south than the current natural southern extent (Cox and Shropshire 2019), though the overall range has still decreased from its original size. Additionally, only 5 plants in this introduction have survived over the course of 13 years (Cox and Shropshire 2019), so unless additional plants/seeds are outplanted at this population, the long-term viability is probably quite poor, and the range may once again decrease. At the other end of four-petal pawpaw's range, the viability of the northern-most documented population at SPSP was enhanced by a seed-addition augmentation, thus helping to preserve the currently occupied range (Cox and Shropshire 2019). Additional introductions and augmentations could help to further ensure that this species' range and extent of occurrence do not shrink from their already limited size.

**[3] Populations (meeting criterion 1) must be protected via a conservation mechanism and/or managed such that enough suitable habitat is present for the species to remain viable for the foreseeable future. (Factors A, D, and E)**

This criterion has been partially met. Seven of the nine extant populations occur either entirely or partially on protected lands. At the sub-population/site level, about 64 percent, or 9 of the 14 extant sites/sub-populations, occur on publicly owned conservation lands with suitable sand pine scrub habitat present. This represents almost the same proportion that was protected at the time of the last review at 62 percent (Service 2009). However, the remaining five sites (two populations and portions of two populations) are privately owned and not adequately protected in a way that will ensure population persistence. This is made apparent by the number of privately-owned populations that have already been eliminated due to development: six of the eight extirpated sub-populations/sites were privately owned and developed. Where development has not occurred on private sites with extant populations, habitat degradation also threatens four-petal pawpaw plants.

Even on publicly owned lands, management efficacy at four-petal pawpaw populations is variable and depends on site ownership, awareness of staff and managers of populations, and available funds for needed actions. One of the most critical management requirements for the persistence of pawpaw populations is careful invasive plant species removal (Cox 2009). At two populations, four-petal pawpaws were accidentally killed during Brazilian pepper (*Schinus terebinthifolius*) and other invasive plant treatments (Cox 2004; Cox and Shropshire 2019). In some situations, it is the surrounding developed landscape that prevents ideal management from occurring on conservation lands, especially in the smaller parcels. For instance,

at the SPSP population, the use of prescribed fire has been limited due to the urban interface and associated control concerns (Rogers 2021). However, four of the extant populations on conservation lands are stable and possibly increasing due to careful invasive plant removals, mechanical fuel reductions, and prescribed fires. Follow-up surveys have shown that the pawpaws have a more upright, unrestricted growth and are increasing their reproductive output after treatments (Tolbert and Witmer 2015; Tolbert 2016; Black Finch 2021; Farmer 2021; Rossmann 2021).

## C. Updated Information and Current Species Status

### 1. Biology and Habitat

#### a. Summary of new information on the species' biology and life history:

Information on the habitat and life history of the four-petal pawpaw, a long-lived aromatic shrub of the custard apple family (Annonaceae), is summarized in the MSRP (Service 1999), the last 5-year review for this species (Service 2009), and the Service's Recovery Plan Amendment for Four-Petal Pawpaw (Service 2019) with additional information provided below.

Goodrich and Raguso (2009) studied the olfactory floral compounds of all the species of the genus *Asimina*, including four-petal pawpaw (*A. tetramera*), using gas chromatography-spectrometry. Both female and male stages of the flowers were analyzed for different compounds, as well as the different floral organ whorls. Results revealed similarities with other maroon-flowered *Asimina* species such as the emission of aliphatic volatiles, but also a unique and evolutionarily informative spectrum of odors. Four-petal pawpaw and dwarf pawpaw (*A. pygmaea*) were both found to produce the benzenoid ether anisole, unlike other maroon-flowered *Asimina* species, highlighting the close phylogenetic relationship of these two species. Both species also produce aliphatic hydrocarbons like the white-flowered *Asimina* species. Taken with the finding that four-petal pawpaw produces the nitrogenous compound indole like the white-flowered woolly pawpaw (*A. incana*), these results point to possible past introgression with this and other white-flowered pawpaw species. Four-petal pawpaw and woolly pawpaw don't overlap in their current ranges, so these results suggest that one or both of these species once occupied larger ranges bringing them in closer proximity to one another.

Unlike any other species in the genus, four-petal pawpaw was found to emit large amounts of butanediol isomers from male flowers and large amounts of gin-scented monoterpenes from female flowers. The presence of both fermentation odors along with the fetid volatiles suggest that four-petal pawpaw uses two types of odiferous mimicry to attract pollinators: fermenting fruit mimicry and feces mimicry, thus allowing for a broader range of insect visitation. The most thorough observations of insect visitation to four-petal pawpaw flowers were made by Cox (1998) which showed beetles in the Cerambycidae, Scarabaeidae, and Tenebrionidae families as the most frequent visitors. Notably, even with the fetid-

smelling odor that Goodrich and Raguso (2009) found, no flies were ever observed visiting flowers.

Flowering of four-petal pawpaw typically begins in late March to early April and lasts throughout the spring into June (Cox 1998). Netted pawpaw (*A. reticulata*), the only other species of pawpaw overlapping in range with four-petal pawpaw, largely flowers first, thus limiting the amount of pollinator competition between the two species. Although geitonogamy (pollination between different flowers on the same plant) occurs, four-petal pawpaw is primarily an out-crossing species (Cox 1998). Fruiting rates are variable between populations, habitat conditions, and years but have been found to be within 2.3-10.8 percent (Cox 1998). Greater numbers of fruits are produced in more open and recently burned habitat compared to mature, dense canopy scrub, most likely because of the greater incidence of pollinators in the former habitat type (Cox 1998; Roberts and Cox 2000; Tolbert and Witmer 2015; Tolbert 2016; Barton and Menges 2018).

While not studied as closely *in situ*, *ex situ* tracking of germination and growth rates has been investigated and can help to understand the life history of this species. A typical germination rate of seeds sown soon after fruit ripening and collection is about 50 percent (Peterson 2008), but seeds don't survive long-term in storage due to their oily endosperm (Moyroud 1985). Growth rates of seedlings peak from early April to June and seedlings may or may not lose their leaves during the winter (Peterson 2008). *In situ* germination and seedling monitoring of the congener scrub pawpaw (*A. obovata*) found intermediate levels of canopy and intermediate frequencies of fire to be most beneficial to germination and recruitment rates (Menges et al. 2012) which agrees with the notion that more mature scrub habitats may provide refugia for recruitment for four-petal pawpaw (Cox 1998, 2009).

### **b. Abundance, population trends, demography:**

Historically, four-petal pawpaw has been known to occur at 27 sites in Martin and Palm Beach Counties on the Atlantic Coastal Ridge in Florida and introduced to 3 additional sites within this range (Peterson 2008; Service 2009). Based on the NatureServe standard separation distance of 1 km (0.62 mi) for distinct occurrences, there are 15 known or introduced element occurrences, also referred to as populations for this review (Table 1). Several sites that were referred to as separate populations in the previous status review (Service 2009) and that occur on properties owned by different entities fall within this separation distance and so are considered as part of the same population and are referred to as sub-populations for this review. It is important to note that a population spanning multiple properties owned by different entities are likely to experience different conditions/management within each sub-population. Based on the most recent survey data, nine populations can be considered either extant or potentially extant while three naturally occurring populations have been extirpated (Table 1). Three additional populations that were introduced/relocated were unsuccessful and are also considered extirpated (Table 1). The total estimated number of plants

## Four-petal Pawpaw 5-Year Review

surviving in these 9 populations at 14 sites/sub-populations is 1,400 (Table 1). Both the number of remaining populations and the number of individual plants represent a decrease since the time of the last review, which estimated 1,800 plants at 21 sites (Service 2009). The most recent information on abundance and trends is summarized below.

### *Jonathan Dickinson State Park*

The largest population of four-petal pawpaw within one site occurs within JDSP and appears to be generally stable based on periodic survey efforts (Cox 2021a; Rossmanith 2021). This population consists of hundreds of plants occurring in at least 3 management units, all of which have been burned at least once in the past 12 years (Rossmanith 2021). Fire application is likely benefiting the population by removing woody competition and allowing for increased flower and fruit production (Roberts and Cox 2000).

### *Juno Dunes Natural Area*

Two large areas of pawpaws exist within JDNA, the North population and the South sub-population (which is part of Element Occurrence 12 along with the FPL Juno Beach, Juno Park, and Pawpaw Preserve sub-populations). Both of the JDNA populations have been monitored by Palm Beach County Environmental Resources Management (PBCERM) staff every few years since 2001 after first being recorded on this property in 1988 (Farnsworth 1988). Up until the most recent monitoring efforts, populations were surveyed to obtain a simple count estimate along with flowering and fruiting rates. Implementation of the protocol developed by Cox and Shropshire (2006) to document age class structure began in 2015/2016 and so demographic results are only available for the last survey event and not the entire 20-year survey period. These field surveys have revealed an increase in the total number of plants observed in the two populations, with about 200 plants noted in the 2001 survey and over 600 plants found in the 2015-2016 and 2018-2021 surveys (Tolbert and Witmer 2015; Tolbert 2016; King 2021). Two factors are likely contributing to the population increases, both related to the prescribed fire and mechanical fuel reduction treatments applied in these areas: 1) these management actions are reducing competition by other woody species and allowing for plants to more frequently break dormancy and reproduce, and 2) these actions have created more favorable conditions for detecting pawpaw plants by surveyors. In the most recent survey, 43 and 21 percent of plants were reproductive in the north and south populations respectively, though no recruitment was observed in the north population and only 4 percent of all plants in the south population were seedlings (Tolbert and Witmer 2015; Tolbert 2016). Further monitoring to document age class structure over time will be needed to determine whether recruitment is lacking in these populations continuously or only intermittently.

### *Pawpaw Preserve*

Pawpaw Preserve, as the name suggests, is another PBCERM property with a significant four-petal pawpaw sub-population and has been surveyed every 2-4

years since 2005 (Tolbert and Witmer 2014; King 2021). The Cox and Shropshire (2006) age class structure methodology was only implemented in the most recent surveys, with previous efforts simply recording population counts and flowering/fruitlet rates. Similar to the JDNA populations, recruitment has been lacking with only one juvenile and no saplings or seedlings found, even with high rates of flowering/fruitlet (66 percent) (Tolbert and Witmer 2014). Despite seemingly low recruitment, the number of adult plants at the Pawpaw Preserve has been consistently between 37-39 individuals over the nine years of monitoring (Tolbert and Witmer 2014). However, the most recent survey data from 2017 reported 44 individuals, though age class was not provided (King 2021).

### *Florida Power and Light Juno Beach*

Plants within the FPL Juno Beach sub-population have been individually tagged and monitored over several years by an independent ecological consultant. Currently, the population appears to be in decline, as 12 plants have died over the most recent monitoring period, leaving only 23 plants on site (Richardson 2021). Recruitment data was not reported, but only 2 plants were reproductive (Richardson 2021). The decline is attributed to lack of fire, love vine (*Cassytha filiformis*) dominance, and overgrown oaks (Richardson 2021).

### *Other Naturally Occurring Populations*

Other natural populations of four-petal pawpaw have not been followed as closely as those discussed above. Information on abundance is available in some cases, while detailed trends or demography data is lacking. For example, at the Palm Beach County Parks and Recreation (PBCPR) Karen Marcus Ocean Park Preserve sub-population, the four-petal pawpaw population was originally documented in 1988 by Farnsworth, but a detailed survey was initiated in 2021 with the intention of recording all plants and their reproductive status (Farmer 2021). Eighty-six plants were found and documented on the property in 2021, with a few flowering/fruitlet in September (several months after the typical flowering season), but more are likely to be found in spring 2022 when survey efforts resume, and plants are in a more detectable phenological state (Farmer 2021). The most recent sub-population estimate for the PBCERM's JRNA population is 150 plants, observed in 2019 (Black Finch 2021). However, more plants are likely to be present given that monitoring has largely been limited to visiting known plant locations, with new plants discovered only occasionally and opportunistically (Black Finch 2021).

Because some populations occur on privately owned properties and may not be accessible to the public or biologists, abundance and trend data for these occurrences are lacking. The Arch Street site is partly accessible so at least 6 plants were seen at this location in 2021, though more may be present (Cox 2021a). However, this still likely represents a decrease from the 33 plants originally located here in 1988 (Farnsworth 1988). Both Silver Maple Way Scrub and Jensen Beach Dunes are private sites that cannot be accessed; therefore, the status of this population is unknown. On-the-ground visits along with inspection

of aerial images reveals that at least some habitat remains intact at both locations, so it is plausible that pawpaw plants are persisting here.

### *Introduced and Augmented Populations*

In comparison to the varying degree to which naturally occurring populations have been monitored, introduced and augmented populations have been more closely monitored in order to document their progress. See Table 2 for a summary of these results. Unfortunately, in several cases these translocation efforts ultimately were not successful, and either no or very few plants remain at these sites. This is the case at Sewall's Point, Rocky Point Hammock, Hobe Sound NWR, and Lake Park Scrub (Cox and Shropshire 2019). The Sewall's Point site was a relocation of 13 plants from a private property destined to be developed to city park properties, but none of these plants survived due to herbicide use on surrounding weeds (Cox and Shropshire 2019; Cox 2021a). Eighteen seedlings and 204 seeds were planted in 2005 at Rocky Point Hammock, but a year later only 12.5 percent of the seeds had germinated and only 5 of the planted seedlings survived; by 2018 no plants remained on site. At Hobe Sound NWR, 11 pawpaws were planted in 2006 and 67 seeds were planted in 2010 as part of a reintroduction effort (Moyroud 1985; Cox and Shropshire 2019). By 2012, only 4 plants survived the original planting with 10 seeds germinated, and by 2019, no plants remained (Cox and Shropshire 2019). At Lake Park Scrub, 28 saplings and 198 seeds were planted as an introduction in 2005, with only 5 plants from seed found in 2018 and in 2021, representing a 3 percent germination and persistence success rate (Cox and Shropshire 2019; King 2021). None of the transplanted saplings survived at this site.

Higher success rates have been documented at the augmented populations and with sown seeds compared to (re)introductions and translocations of seedlings/saplings. These have occurred at SPSP and at JILONA in 2001 and 2008-2011, respectively. At SPSP, the diminished existing population was augmented by adding almost 300 seeds which originated from hand-pollinated and open-pollinated flowers involving 4 plant crosses (Cox and Shropshire 2019). Three years later, 53 percent of seeds had germinated and survived while 17 years later in 2018, 32 percent had persisted (Cox and Shropshire 2019). It should be noted that the introduced plants remain small and have not flowered, while plants in the existing part of the population have flowered and produced fruit, but do not show signs of recruitment (Rogers 2021). Thus, the long-term viability of this population is still uncertain. The JILONA project differed from other translocation efforts in that all plants added to the site were in the form of saplings propagated from seed by Bok Tower Gardens (Cox and Shropshire 2019; Peterson 2021), with no seed planted at the site. Only 6 plants were naturally remaining at this location at the time of the augmentation. The project was completed in 2 phases between 2008 and 2011 with 19 percent surviving from the first out-planting and 33 percent surviving from the second by 2018 (Cox and Shropshire 2019). Plants likely benefited from supplemental watering from irrigation added on-site during the first year (Cox 2021b). While the long-term

persistence of this augmented population is encouraging, very little flowering or fruiting (about 5-6 percent) has ever been observed and rates have only decreased over time (Peterson 2021). While the exact reason for the poor success with introductions and transplanting seedlings/saplings is unknown, factors that may be contributing include the generally difficulty of transplanting pawpaws due to their long taproots (Kral 1960), differences in environmental conditions from greenhouse to planting location, and an incomplete understanding of the ecological and microhabitat needs of the four-petal pawpaw.

**Table 2:** Summary of four-petal pawpaw translocation results from seven sites/projects, presented as percent survival over >10 years. Ranges are included where more than one project was completed for a category.

	<b>Introduction</b>	<b>Re-introduction</b>	<b>Augmentation</b>
<b>Seeds</b>	0-3%	0%	32%
<b>Seedlings/saplings</b>	0%	0%	0-33%

**c. Genetics**

All occurrences of four-petal pawpaw are distributed along a 30-mile stretch of fragmented coastal scrub in Martin and Palm Beach Counties; most are thought to be currently reproductively isolated from one another which could lead to a reduction in genetic diversity over time from the lack of cross pollination between sites. However, the presence of similar genotypes among populations as revealed by Randomly Amplified Polymorphic DNA (RAPDs) analysis indicates that these occurrences were probably more contiguous in recent history (Peterson et al. 2007). Similarly, inter-simple sequence repeats markers (ISSRs) analysis showed that only 38 percent of the molecular variance in the four-petal pawpaw was due to differences among populations compared to within (Loring et al 2003). Unfortunately, plans to collect and analyze RAPD data on additional leaf samples from unsampled populations and create an updated phylogenetic tree were not realized due to lack of funding for this work (Peterson 2021). A more thorough understanding of this species’ remaining genetic diversity could be developed if these unsampled populations were examined. Efforts should be made to include these populations in future genetic research. The previous status review (Service 2009) incorrectly assumed that one privately owned sub-population with seven unique alleles had been destroyed: this site, Arch Street, is still extant, though the population size may be reduced (Loring et al. 2003; Cox 2021a). Efforts should be made to collect samples from this sub-population to preserve the genetic diversity and perhaps improve translocation and augmentation efforts (see Section II.C.1.g.).

**d. Taxonomic classification or changes in nomenclature:**

Four-petal pawpaw was first named and described by John K. Small as a new species within the genus *Asimina* in 1926. He separated this from other species based on taller height, smaller flowers, and flowers being tetramerous (consisting of four petals) (Small 1926). However, seven years later Small placed this and five other species in a separate genus, *Pityothamnus* based on corrugations on the

inner whorl of petals and the leathery texture of leaves compared to membranous leaves in other species. Thus, the full name became *Pityothamnus tetramerus* (Small 1933). Disagreeing with Small, Fries (1939) placed these species back into the *Asimina* genus and subsequent treatments of taxonomy have thus far been consistent in considering four-petal pawpaw to be *Asimina tetramera* (Kral 1960; Wilbur 1970; Mercer et al. 2015). Yet, Weakley has suggested that further analysis may reveal that *Pityothamnus* should be resurrected as a genus (2020). What is agreed upon, whether placed in *Asimina* or *Pityothamnus*, is that four-petal pawpaw is a distinct species. The Integrated Taxonomic Information System (2021) was also checked while conducting this review and did not indicate any formal changes to the name *Asimina tetramera*.

**e. Distribution and trends in spatial distribution:**

Historically, four-petal pawpaw occurred in sand pine scrub habitat on the coastal dune system in Martin and northern Palm Beach Counties in southeastern Florida (Kral 1960). Although the species still occurs in disjunct locations within its historical range, most of the suitable habitat has been degraded or developed for residential housing and commercial activities (Fernald 1989; Service 1999). Trends in spatial distribution show increasing fragmentation of four-petal pawpaw habitat as the Atlantic Coastal Ridge has become developed and fire has been excluded in some areas. Plants remain on sites in Martin and northern Palm Beach Counties along a 30-mile stretch of coastal sand pine scrub but are highly fragmented on the landscape (Peterson et al. 2007). Four of the remaining 9 extant populations occur in Martin County, while 5 occur in Palm Beach County. Of the populations that have been wholly extirpated, 3 each occurred in Palm Beach and Martin County (Table 1). Several other populations have been partially extirpated, losing one or more of their sub-populations (Table 1). Based on current ownership and trends, at least 3 additional populations with extant or possibly extant sub-populations could become extirpated in the future. Most of these sites are privately owned and not protected from destruction.

The range extent of this species has not changed significantly since the time of the last review. All newly extirpated sites/sub-populations (Ocean Boulevard, Carlin Park, and Juno Park) lie within the core range of this species and are located near extant sites. The current extent of occurrence is approximately 171 km<sup>2</sup> (66 mi<sup>2</sup>) and the area of occupancy is 48 km<sup>2</sup> (18.5 mi<sup>2</sup>) based on a 2 km (0.77 mi) cell width, which are both reductions compared to their documented historical counterparts of 183 km<sup>2</sup> (70.6 mi<sup>2</sup>) and 60 km<sup>2</sup> (23 mi<sup>2</sup>), respectively (Bachman et al. 2011; FNAI 2021). Because introductions have largely been unsuccessful, with the exception of Lake Park Scrub, these have not significantly helped to increase the range or area occupied by the species.

**f. Habitat or ecosystem conditions:**

The habitat four-petal pawpaw occupies can be described as coastal sand pine scrub, which is characterized by a canopy of sand pine (*Pinus clausa*) that can range from sparse to dense in concentration. The understory consists of scrub



oaks (*Quercus geminata*, *Quercus myrtifolia*, *Quercus chapmannii*) with patchy, sandy openings interspersed. Historically, fire return intervals were most likely on the order of every 10-50 years, and burns would have been very intense (FNAI 2010). Much of this natural community has been developed, as its dry, upland nature along the coast makes these lands highly desirable for residential and commercial purposes. Indeed, the scrub community is considered imperiled both within the state and globally (FNAI 2010). Even the remaining suitable habitat is fragmented throughout the species' narrow range. Within the coastal areas of Martin and Palm Beach counties, approximately 7,600 acres (3,075 hectares) of potentially suitable habitat remains (Kawula and Redner 2018).

While four-petal pawpaws can persist in densely shaded, overgrown habitat, possibly for long periods of time (Cox 2009), habitat management is beneficial to this species because it allows for increased reproductive output and more vigorous vegetative growth (Cox 1998; Moyroud 2021). On a coefficient of conservatism scale from 0-10, Mortarello et al. (2012) ranked four-petal pawpaw as a "9", meaning the species has a very high affinity to high-quality natural areas. Therefore, it is extremely important that proper habitat management occurs at pawpaw occurrences. The nature and frequency of management actions varies by site, with populations on conservation lands receiving the most attention (Black-Finch 2021; Cox 2021a; Farmer 2021; Rogers 2021; Rossmanith 2021; Tolbert 2021). At JDSP, four-petal pawpaw plants occur throughout three management units, all of which have been managed with prescribed burns. The average fire frequencies have been every 12.5-16.7 years over the last 50 years, and all areas with pawpaws have been burned twice since the time of the previous status review in 2009 (Rossmanith 2021). However, some areas may be suffering from Natal grass (*Melinis repens*) invasion (Rossmanith 2021). The situation is different at the other state park where this species occurs, SPSP, due to the spatial orientation of the portion of the park containing the pawpaw population. Because this area of the preserve is bordered on three sides by private residential properties, the wildland-urban interface and public resistance have prevented prescribed burning (Martí et al. 2005; Rogers 2021). Consequently, the scrub has become overgrown with a canopy cover exceeding 50 percent; scrub oaks have significantly encroached; and a deep leaf litter layer has formed. The pawpaw plants originating from seeds planted in this area have grown little and likely not flowered or produced fruit (Rogers 2021). In 2012, a wildfire occurred that may have reached a small portion of the population but not the entirety of it. Park staff devote time to cutting back encroaching vegetation around pawpaw plants by hand, but this has not been sufficient to reduce the overgrowth (Rogers 2021).

Some of the most actively managed properties include those owned by PBCERM. For example, at JDNA, four-petal pawpaws occur throughout most of the management units in both the north and south parcels, almost all of which have been burned and/or mowed for mechanical fuel reduction at least once in the last twenty years. Often, the mowing is completed as a pre-treatment in preparation for burning, which can otherwise be difficult due to the narrow prescription

parameters and the smoke mitigation requirements (Tolbert and Witmer 2015). At JRNA, prescribed burns and mechanical fuel reductions are conducted periodically, though only one burn has reached the area of the pawpaws (Black-Finch 2021). Generally, plants found in more recently burned/mowed areas have greater rates of flower and fruit production while those that are surrounded by overgrown vegetation grow taller but tend to be vegetative (Tolbert and Witmer 2014; Tolbert 2016). Another PBCERM property, the Pawpaw Preserve, has been managed with mechanical mowing in the fall, the result of which has been very high rates of reproduction the following spring: 73 percent of mowed plants flowered/fruited (Tolbert and Witmer 2014). While these short-term effects are encouraging, longer-term population effects should be determined through annual monitoring, especially since recruitment has been little to none. In addition to the burning and mowing forms of management, PBCERM also engages in invasive species removal through careful herbicide application, so as not to negatively impact pawpaw plants. Invasive plant species dominance in pawpaw habitat is one of the primary threats to this species (Cox 2009). Simultaneously, heavy, imprecise herbicide application can eliminate a population or sub-population and was documented at the Juno Park sub-population and Sewall's Point population (Cox 2004; Cox and Shropshire 2019). Therefore, the judicious use of herbicide is critical for proper habitat maintenance for the pawpaws.

The PBCPR also owns properties with current or historical populations, with varying degrees of habitat suitability. At Karen Marcus Ocean Park Preserve, a presumably stable population of four-petal pawpaw exists within intact scrub habitat. Although the population has not had any fire history since the property was acquired by the county over twenty years ago, staff have begun to remove overgrowth of oak and vine vegetation in the immediate vicinity of pawpaw plants, thus creating more favorable conditions for growth and reproduction (Farmer 2021). Unfortunately, populations at other PBCPR properties, namely at Carlin Park and Juno Park, have been extirpated. Scrub at both sites have become overgrown, with the latter fully transitioned to a hardwood hammock community and several invasive species present (Cox 2021a). However, because parks may at least have small areas of suitable scrub habitat remaining and with complete restoration in areas of former scrub possible, these could be potential re-introduction sites in the future. A budding partnership between PBCPR and a local horticultural expert may lead to propagation and translocation projects taking place at these properties in the future (Cirillo 2021; Cox 2021a).

Generally, private sites with pawpaw populations are not being managed with fire, mechanical fuel reduction, or invasive species control. Not surprisingly, these areas tend to have the smallest population sizes (although the properties are generally smaller in size compared to public sites). At two inaccessible sites (Jensen Beach Dunes and Silver Maple Way Scrub), suitable scrub habitat appears to be present, but the status of the sub-populations is unknown (Table 1). At the FPL Juno Beach sub-population, an independent ecological consultant noted that the pawpaws appeared to be in decline due to the maturation of scrubby

oaks and dominance of love vine, conditions that have developed from a lack of fire or mechanical maintenance. Removal of over-shadowing branches and love vine in the immediate area occupied by pawpaw plants was recommended as a mitigating action (Richardson 2021).

**g. Other:**

Given the limited number of remaining populations in the wild and the need for successful conservation translocations, *ex situ* propagation and resulting collections are an important component of this species' recovery. Bok Tower Gardens (BTG) has completed much of the research in this area (see Section II.C.1.a.) and currently maintains 51 plants in their collection beds as a part of the Center for Plant Conservation National Collection. The plants originate from six wild sites: JDSP, JDNA, Pawpaw Preserve, FPL Juno Beach, JILONA, and JRNA (Peterson 2021). As funding is available and as populations can support it, additional collections should be made from the remaining wild populations to ensure their genetic diversity is safeguarded. Unfortunately, it may not be possible to collect seeds from many private sites where landowner cooperation is lacking (Peterson 2021). Seeds of this species cannot be stored past two weeks due to their lack of viability when not fresh (Peterson 2021), most likely a result of their oily endosperm (Moyroud 1985).

Additional *ex situ* strategies involve tissue culture and cryopreservation, through which several lines of four-petal pawpaw are maintained by the Center for Conservation and Research of Endangered Wildlife (CREW) at the Cincinnati Zoo and Botanical Garden (Pence 2006, 2012, 2013). In the past, contamination and browning of tissue cultures of this species presented an obstacle to preservation, though even with these issues bud initiation rates were high (Pence 2004). Reassuringly, when cryopreserved samples were tested for genetic change since the time of collection, no changes were detected, although sample sizes were small (Philpott 2018). This *in vitro* material has proven both important and efficacious in *ex situ* collections and transplantation projects, with excellent survival and reproductive results both in the short and long-term (Peterson 2008, 2021). Recently, the cryopreservation technique of droplet vitrification (plant tissue is directly treated with vitrification solution, frozen in individual microdroplets, then rapidly immersed in liquid nitrogen) has been tested as a method for long-term storage of shoot tips and nodes. Survival was 62 percent after 18 weeks, though further research is needed (Karbowski and Pence 2018). This technique may be an additional strategy to add to the recovery toolbox for this species. In the Botanic Gardens Conservation International (BGCI) Database, eight *ex situ* sites are listed as having four-petal pawpaw in their collections (including BTG and CREW) (BGCI 2021).

Translocation projects have had mixed results depending on the type of plant material used (seeds versus seedlings) and the outplanting location, with sites already having four-petal pawpaw present (augmentations) being much more successful than those without (introductions) (Cox and Shropshire 2019, see

Section II.C.1.b.). Recently, a new augmentation and propagation project has developed as a collaboration of PBCERM and a founding member of the Florida Association of Native Nurseries who have experience growing these plants (Black-Finch 2021; Moyroud 2021). As a result of mechanical fuel reduction, the JRNA sub-population produced abundant fruits in 2021, from which seeds were collected. Approximately half of these seeds (57) were directly planted on site in areas with an open ground layer and moderate canopy cover while the remaining seeds are being propagated in the greenhouse. Any plants that germinate and survive while in propagation will also be added to the site to further the augmentation. Seedlings started sprouting in the greenhouse within two weeks of planting and initially tended to produce much greater root biomass than aboveground vegetative biomass (Moyroud 2021).

- 2. Five-Factor Analysis (threats, conservation measures, regulatory mechanisms):**

The purpose of a 5-Year Review is to recommend whether a listed taxon continues to warrant protection under the ESA and, if so, whether it should be reclassified (from threatened to endangered or from endangered to threatened). This task requires that the analysis of the threats to the species be performed while assuming that the species is not receiving the regulatory protections, funding, recognition, and other benefits of ESA listing. Summaries of ongoing applications of ESA protections may shed light on some future activities that constitute threats to the species. However, the analysis under Factor D (Inadequacy of Existing Regulatory Mechanisms) focuses on the adequacy of existing alternative (i.e., non-ESA) mechanisms to address the continuing and foreseeable threats.

  - a. Present or threatened destruction, modification or curtailment of its habitat or range:**

Continued habitat loss, fragmentation, and changes in land use threaten the existence of four-petal pawpaw. Where plants occur on private sites, development has led to direct destruction of habitat because of land clearing and habitat degradation from lack of management. Of the 27 historically documented and 3 conservation translocation sites/sub-populations, 6 privately and 5 publicly owned sites are known to have been extirpated or failed as a translocation effort within the last 40 years, most of these within the last 20 years (Table 1). In most cases these sub-populations or whole populations were eliminated because of residential or commercial development or habitat degradation. Even where plants still exist on privately owned properties, habitat degradation negatively impacts these populations and sub-populations. None of the three privately-owned sites where plants are known to still occur or the two sites that are inaccessible and where plants may occur are being managed with fire, mechanical fuel reduction, or invasive species removal (Table 1). These sites have some of the lowest population numbers and viability is likely poor. Threats from development and habitat degradation on private sites are expected to continue and increase. Within the range of four-petal pawpaw, the human population is predicted to grow from approximately 157,000 to more than 216,000 in Martin County and from 1,463,900 to over 2,177,000 in Palm Beach County between 2020 and 2070 (Carr

and Zwick 2016). The amount of developed land as a percentage of this region of Florida may double from approximately 15 percent to over 30 percent, adding an additional 470,000 acres of development (Carr and Zwick 2016).

Even though over half (9 out of 14) of sites/sub-populations containing four-petal pawpaw are publicly owned and not at risk of being developed, the plants on these sites may still be vulnerable to habitat degradation from encroachment of invasive plant species, lack of fire, and/or other mechanical treatment. If sites are not properly managed, habitat structure and function of the coastal scrub may deteriorate. At least two publicly owned properties have no or little history of fire management. For example, in the area surrounding SPSP, public resistance due to concerns about smoke and potential property damage has presented a challenge to implementing prescribed burns in the past, though educational outreach completed through a “Parknership” program by Florida Park Service staff and Florida Atlantic University may have helped to reduce negative viewpoints of nearby landowners (Marti et al. 2005). Unfortunately, the part of the park containing pawpaw is isolated from most of the park with private property bordering on three sides; therefore, the park has not been able to implement prescribed fire at the site (Rogers 2021). Because even publicly owned sites are fragmented from one another on a developed landscape, fire management may not always be feasible and encroachment by invasive plant species from neighboring properties is likely (Marti et al. 2005). Four-petal pawpaw plants can survive in overgrown scrub habitats that have not been burned, but fire is important for flower and fruit production and therefore the long-term viability of populations (Cox 2009). Short-term, invasive plant species may be even more detrimental to populations (Cox 2009). Therefore, habitat loss, degradation, and fragmentation due to increasing development and lack of management in sand pine scrub habitat and the encroachment of invasive plants continue to threaten four-petal pawpaw.

**b. Overutilization for commercial, recreational, scientific, or educational purposes:**

This was not identified as a threat in the original listing rule (Service 1986), the recovery plan (Service 1988, 1999, 2019), or the previous 5-year review (Service 2009) and is not known to be a current threat.

**c. Disease or predation:**

Disease or predation was not considered a threat to four-petal pawpaw at the time of listing, though fungal infections had been noted (Moyroud 1985; Service 1986). The previous status review (Service 2009) described damage to four-petal pawpaw flowers and leaves from the larvae of two lepidopteran species (a pyramid moth [*Omphalocera munroei*] and the zebra swallowtail butterfly [*Eurytides marcellus*]) and to the fruit and seeds from other insects and weevils. Spiral whitefly (*Aleurodicus sp.*) and witch’s broom caused by a virus or phytoplasma was reported in low numbers of four-petal pawpaw plants at JILONA and JDNA, but neither appear to be affecting the populations (Tolbert and Witmer 2014; Tolbert 2016). Although not reported for the four-petal

pawpaw, there is a report of consumption of the fruit from a flag pawpaw (*Asimina incarna*) by the Florida mouse (*Podomys floridanus*) (Jones 1989). In the related and co-occurring species, netted pawpaw, a raccoon (*Procyon lotor*) has been observed to ingest fruit, seemingly without damaging the seeds (Barton and Menges 2018). In fact, this ingestion may provide beneficial scarification to seeds (Barton and Menges 2018). Similarly, some management units at the JDNA had greater than 40-60 percent of pawpaws showing evidence of herbivory, though reproductive rates did not appear to be impacted (Tolbert 2016). Overall, these occurrences of fungal and viral infections and predation are not known to constitute threats to the four-petal pawpaw.

**d. Inadequacy of existing regulatory mechanisms:**

Generally, managing agencies have limited regulatory tools. The ESA prohibits the removal of federally listed threatened and endangered plants or the malicious damage of such plants on areas under federal jurisdiction, or the destruction of endangered plants on non-federal areas in violation of state law or regulations or in the course of any violation of a state criminal trespass law. The ESA does not provide protection for plants on non-federal lands unless it is in violation of state law.

The four-petal pawpaw is also listed at the state-level by the Florida Department of Agriculture and Consumer Services (FDACS) as State-endangered (5B-40.0055 Regulated Plant Index), which is not dependent upon an ESA listing. The State listing does not provide any direct habitat protection. Regulations associated with this listing require both written permission from the owner or legal representative and a permit issued by FDACS to collect or remove plants listed as endangered on the Florida Regulated Plant Index. Additionally, Title 62D-2.013 of the Florida Administrative Code prohibits the removal, destruction, or damage of plants from Florida Department of Environmental Protection, Division of Recreation and Park properties. This regulation provides protection for the populations that occur on state park lands but does rely on public adherence to the Code since monitoring is limited.

At the county level, some protections are provided through provisions in their respective land developments codes. In Martin County, an environmental assessment must be completed prior to land use change that includes a survey for rare, endangered, threatened and species of special concern. The “Upland Protection” section details that developers are required to preserve at least 25 percent of native upland habitat, such as scrub, and areas with protected species must either be a) preserved or b) individuals of the protected species must be moved to an area of the property that is being preserved, or a conservation land. Notably, four-petal pawpaw is used as a specific example of listed species found in the area covered under the code (Martin County 2020). In Palm Beach County, development for commercial projects will not be approved unless it can be proven that the project “will not adversely impact endangered or threatened species, and species of special concern, or their habitat” or these species can be relocated

(Palm Beach County 2021). Although the option in both codes to relocate endangered species helps limit direct destruction of endangered or threatened species, it is especially challenging and concerning in the case of the four-petal pawpaw because of the difficulty of transplanting this species and the low success rate of such past attempts (Cox and Shropshire 2019).

Even with these regulations, existing mechanisms do not appear to provide sufficient protection, as several properties with pawpaws on private lands have been developed (Table 1). Because this plant occurs in habitat along the Atlantic Coastal Ridge, which is desirable for development due to its elevation, it remains vulnerable to development pressures where it occurs on private property. As mentioned above, plants on Sewall's Point were relocated from a private site slated for development to publicly owned properties nearby. However, none of these plants survived past 4 years after transplanting, likely due to 1) the general difficulty of transplanting pawpaw species because of their long taproots and 2) heavy, imprecise herbicide spraying. Additionally, even if translocation were to have greater success rates, the Service or conservation partners must first know of both the presence of the pawpaws on these sites and of the imminent land use change, as well as have permission to be able to perform the rescue. In conclusion, there are only limited protections if the species was not protected under the auspices of the ESA; therefore, existing regulatory mechanisms are inadequate to protect this species.

**e. Other natural or manmade factors affecting its continued existence:**

*Intrinsic Factors*

Several intrinsic aspects of four-petal pawpaw's life history and species ecology render it especially vulnerable to extinction. This species specializes in a restricted habitat type and naturally has a limited geographic distribution, reducing the potential for resiliency and representation. Additionally, in the absence of fire or mechanical treatment, these pawpaws tend to have low reproductive rates which limits the amount of population growth possible. Many populations are already small and would benefit from such growth. Even when fruit set and seed production is successful, the opportunity for outplanting and propagation is limited by the fact that these seeds are only viable a short time after collection and therefore preservation seed banking by traditional means is not possible (Moyroud 1985; Pence 2013; Peterson 2021).

*Invasive Plants and Their Removal*

Invasive plants pose a major threat to pawpaws in two substantial ways: 1) through their ecological dominance of otherwise suitable habitat and 2) through sometimes imprecise control methods used to remove them. The establishment of invasive plant species such as Brazilian pepper, rosary pea (*Abrus precatorius*), guinea grass (*Panicum maximum*), and Natal grass has been documented at multiple locations in the absence of maintenance, or even where maintenance efforts are applied but cannot keep up with invasive plant species' growth (Richardson 2021; Rossmanith 2021). Invasion can be especially severe where

native soil is disturbed (Cox 2009). At the same time herbicides used to control this overgrowth, if not properly applied, also pose a threat to the four-petal pawpaw. Broad application of herbicide to remove Brazilian pepper and tall grasses can be especially damaging. Herbicide treatments are thought to have directly caused the extirpation of one naturally occurring population (Juno Park) as well as the Sewall's Point relocation failure (Cox 2004; Cox and Shropshire 2019). Thus, it is critical that invasive plants at pawpaw sites are noticed and treated early, but with careful avoidance of the endangered plants. Hand removal of these species in the immediate vicinity of pawpaws would be a safer measure than using herbicide. Encouragingly, some land managers have become aware of this issue and take mitigating actions to ensure pawpaw protection. PBCERM staff take the time to meet with herbicide contractors in pawpaw-occupied areas that are to be treated to teach plant identification and application techniques necessary to safeguard the pawpaws.

### *Climate Change*

There is currently no direct evidence of negative impacts to four-petal pawpaw from climate change factors, but this could change in the future as Florida is vulnerable to changes in rainfall and temperatures expected due to climate change. While the strong influence of ocean currents makes projecting regional climate in Florida difficult (Kirtman et al. 2017), estimates project that Florida's average annual temperatures will increase approximately 1.5 to 5.5 degrees Fahrenheit (°F) (0.8 to 3.1 degrees Celsius [°C]) by 2050 and from 2.0 to 11.5°F (1.1 to 6.4°C) by 2100 depending on the greenhouse gas emission rates and the region in Florida (Runkle et al. 2017). In addition, it is predicted that Florida will experience drier wet seasons (summer) and wetter dry seasons (winter) (Sun et al. 2015). Higher temperatures and changes in precipitation patterns could alter relative humidity levels and evapotranspiration rates, leading to the potential for more frequent and intense droughts and wildfire events. In general, scrub species such as four-petal pawpaw can tolerate drought conditions, but it is unclear how this anticipated future threat will fully affect these plants. Notably, decreased reproductive rates at the JDNA North population were observed in a severe drought year (Tolbert 2016). If prolonged droughts were to occur for several years in a row, as may occur with climate change, and if reproductive rates are decreased range-wide, populations would likely suffer from even lower recruitment rates than they already do. Additionally, if wildfire incidence were to increase and burn scrub habitat more frequently than the historic return intervals of every 10-50 years, recruitment in pawpaw populations could be reduced. Prolonged droughts could cause fires to occur later in the growing season than they have historically over the last thousands of years, at a time before pawpaw seeds could be produced and/or dispersed by the plants. This would also negatively impact fecundity and population viability.

In addition to changes in precipitation and temperatures patterns, there are also anticipated changes to the severity of tropical storms and hurricanes. Sweet et al. (2017) predicted a 20 percent increase in both rainfall rates and wind speeds near



the center of storms due, in part, to higher sea surface temperatures. Monitoring after previous severe hurricanes that made landfall at pawpaw populations has shown little negative impact to plants, with most surviving the storms completely in-tact (Cox and Shropshire 2007). Of course, the exact impacts from hurricanes vary with each storm and prior lack of impact does not mean that all future hurricanes will be similarly benign. Greater storm surge or debris downfall could easily occur in this coastal region. Treefall and limbfall from sand pines could cause very heavy fuel accumulation that increases the intensity of wildfires within the scrub beyond the already extreme conditions under which these habitats burn. Fires that become too hot within the ground layer could sterilize soil and create unfavorable conditions for subsequent seed germination and growth.

Sea-level rise (SLR) is another anticipated consequence of climate change in Florida that must be considered for four-petal pawpaw. The coastal areas this species occupies will be especially susceptible; a recent acceleration in SLR suggests that by 2120, sea levels are likely to rise according to the medium to extreme-high SLR scenarios (1.3 to 3.6 meters [4.3 to 11.8 feet]) (Sweet et al. 2017). Based on the extreme scenario of 3.6 meters (11.8 feet) of SLR by 2120 and current elevations of the four-petal pawpaw populations, there could be negative impacts to as many as five sub-populations (JILONA, JRNA, Karen Marcus Ocean Park Preserve, JDNA South, and FPL Juno Beach), which could cause extirpations of two to three of the nine extant populations. While this potential SLR inundation is well into the future, the impacts to four-petal pawpaw could begin earlier. Prior to inundation, habitat transitions related to changes in the salinity of the water table and soils are possible. Ross et al. (2009) suggested that interactions between SLR and pulse disturbances, such as storm surges, can cause vegetation to change sooner than projected based on sea level alone.

**D. Synthesis:**

Four-petal pawpaw is a long-lived shrub that occurs in coastal sand pine scrub within a limited range in Martin and Palm Beach counties, Florida. Remaining occurrences are fragmented and isolated within this range, and the species is estimated to occur in only 9 populations made up of 14 natural and augmented sub-populations with approximately 1,400 plants (Table 1). The previous status review (Service 2009) reported 16 populations made up of 21 sub-populations with approximately 1,800 plants. The status of some populations has been well documented while others remain in question due to accessibility issues. Approximately half of the extant populations appear to be stable or increasing, while the rest are decreasing, or their status is unknown.

Despite translocation efforts and ongoing habitat management described above, the criteria for delisting have not been fully met because there are currently not at least 25 populations with a stable or increasing trend that are protected via a conservation mechanism and managed such that enough suitable habitat is present for the species to remain viable for the foreseeable future. Since only 4 or 5 populations are exhibiting a generally stable to increasing trend and the rest are decreasing or unknown, introductions within protected areas containing suitable habitat will be necessary to meet this objective.

## Four-petal Pawpaw 5-Year Review

Although augmentations of current populations have had some success, no introductions at sites where pawpaws were not previously found have persisted for more than a few years after initial outplanting. Habitat and horticultural requirements for long-term introduction persistence need to be more thoroughly investigated so that any future efforts have a higher likelihood of succeeding.

Many sites formerly containing pawpaw populations have been destroyed as a direct result of development. These were private properties where no protections for the pawpaw plants exist and current regulatory mechanisms have proven inadequate. Only a few pawpaw populations are still extant on private lands and are also at risk of development. Habitat loss, fragmentation, and changes in land use continue, and conversion of scrub habitat to urban use along the Atlantic Coastal Ridge is projected to increase over the next several decades. Even where plants are protected on public lands, the threats of invasive plants, lack of habitat maintenance, and climate change remain. While land managers in many cases attempt to maintain/restore habitat, sometimes lack of resources (i.e., funding, staff) or being located in an urban interface can hinder these efforts.

Due to the loss of populations, continued challenges with introduction efforts, and ongoing threats on both public and private lands, this species continues to meet the definition of endangered under the ESA.

### III. RESULTS

#### A. Recommended Classification:

X No change is needed

### IV. RECOMMENDATIONS FOR FUTURE ACTIVITIES

A detailed discussion of recovery actions and criteria are presented in the Recovery Plan and amendment (Service 1999 and 2019, respectively). During this status review, new and/or targeted potential recovery activities were identified and are included below.

#### Recovery Activities:

- Collect germplasm from the remaining sites not currently represented in the Center for Plant Conservation's National Collection of Endangered Plants for *ex situ* safeguarding.
- As informed by research on best methods and site characteristics (see Research/Monitoring below), continue seed collection, propagation, and direct planting for both augmentations and introductions.
- Identify the most suitable introduction sites and carefully monitor any plants translocated or seeds planted. Use irrigation to help increase plant survival the first year.
- If suitable habitat remains on publicly owned sites with extirpated populations, consider re-introducing four-petal pawpaw. Where habitat has degraded in areas of historical populations, perform restoration to return to suitable scrub pine habitat.
- Carefully apply herbicide to invasive plant species in pawpaw habitat as needed and avoid pawpaw plants by ensuring all applicators know exactly where it is safe to spray.

## Four-petal Pawpaw 5-Year Review

- Conduct prescribed fires, preferably in the spring lightning season, within appropriate fire return intervals to prevent accumulation of large fuel loads and create more favorable conditions for pawpaw reproduction.
- If habitat/landscape level burns are not feasible because of wildland-urban interface or other challenges, experiment with conducting micro-burns around pawpaw plants.
- As informed by additional genetic analysis (see Research/Monitoring below), focus conservation efforts on marginal and small sites to preserve genetic diversity.
- As landowners are willing, acquire private sites with remaining pawpaw populations to ensure their protection or alternatively, enact conservation easements.
- As a last resort and where needed, perform rescues of plants on private sites to be developed and translocate to protected land with suitable habitat.

### **Research/Monitoring:**

- Investigate methods and site characteristics that lead to long-term introduction success.
- Continue to survey potential coastal sand pine scrub habitat for new occurrences and provide updated information to FNAI.
- Continue demographic monitoring on sites where populations have been followed and begin demographic monitoring on those sites where populations only have been periodically observed. Data on population size, reproductive rates, age class structure, and habitat conditions should all be documented.
- Closely monitor for recruitment and determine the conditions required for growth.
- Obtain permission from private landowners with historical pawpaw occurrences to survey and determine the status of these populations. If present, foster partnerships/working relationships with these landowners to protect plants.
- Complete genetic analysis of populations to determine the amount and spatial distribution of diversity remaining to help inform further conservation actions, such as appropriate translocation material and locations.
- Collect and analyze RAPD data on leaf samples from unsampled populations and create an updated dendrogram.
- Continue to evaluate insect pollinators associated with the species and determine the status of these insect populations.
- Evaluate the effects of climate change on the species, including those that result from precipitation pattern changes and temperature rise.

### **Outreach/Collaboration Activities:**

- Promote partnerships between county, state, and federal agencies to share information and conduct collaborative research on coastal scrub habitat conservation.
- Convene another ad hoc meeting to compile new information, discuss recovery actions, share land management strategies, and set and prioritize five- and ten-year goals.
- Seek opportunities to include the media in conservation efforts to provide information about this species to the public.
- Continue educating landowners with properties near pawpaw-occupied protected lands on the benefits of prescribed fire.
- Continue using volunteer assistance (e.g., Florida Native Plant Society) and engaging youth in the monitoring and recovery of this species.

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Four-petal Pawpaw 5-Year Review

**U.S. FISH AND WILDLIFE SERVICE**  
**5-YEAR REVIEW of Four-petal pawpaw (*Asimina tetramera*)**

**Current Classification:** Endangered

**Recommendation resulting from the 5-Year Review:**

- Downlist to Threatened
- Uplist to Endangered
- Delist
- No change needed

**Review Conducted By:** Heather Hitt, Florida Ecological Services Field Office, Vero Beach

**FIELD OFFICE APPROVAL:**

**Division Manager, Classification and Recovery, Florida Ecological Services Field Office,  
Fish and Wildlife Service**

Approve: \_\_\_\_\_

\* The Classification and Recovery Division Manager in the Florida Ecological Services Field Office has delegated authority to approve 5-year reviews that do not recommend a status change.