Species Status Assessment Report
for the
Ghost Orchid
(*Dendrophylax lindenii)*

Version 1.1

March 2025

U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

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Suggested Reference: U.S. Fish and Wildlife Service. 2025. Species status assessment for the ghost orchid (*Dendrophylax lindenii*), Version 1.1. March 2025. Southeast Region, 68 pp.

VERSION UPDATES

The change from version 1.0 (July 2024) to 1.1 (March 2025) was to incorporate new data and information that was provided during peer and technical review and to provide minor updates to the entire SSA including updated references, re-wording, and new life history information. New data including information on population abundances and threats were included and we made changes to tables and figures based on additional data.

EXECUTIVE SUMMARY

We conducted a species status assessment (SSA) to assess the viability of the ghost orchid (*Dendrophylax lindenii*). We define viability as the ability of a species to maintain populations in the wild over a biologically meaningful timeframe. We characterized ghost orchid viability over time by assessing its ability to withstand environmental, genetic, and demographic stochasticity and disturbances (resiliency), catastrophic events (redundancy), and novel changes in its biological and physical environment (representation). Ghost orchid viability is fostered by maintaining the demographic and genetic health of its populations and preserving potential connections between populations.

Biology and habitat requirements: Ghost orchid is a flowering epiphyte species with either extremely inconspicuous, bract-like leaves or missing leaves entirely. Their gray-green roots provide the primary means of photosynthesis and also act to keep plants anchored to their host trees. Their white flowers are highly showy, usually blooming in the summer from May to August. Flowers are fragrant at nighttime when potential pollinators may visit; if reproduction is successful, a many-seeded capsule fruit is produced. Seeds are mainly dispersed via wind and gravity and must land on an appropriate substrate to survive and germinate, i.e. on a host tree and with their *Ceratobasidium* fungus symbiont present. Pollinators are needed to complete reproduction and include the fig sphinx moth (*Pachylia ficus*), pawpaw sphinx moth (*Dolba hyloeus)*, and possibly the giant sphinx moth (*Cocytius antaeus*). The species has two main centers of its range: one in southwest Florida and one in western Cuba. Plants are primarily found growing in strand swamps, sloughs, and dome swamps, all of which are high hydroperiod forested wetland environments. However, in Cuba, plants are found in tropical semi-deciduous forest on host trees that are rooted in fractured reef limestone with little or no standing water. In Florida, the majority of ghost orchid host trees consist of either pond apple (*Annona glabra*) or Florida water ash (*Fraxinus caroliniana*) while in Cuba a much wider variety of host trees are utilized by the species.

Ghost orchid is listed as endangered by the State of Florida and is ranked as 'critically imperiled' in the state by the Florida Natural Areas Inventory (FNAI). The global rank of the species is also classified as 'critically imperiled' by NatureServe. The species is listed under Appendix 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which requires special permits for moving specimens collected from the wild between countries. In spite of these designations and restrictions, plants have historically been under high poaching pressure and such illegal collection continues to this day.

Methods: We assessed ghost orchid viability by evaluating its current condition (e.g., abundance, population growth, habitat quality) and identifying the primary influences leading to its current condition. For the purposes of our analysis, we divided the ghost orchid distribution into 12 analysis units (10 analysis units in Florida and 2 analysis units in Cuba), primarily corresponding to their managed area locations. We then analyzed each analysis unit for specific demographic and habitat factors to determine the current condition of each analysis unit. The factors included in our approach were: total abundance, recruitment rate, fruiting rate, population abundance trends, degree of poaching pressure, hydrological condition, and forest condition. These

categories were selected as metrics because they are considered to be some of the most important habitat and demographic factors that contribute to the resilience of ghost orchid at the population level, and that we have sufficient data to analyze. Other important factors like presence of pollinators did not have adequate data to include, although we recognize their high significance. Information was available from a variety of sources including annual monitoring data, published literature, and expert knowledge.

Results: Of the 12 analysis units, one is extirpated and two are considered likely extirpated. Of the nine extant analysis units, four were classified as high condition for total abundance of plants, while the remaining five analysis units were classified as low condition based on the most recently available population numbers. Only two analysis units were in the moderate condition for seedling abundance and only three were moderate or high for reproductive rate. All analysis units have a declining population according to recent data and thus all were classified as low for this factor. For the habitat factors, all analysis units were found to have some degree of hydrological change and recent negative impacts from hurricanes. Two-thirds of the analysis units have a significant amount of poaching pressure, including two units that were found to have an especially high degree of poaching pressure (Fakahatchee Strand Preserve State Park (SPSP) and Big Cypress National Preserve); simultaneously these have two of the largest populations of ghost orchid. Taking these factors together, almost all the analysis units are considered to be in overall low condition, except for one analysis units with low-moderate condition, and two analysis units with moderate condition.

Given the current condition results, we provided a simplified future conditions narrative, rather than a full analysis with different possible future scenarios. We determined that nearly all the negative factors currently affecting viability of ghost orchid populations will continue to affect the species in the future. In the case of some factors such as poaching, this may be at a similar level to the present, while for many factors like climate change associated sea level rise and hurricane impacts, these are expected to worsen.

With declining population health (low abundances and/or decreasing abundance over time) coupled with small geographic extent (low redundancy) and relatively low representation, the species now possesses limited ability to withstand inherent stochasticity (environmental, demographic, and genetic), catastrophic events (e.g., hurricanes), and changing environmental conditions (e.g., sea level rise and associated storm surge events).

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CHAPTER 1 – INTRODUCTION AND ANALYTICAL FRAMEWORK

This report summarizes the results of a species status assessment (SSA) conducted by the U.S. Fish and Wildlife Service (Service) for the ghost orchid (*Dendrophylax lindenii*) and is intended to provide the biological support for the decision on whether the species warrants listing under the Endangered Species Act of 1973, as amended (ESA) and subsequent decisions if added to the list of endangered and threatened species. Importantly, the SSA is not a decisional document by the Service; rather it provides a review of available information strictly related to the biological status of the ghost orchid. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input.

The purpose of the SSA is to assess the viability of the species in light of current and future threats and conservation efforts, collectively referred to as influences. We define viability as the ability to maintain populations in the wild over time and is assessed using the conservation biology principles of resiliency, redundancy, and representation (3Rs, adapted from Shaffer and Stein 2000, pp. 308–311; Wolf et al. 2015, entire).

<u>Resiliency</u> is the ability of a species to withstand environmental stochasticity or normal, year-to-year variations in environmental conditions such as temperature and rainfall; periodic disturbances within the normal range of variation such as fire, floods, and storms; and demographic stochasticity, chance variation in demographic rates such as mortality and fecundity (Redford et al. 2011, p. 40). Therefore, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

<u>Redundancy</u> is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). Examples include hurricanes, invasive species, and wildfire.

<u>Representation</u> is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Nicotra et al. 2015, p. 1270; Beever et al. 2016, p. 132). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, pp. 290–291; Zackay 2007, p. 1; Sgrò et al. 2010, p. 327).

In conducting our analyses, we reviewed and collected information from peer-reviewed literature, unpublished reports, government reports, expert input, land management policies and directives. We identified uncertainties and data gaps in our assessment of sources of threats influencing the species' overall viability.

CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS

In this chapter, we provide biological information about the species, including its taxonomic history, morphological description, historical and current distribution and range, known life history components, resource needs, and habitat occupancy.

2.1 Taxonomy

Dendrophylax lindenii (Lindl.) Benth. ex Rolfe is the currently accepted scientific name for the taxon. The current name is synonymous with four previously accepted names: *Polyradicion lindenii* (Lindl.) Garay, *Polyrrhiza lindenii* (Lindl.) Cogn, *Angraecum lindenii* Lindl., and *Aeranthes lindenii* (Lindl.) Rchb.f. (Brown 2002, p.80; FNA 2002 p. 621; Integrated Taxonomic Information System [ITIS] 2017, entire; Weakley 2023 p.171, Catalogue of Life 2024, pg. 1).

2.2 Species Description

Ghost orchid (also known as frog orchid, palm-polly, and white butterfly orchid) (Orchidaceae – Orchid Family) is an epiphytic, flowering, herbaceous, perennial plant species with either extremely inconspicuous, bract-like leaves or missing leaves entirely (Figure 1). The gray-green roots provide the primary means of photosynthesis, have distinctive white markings throughout, are 0.12–0.20 inches (in) (0.3–0.5 centimeters (cm)) wide, and fascicled in form (i.e., growing in clusters), obscuring the stems. Inflorescences occur as ascending racemes and may consist of 1–10 flowers, though only one or two will be open at a time. The white flowers are highly showy, with spreading petals and sepals usually blooming in the summer from May to August. Flowers are fragrant at nighttime when potential pollinators may visit and produce orange pollinia (specialized pollen structures found in orchids and some other plant groups). Flowers have a long and curved nectar spur up to 6.7 in (17 cm) in length. The fruit is a many-seeded capsule (Brown 2002, p. 80; FNA 2002 pp. 619–621; Weakley 2023 p. 171).

Figure 1. Photo of flowering ghost orchid (*Dendrophylax lindenii*). Courtesy Mark Danaher.

2.3 Range and Distribution

<u>USA – Florida</u>

In the United States, ghost orchid is currently only known from south Florida in Collier and Hendry Counties. The species may also be present in Lee County, as it was definitively last seen there in 2003 and possibly seen in 2015, though the Institute for Regional Conservation lists the species as “presumed extirpated” in the county (Gann et al. 2001–2024, p. 2). The only documented population in the county was lost due to frost. Although ghost orchids have been recorded for Miami-Dade County within Everglades National Park, this was due to an out-planting and not a natural occurrence. The translocation was not successful and plants at this location have all died (Gann et al. 2001–2024, p. 2).

<u>Outside of the USA</u>

The only other geographic location that ghost orchids occur outside of the United States is in Cuba. Although some botanical references have indicated that this species also occurs in the Bahamas, there are no herbarium specimens or other records from here, thus this is likely a mistaken reporting. Within Cuba, plants are found in the western part of the country in Guanahacabibes National Park. There have also been reports and records of the species from Ciénaga de Zapata National Park in the central part of the country and from more eastern parts of the country, but whether the species is currently extant in these regions is uncertain (Mújica 2021, pers. comm.).

2.4 Life History

The ghost orchid is a long-lived perennial with a typical orchid life cycle (Figure 2).

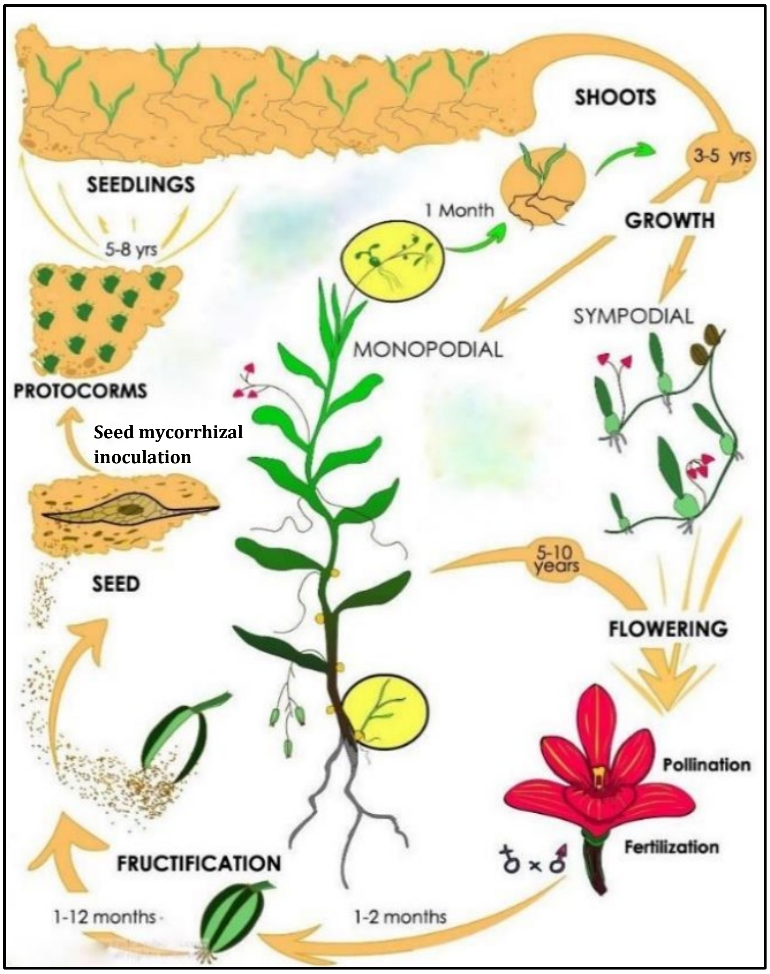


Figure 2. Diagram of orchid life cycle. (adapted from Telapova et al. 2018, entire)

<u>Flowering</u>

Reproductively mature plants occurring in south Florida usually produce flowers in the summer from May to August, though flowers have occasionally been observed outside of this time period (Brown 2002, p.80; FNA 2002 p. 621). Plants in Cuba typically flower between October and December (Mújica et al. 2018, p. 575). In the wild, it may take over fifteen years for a ghost orchid plant to first produce flowers, though in controlled environments plants can become reproductive earlier in their life cycle (Davis 2009, pp. 414–415; Hoang et al. 2017, p.390; Houlihan et al. 2019, p. 7). During the nighttime, flowers produce a sweet, fruity fragrance found to be primarily composed of terpenoids, common compounds found in flowering plants (Sadler et. al. 2011, p. 139). This scent may attract ghost orchid pollinators which include the fig sphinx moth (*Pachylia ficus*) and pawpaw sphinx moth (*Dolba hyloeus),* and possibly the giant sphinx moth (*Cocytius antaeus*) all of which are nocturnally active (Danaher et al. 2019, p. 673; Houlihan et al. 2019, p. 4). These Lepidopteran visitors use their proboscis to reach the nectar located within the end of the flower's moderate-sized nectar spur and can simultaneously pick up pollinia or deposit pollinia from a previous floral visit. Ghost orchid's nectar consists primarily of three different sugar compounds (making it highly desirable for insects that can reach it) and three different acid components (the function of which is less certain) (Chandler et al. 2022, p. 11). While probing for nectar, fig sphinx moths and pawpaw sphinx moths both have been observed with ghost orchid pollinia on their proboscises implying that they are true pollinators of the species, while giant sphinx moths have only been observed visiting flowers and may not necessarily be effective pollinators (Danaher et al. 2019, p. 673–677; Houlihan et al. 2019, p. 4).

<u>Fruiting</u>

If successful pollination and subsequent fertilization does occur, orchids may produce capsules containing thousands of miniscule seeds that are dispersed by wind. However, ghost orchids have been found to have very low fruit production rates, with only a few capsules among a population of hundreds of plants being produced at a time (Mújica et al. 2021, pp. 4–5; Houlihan et al. 2019, pg. 7; Mújica et al. 20, pg. 577–585). Additionally, while wind and gravity are the main mechanisms of seed dispersal, ghost orchid seeds do not possess any structures to aid in this dispersal (i.e., anything to help "carry" them) and thus likely only travel short distances from the parent plant.

<u>Seed Recruitment and Growth</u>

Orchid seeds require a fungal symbiont to be present where they land in order for them to survive and germinate. Unlike other angiosperms, orchid seeds do not possess endosperm to act as a nutrient supply. In the case of ghost orchids, this fungal symbiont is a *Ceratobasidium* species not yet named but recognized as distinct (Johnson et al. 2023, p. 4). In addition to the presence of this fungal partner, seeds must also land on the appropriate substrate to allow them to germinate. As these plants are epiphytic and not terrestrial, seeds must land on the bark of a host tree (see 'Habitat' below) at a suitable height, and not on the ground, in standing water, or on the tree too low to the ground as to periodically become inundated. Once these conditions are met and seeds germinate, seedling growth can occur. Seedling survival tends to occur at higher rates in wetter environments where high moisture levels extend into the winter dry season. This is likely important both for the survival of the sensitive, young tissues of the seedling itself as well as its mycorrhizal basidiomycete symbiont (Mújica et al. 2021, p. 9). First-year seedlings have one small leaf which eventually withers as the plant and its roots grow (Brown 2002, p. 80). From this point, individual plant lifespan is unknown, but is likely many years to decades since it appears that it can take over 15 years for plants to first begin flowering (Houlihan, et al. 2019, p.7). However, time to flowering in greenhouse conditions is much lower at around five years (Zettler et al. 2021, p. 260). Thus, the time to flowering in the wild may on average lie somewhere between 5 and 15 years (Zettler pers. comm. 2024). Plants complete CAM photosynthesis through their spreading root system, which also keeps them attached to their host tree (Figure 3). This type of photosynthesis allows for plants to reduce respiration by having their stomata (or similar structures such as pneumathodes in the case of ghost orchid roots) open and let carbon dioxide in at night, instead of during the day. Fungal associations continue from the seed stage to these later life stages where endomycorrhizal presence on the underside of roots allows for the uptake of additional carbon (Chomiki et al. 2014, pp. 88–93). Plants tend to grow on the north side of host trees where sun exposure may be lower and moisture levels may be higher, typically about 3–6.5 feet (ft) (1–2 meters (m)) high in the host tree (Mújica et al. 2018, p. 583). Unlike many other epiphytic orchid species, ghost orchids do not produce pseudobulbs, a plant structure that can help with water storage; thus, growth strategies like growing on the north side of host trees, using CAM photosynthesis, and the absence of leaves are all likely important ways the orchids prevent desiccation. Additionally, their roots have been found to have high water retention capabilities (Benzing et al. 1981, p. 134; Coopman and Kane 2019, p. 69). New, emerging roots grow underneath the old roots in an “upside down/inside out” pattern, which is thought to protect the developing tissue (Hoang et al. 2017).

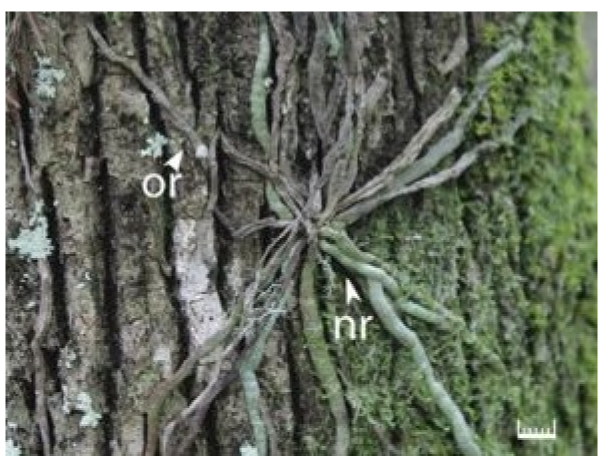


Figure 3. Photograph of vegetative ghost orchid individual showing old ("or") and new ("nr") root growth (Hoang et al. 2017).

2.5 Habitat

Ghost orchids occur in a few different habitat types in Florida, each of which is discussed below. Across habitat types, known plants are mostly found on Florida Water Ash (*Fraxinus caroliniana* Grisebach.; also considered as *Fraxinus caroliniana* Mill. var. *cubensis* (Griseb.) Lingelsh. or *Fraxinus cubensis* Griseb. by some (Weakley 2023, pp 818–819; Nesom 2010, entire) and Pond Apple (*Annona glabra*) host trees, and to a lesser extent on old growth bald cypress (*Taxodium distichum*). It is important to note that when growing on this last species, ghost orchids tend to occur much higher in the canopy and thus their presence in old growth bald cypress swamp forests may be underestimated due to survey difficulty and/or their presence in this forest type may have once been much greater prior to the widespread logging of old growth bald cypress in the region. Furthermore, ghost orchid habitat differs between the two areas of its range in Florida and Cuba and thus are categorized separately below.

Florida (Collier and Hendry Counties)

Dome Swamp

A dome swamp is an isolated, forested, depression wetland occurring within a fire-maintained community such as mesic flatwoods. These swamps are generally small but may also be large and shallow. The characteristic dome shape is created by smaller trees that grow in the shallower waters of the outer edge, while taller trees grow in the deeper water in the interior of the swamp. Bald cypress and pond cypress (*Taxodium ascendens)* dominates as a canopy species, and importantly for ghost orchids, pond apple often occurs as a sub-canopy species. Other epiphytic orchids as well as epiphytic *Tillandsia* species are common. Other canopy or subcanopy species include red maple (*Acer rubrum*), dahoon (*Ilex cassine*), swamp bay (*Persea palustris*), slash pine (*Pinus elliottii*), sweetbay (*Magnolia virginiana*), and coco plum (*Chrysobalanus icaco*). Dome swamps are most often found on flat terraces, where they develop when the overlying sand has slumped into a depression in the underlying limestone, creating a rounded depression connected to a shallow water table. In South Florida, dome swamps can also occur on peat directly overlying limestone. Dome swamps derive much of their water through surficial runoff from surrounding uplands. Water levels in dome swamps naturally fluctuate with seasonal rainfall changes. They may also be connected directly to the aquifer, where groundwater influences the hydrological regime, especially during periods of drought. The normal hydroperiod for dome swamps is 180 to 270 days per year, 50 with water being deepest, and remaining longest, near the center of the dome creating a larger buildup of peat there. Fire is essential for maintaining the structure and the species composition of the community, where it is most frequent toward the edges of the swamp and much less frequent toward the interior. Dome swamps can be found throughout the state of Florida (except the Florida Keys) and is ranked as a G4/S4 community, or "apparently secure" at both the global and state levels. However, there are still threats to this natural community including invasive plant species, pollution from agricultural runoff, changes to historical fire frequency (in either direction depending upon location in the swamp), and hydrological changes through ditching, impoundment, and other projects. In the late nineteenth and early twentieth centuries, these communities suffered from extensive logging of cypress trees (FNAI 2010, pp. 167–170).

Slough

Sloughs are broad channels inundated with slow moving or nearly stagnant water, except during extreme droughts, and represent the deepest drainageways within swamps systems. While not all sloughs are canopied, those that the ghost orchid occupies must be to allow for plants to grow on their host tree. In such cases, Florida water ash is a common canopy tree, as is pond apple which can withstand even deeper water. In south Florida sloughs, submerged plants and algae can form mats that contribute food and oxygen. Aside from ghost orchids, pond apple trees and Florida water ash trees in south Florida sloughs are often densely covered in other epiphytic plant species such as bromeliads, ferns, mosses, lichens, strangler figs, and peperomias. Sloughs occur in irregular linear arrangements within different swamp communities, often forming an intricate mosaic of wetlands. They can be found throughout Florida and other parts of the Southeast, but in south Florida, sloughs are larger and more distinctive communities. The high humidity and long hydroperiod of these sloughs dominated by pond apple provide frost and fire protection to the plant species growing there. In fact, some of these sloughs may never experience fire. Sloughs are extremely vulnerable to hydrologic disturbances and must have a reliable water source to persist. In pond apple sloughs, the maintenance of a natural hydrology is important to sustain epiphyte diversity, as well as wildlife populations. Watershed disturbance from the creation of canals and roads can cause ponding in some areas, and unnatural drought conditions in others. This can result in increased soil oxidation and fire frequency. Currently, sloughs are ranked as a G3/S3 natural community type, meaning they are considered vulnerable at both the global and state levels (FNAI 2010, pp. 153–155).

<u>Strand Swamp</u>

Strand swamp is a shallow, forested, usually elongated depression or channel situated in a trough within a flat limestone plain, and dominated primarily by bald cypress. Smaller strand swamps and shallow edges may instead contain pond cypress (*T. ascendens*). Small, young cypress trees at the outer edge of strand swamps grade into large old ones in the deeper interior, giving a strand a distinctly rounded cross-sectional profile. The warm, humid climate in strand swamp make it ideal habitat for epiphytic orchids and bromeliads. Strand swamp soils are peat and sand over limestone and have a typical hydroperiod that ranges from 100–300 days. Water levels rise with increasing rainfall in the summer and then decrease to their lowest levels during the spring, especially late April to early May. Water is deepest and remains longest near the center of the swamp. Strand swamps are restricted to South Florida, and probably do not occur north of Lake Okeechobee. They are mainly in Collier County where the Fakahatchee Strand and Corkscrew Swamp are perhaps the finest examples. Corkscrew Swamp specifically has some of the last old growth cypress stands in the state and has well developed epiphyte communities high up in the canopies of these trees. Fire occurs rarely in strand swamps, with the largest trees on the deepest peat towards the center of the strand burning least frequently and the outer edges of the swamp burning most frequently. Threats to this habitat type include logging (as had been done extensively a century ago) and hydrological changes (i.e. reduced hydroperiod and increased flash flooding) due to conversion of the surrounding landscape and road creation. Because of the limited range of this community type and these threats, it is ranked as G2/S2, meaning that strand swamps are considered imperiled at both the global and state levels (FNAI 2010, pp. 167–169).

Figure 4. Strand swamp habitat at Audubon Corkscrew Swamp Sanctuary. Photo by Gary Knight.

It should also be noted that ghost orchids have previously been found growing in mesic and maritime hammock habitat types, in addition to those listed above. These are characterized by an evergreen closed canopy predominantly of live oak (*Quercus virginiana*) and cabbage palm (*Sabal palmetto*) trees with abundant epiphyte presence. However, no ghost orchid plants have been seen in mesic/maritime hammocks in over twenty years. Thus, the importance of this habitat type seems to be historical only and a full community description is not included here.

Cuba

The habitat in which ghost orchids are currently found in Cuba is different to the habitat types described above. Ghost orchids are currently known from Guanahacabibes National Park where plants are found growing on tropical semi-deciduous hardwood host trees that are rooted in fractured reef limestone with little or no standing water (Mújica et al. 2018, p. 573). Plants grow on a much wider variety of tree species in Cuba compared to Florida, with 18 tree species recorded as hosting ghost orchids, none of which overlap with the Florida species. However, five tree species can be said to host the majority of ghost orchid plants: Feather-bed (*Maba crassinervis)*, False Cocaine (*Erythroxylum aerolatum*), Toothed Maidenplum (*Comocladia dentata*), False Mastic (*Mastichodendron foetidissimum*), and Blushing Bride (*Tabebuia angustata*) (Mújica et al. 2018, p. 578).

CHAPTER 3 – FACTORS INFLUENCING VIABILITY

The following discussion provides a summary of the factors that are affecting or could be affecting ghost orchid throughout some or all of its range. Major stressors include habitat modification and destruction due to changes in hydrology, climate change associated factors like seal-level rise, hurricane intensity, and wildfire frequency, and the ongoing threat of poaching.

3.1 Habitat degradation related to hydrological changes

While ghost orchids today are mostly found within conservation areas protected from development, these areas are not immune to habitat modification caused by anthropogenic activities. Collier, Lee, and Hendry counties have undergone transformative canalization over the last century in order to divert water away from residential areas and roads. Ditching associated with past cypress logging has also contributed to alteration and diversion of natural water flow (Fakahatchee Strand Preserve State Park Unit Management Plan 2014, p. 19). Groundwater extraction for crops and residential use has also markedly increased in the last several decades as both agricultural land use and population size have exploded in the region, the latter in Collier County by over 1000% from 1969 to 2022 (Florida Regional Economic Analysis Project 2024, pp. 1–2). Unfortunately, these hydrological changes to the landscape have also likely contributed to reducing water flow and water availability to the adjacent natural areas that ghost orchid occupies. For example, at the Corkscrew Swamp Sanctuary, hydroperiod in old growth cypress swamps has decreased by 18% since 1959, with an especially notable decrease occurring from the 1990s to the 2010s (Clem and Duever 2019, pp. 365–367). Similarly, water level recession rates during the dry season have greatly increased in the Sanctuary this century, by at least 32% when compared with earlier decades (Clem and Duever 2019, p. 365). Drier conditions have also been observed in Collier-Seminole State Park (Collier-Seminole State Park State Park Unit Management Plan 2004, p. 18) and Big Cypress National Preserve (NPS 2021, entire) in recent years.

These documented hydrological changes within the ghost orchid range in Florida present several threats to populations, both directly through demographic factors and indirectly through subsequent climate related factors. First, it appears that ghost orchid recruitment is dependent on having sufficiently wet conditions present throughout the year. Of the seven subpopulations studied at the Panther National Wildlife Refuge (NWR), only the one occupying the wettest part of the swamp showed consistent, successful seedling recruitment during the time monitored (Mújica et al. 2021, p. 8). Without successful recruitment, populations will become “senile” and eventually die out when the mature individuals perish (Rasmussen et al. 2015, p. 392). Drier conditions also mean that ghost orchids are more prone to experience frost, to which they have not evolutionarily adapted and of which they are largely intolerant. Historically, the long hydroperiods and high humidity of the orchid’s swamp and slough habitats would protect these areas from otherwise potential frost conditions in the subtropical region. With recent decreases in hydroperiods, frosts have become more common and indeed have already contributed to extirpation of the only population at Six Mile Cypress Slough Preserve in Lee County (Greeno 2024, pers. comm.), possibly one population out of a total of three at a location we refer to as "Coastal Transition Site 1" throughout this document (for plant protection purposes) in Collier County (Florida DEP 2024, pers. comm.), and 35 or more plants across populations at Fakahatchee SPSP in Collier County during a January 2010 frost (Owen 2024, pers. comm.).

As a result of the hydrological changes that have occurred across the range of Florida ghost orchid populations, wildfires now represent a significant threat due to the drier conditions. The most recent example of this is at Big Cypress National Preserve where the Silver King Wildfire in 2020 burned a total of over 600 acres (243 hectares) and reached within less than 6.5 ft (2 m) of the closest known ghost orchid, just narrowly missing the population (Angelo 2024, pers. comm.). Nearby, the fire burned into the peat ground layer and burned tree roots; had the fire reached just slightly farther, ghost orchid host trees could have been directly impacted and even killed from the intensity of the flames killing their root system. Even without reaching the host trees themselves, an intense fire in such close proximity may still have negative future effects on ghost orchids nearby, as the increased sunlight reaching the understory where the plants are located can increase the temperature and decrease the humidity of the microenvironment (Herdman pers. comm. 2024b).

3.2 Poaching

Poaching is one of the main, ongoing threats to ghost orchid populations throughout its range. Orchids as a group are highly prized and sought after by collectors for their beauty and diversity, with enthusiasts traveling great distances for the express purpose of observing (and sometimes collecting) flowering plants (Wraith and Pickering 2017, pp. 3410–3414; Fay 2018, p. 2). Ghost orchid tops the list of desirable species for collection in this already greatly desired group for its rarity, unusual growth form, and overall stunning appearance. This desirability is made worse by the fact that plants can be difficult to successfully grow ex situ. Not only is such collecting from wild populations illegal under Rule 5B–40 in the Florida Administrative Code, it also endangers the viability of populations by removing the individuals most likely to contribute to reproduction and recruitment.

Unfortunately, many ghost orchid populations in otherwise protected conservation areas have experienced poaching in the last several decades. For example, a recent poaching event in the summer of 2020 at one of the populations in Big Cypress National Preserve caused a significant decline there (Angelo 2024, pers. comm.). Although staff have taken important steps to reduce the accessibility of the site, such as locking the gate to the access road near the population and discontinuing maintenance of the road, this and other locations are still likely known by other potential perpetrators and populations here remain vulnerable. There are several informal, sometimes flagged trails to ghost orchid sites within the Big Cypress National Preserve that contribute to this poaching threat (Angelo 2021, pers. comm.). The unauthorized flagging is an ongoing problem and has been discovered and removed by Big Cypress National Preserve staff as recently as summer 2024 (Angelo 2024, pers. comm.). In another population at Fakahatchee SPSP where individual ghost orchid plants are closely monitored, 10 plants were poached between 2005 and 2020 which represents 8% of those monitored (Owen 2024, pers. comm.). Even as recently as 2023, poachers have been caught at Fakahatchee SPSP attempting to steal reproductively mature ghost orchid plants (Fox13 Tampa Bay 2024, entire). While poaching has not been specifically documented at the population within Collier-Seminole State Park, local managers believe it has been a problem in the past (Patel 2024, pers. comm.). Similarly, it is plausible that poaching has also occurred at other Florida populations and simply not been recorded or even noticed, since populations are hard to access and not all are visited regularly. In Guanahacabibes National Park in Cuba, poaching of at least one mature ghost orchid has been documented (Zettler 2024, pers. comm.) and 42 individuals of another co-occurring epiphytic orchid (*Broughtonia cubensis*) were illegally collected (Raventos et al. 2015, p. 180). What is especially detrimental to the health of the ghost orchid populations is the almost universal preference of poachers to remove reproductively mature plants, those that take 15 or more years to reach this life stage and are critical to the contribution toward future generations. Thus, for many of these populations where poaching has occurred recently, the population level effects may not be realized for many years. Even though plants have been made available in the commercial horticultural trade in recent years, poachers are still persistent in their efforts (Herdman pers. comm. 2024b).

3.3 Climate change (hurricanes, sea level rise, saltwater intrusion)

Hurricanes are both a major and regularly occurring natural disaster that affect all parts of the ghost orchid range. Although hurricanes have always been a component of Florida and Cuba's climate, their intensity and frequency are increasing due to climate change (Jay et al. 2023, p. 16). This poses a threat to ghost orchids in at least two main ways: direct mortality or significant damage to host trees and storm surge. Category 4 and 5 hurricanes produce high winds that can exceed 130 mph and can uproot and kill host trees or take out branches, thereby killing any ghost orchid plants on host trees and their branches. A host tree can easily support more than one ghost orchid plant on the same tree, thus the loss of even just one host tree can mean the loss of multiple ghost orchid plants. Possibly even more significant may be the sudden and near complete loss of leaf canopy overtopping ghost orchid populations. While normally ghost orchids would be shaded from intense summer-early fall sun exposure and the deciduous leaf canopy would gradually be lost over a period of two months in mid-late fall, hurricane winds can altogether take out the leaves in a day. Such a dramatic change leaves the orchids exposed to direct instead of dappled sunlight and leaves them prone to desiccation stress. These orchids may not immediately perish, but instead decline in health over a couple of years and die afterward (Owen 2024, pers. comm.). Any ghost orchids occurring higher in the canopy, on old growth bald cypress for example, would be especially susceptible to this heat/desiccation threat, as well as to direct wind damage from the storm (Clem 2024b, pers. comm).

These impacts have already been observed at multiple populations. For example, at the Panther NWR, at least 48 orchids died after their host tree fell or had branches damaged during Hurricane Irma in 2017 (Mújica et al. 2021, p. 8). Additionally, the number of seedlings observed in the population dropped the following two years after the hurricane, demonstrating the possibility of long-term negative demographic effects from storms (Mújica et al. 2021, p. 3). The recent 30 percent decline of a population at Big Cypress National Preserve is also directly attributable to Hurricane Irma: a survey of the largest population within the preserve took place just a few months before the storm and then subsequently following the storm and the host tree loss was obvious. Additionally, loss of ghost orchid due to changes in canopy cover and humidity in the damaged area of the slough was also evident (Angelo 2024, pers. comm.; Angelo 2021, pers. comm.). The loss of one ghost orchid at Audubon Corkscrew Sanctuary also occurred as a direct result of Hurricane Irma (Clem 2024a, pers. comm.). Earlier in 2005, Hurricane Wilma caused a significant decline in the Fakahatchee SPSP populations (Owen 2024, pers. comm.). Strong hurricanes also produce flooding events from the high amount of rainfall in a short period of time, which greatly increases normal water levels in ghost orchid habitat. Some plants that would normally be situated above the water line on their host tree become inundated as a direct result from this flooding and if prolonged, can perish. Indeed, this type of mortality was observed at the Panther NWR following Hurricane Irma (Mújica et al. 2021, pp. 3–4) and has been observed at Fakahatchee SPSP (Owen 2024, pers. comm.). Similarly, after Hurricane

Irma a dramatic downward trend in the numbers of another Florida native orchid, ribbon orchid (*Campylocentrum pachyrrhizum*), was also observed in the Panther NWR (Herdman et al. 2023, p. 9).

Sea level rise is another climate change associated factor considered a stressor for ghost orchid. Both the increase in frequency and severity of storm surge events after major tropical storms and increasing water salinity in wetland habitats are threats for populations near the coast. At Coastal Transition Site 1, measured surface water salinities have reached as high as 2.0 ppt at the ghost orchid population; soil porewater salinities at this level are high enough to kill off host canopy trees (Florida DEP 2024, pers. comm.). Nearby surface water salinities have been measured even higher at up to 5.3 ppt which has led to complete canopy die-off and a steep decline in epiphyte diversity. A similar fate is possible for additional populations as sea levels are forecasted to increase in the Naples area by 8 to 22 in (20 to 56 cm) by 2050 (https://sealevelrise.org/states/florida/). See future condition for a brief discussion of projected impacts of sea level rise.

In summary, the increased intensity of storm events over the last couple of decades has led to a reduction in ghost orchid populations, thereby reducing overall population resiliency and the species' redundancy.

3.4 Invasive Species, Disease, and Predation

There are over 1,500 non-native plant species occurring in Florida (Atlas of Florida Plants 2024). Of these, 83 are listed as Category I invasive species, meaning that they alter native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives (Florida Invasive Species Council 2023, pg.1). An additional 89 plant species are listed as Category II invasives which have increased in abundance or frequency but have not yet altered Florida plant communities to the same extent that Category I species have. At least half of these Category I and II invasives occur within the range of ghost orchid populations. The invasive species that probably poses the most risk to ghost orchid populations is old world climbing fern (*Lygodium microphyllum*), which thrives and can indeed take over the same wetland habitats that ghost orchid occupies. In addition to reducing the amount of sunlight available to ghost orchid plants themselves, old world climbing fern can also kill host trees and potential host trees if not controlled. While most protected areas do perform surveys to find and quickly treat this invasive species (e.g. Fakahatchee Strand Preserve State Park Unit Management Plan 2014, pp. 49–50; Collier-Seminole State Park State Park Unit Management Plan 2004 pp. 19–22), if not found early on it can become difficult to control, climbing into the canopy and forming dense masses. Additionally, some parks may not have adequate staffing to complete these demanding invasive plant species control measures frequently enough (Collier-Seminole State Park Unit Management Plan 2004, p. 22).

Another invasive species to consider with respect to ghost orchid host trees is the emerald ash borer (*Agrilus planipennis).* In just over twenty years, this insect has killed millions of ash trees in the eastern half of the United States by boring into trees and feeding on the phloem (Ray and Gillete-Kaufman 2022, pp. 1–2). Emerald ash borer has not yet been detected in Florida, but its host tree of ash species (genus *Fraxinus*) are abundant and widespread in the state. Florida water ash is one of the two main host trees for ghost orchid in the state, so if emerald ash borer were ever to invade Florida it could have devastating consequences for ghost orchids. However, it seems unlikely at this point that the insect will establish in Florida, as the subtropical climate seems to be preventing its spread to the state. Thus, this can be considered a low probability threat for ghost orchids.

In terms of insect predation directly on ghost orchid plants, the biggest concern is the damage that sucking insects likes scales, leaf hoppers, and mites can cause, especially exotic ones. Likely, these insects have entered natural habitats from adjacent developed areas where they are a known problem on cultivated orchid species (Johnson 2010, entire). Indeed, in 2009 at one population in Collier County, both mealy bugs (*Ferrisia* sp.) and soft scales (*Pulvinaria* sp.) were documented on flowers, the latter of which were attended by an exotic ant species (Zettler et al. 2012, p. 128). However, one year later none of these insects were seen on any ghost orchids checked by surveyors at this same location. Similarly, none of the ghost orchids chosen for insect surveys at Fakahatchee SPSP were found to harbor any scales or hoppers (Flatidae), but only 4 plants were checked (Ray et al. 2012, p. 316). Nevertheless, the presence of exotic scale insect species on other orchid species and even in remote locations raises concern for ghost orchids.

3.5 Recreational impacts and unregulated human activities

Because the vast majority of known ghost orchid sites occur on public lands open to the public and to different types of recreation, these activities must be taken into account as potential stressors for the species. The main concerns under this category are off-road vehicle (ORV) use and the creation of unsanctioned hiking trails. These are both tied to the threat of poaching, as easier access to ghost orchid populations increases the risk of illegal collecting. However, these activities come with threats of their own, including modification of habitat and hydrology. ORV and informal hiking trails can contribute to soil compaction and decrease recruitment from native plants, including host trees for the ghost orchid. ORV trails can be especially damaging to wetland habitat types, such as the swamps and sloughs that ghost orchids occupy, causing deep ruts in the mucky soil, increasing sunlight exposure, and allowing for permanent standing water conditions in the areas they have been created and are frequently used. Even areas not directly in the path of ORV trails can be affected, as water flow in adjacent habitat may instead be channeled to these trails, instead of its natural flow. Additionally, during the 2024 flowering season, Big Cypress National Preserve staff found three unpermitted cameras directly on or facing ghost orchids which law enforcement further investigated and removed (Angelo 2024, pers. comm.). This is an ongoing investigation, but it is quite possible these cameras were put in place to aid poachers with the timing of their collection. Even if this were not the case, the placement of cameras directly on the delicate root/flower structures of the orchids would likely cause direct harm to the plants.

3.6 Pesticide Use

In South Florida, the use of pesticides to control mosquito populations is common and widespread. Within the range of ghost orchids, the Collier Mosquito Control District exists as an independent special taxing district and is tasked with "the Mission of protecting public health and comfort by and through the control of disease-carrying and nuisance mosquitoes." Both aerial and ground-level treatment techniques are used to control both mosquito larvae and adults over 401 square miles of Collier County. It is the latter type of treatment that poses the most risk to the ecological relationships of ghost orchid populations. Treatments to control adult mosquitos are usually completed at nighttime, the same time when the hawk moth pollinators of ghost orchids would be flying. While the protected lands that ghost orchids occur within are not directly contained in the tax district borders, they are directly adjacent to the more developed, urbanized areas being treated. Because the several different types of adulticides used are not specific to mosquitos, non-target insect species may be affected and face mortality. Indeed, there is some evidence that butterfly species overall (Bargar 2012, entire) and specifically the extremely rare, endangered Miami blue butterfly species has suffered in areas of mosquito control with the adulticide naled (Zhong et al. 2010, pp. 1966–1967), as have dragonfly and damselfly species (Jakob and Poulin 2016, pp. 164–167), and Hemipteran species (Rochlin et al. 2022, p. 8). Negative effects on flying insect communities in wetland habitats may be felt not only immediately following the spray application, but for a month afterward or longer (Everham et al. 2014, pp. 68–69). These studies contradict the idea that only small insects would be impacted by these pesticides in a very short-lived manner, as is sometimes put forward. Additionally, the "minimum risk" designation assigned to many pesticides can be misleading, as this refers to the risk to humans and not insects which may be very much at risk. Even "natural" insecticides intended to reduce mosquito populations would be expected to also pose toxicity to pollinator species (Ginsberg et al 2017, p. 1468). The impact of adulticides on nocturnal insect fauna has not been as well documented, though given that night-flying insects are the most vulnerable (Florida Mosquito Control 2018, pp. 190–193), they must be considered as at least possibly threatened by these applications. If mosquito control applications did have the effect of reducing hawk moth numbers, the amount of pollination and fruit set in ghost orchid pollinations could also be reduced (Mújica et al. 2018, p. 584).

3.7 Synergistic Effects

In addition to impacting ghost orchid individually, it is likely that several of the above summarized negative factors are acting synergistically or additively on the species, or soon will. The combined impact of multiple negative influencing factors is likely more harmful than a single negative factor acting alone. For example, drier conditions in ghost orchid habitat due to hydrological changes makes the species more susceptible to frost and wildfire impacts, both of which may occur more frequently as extreme weather events with climate change. Additionally, climate change associated sea-level rise would be expected to worsen storm surge impacts from hurricanes.

3.8 Conservation Efforts

3.8.1 State and Federal Protections

Ghost orchid is currently state-listed as an endangered species by Florida's Department of Agriculture and Consumer Services and is included in the regulated plant index (endangered, threatened and commercially exploited species) as defined in Rule 5B–40, Florida Administrative Code. This list of plants is reviewed each year by the Florida Endangered Plant Advisory Council whose members include botanists at state universities, and at least one member each from the Committee for Rare and Endangered Plants and Animals, the Florida Federation of Garden Clubs Inc., the Florida Forestry Association, the Florida Native Plant Society and the Florida Nurserymen and Growers Association Inc. The State listing does not provide any direct habitat protection or automatic conservation funding for the species. 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. As has already been alluded to in the poaching section of this chapter, these state-level legal restrictions have not done much to dissuade illegal harvesters. Additionally, all orchid species, including ghost orchid, are covered under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) treaty which requires permits for the "trade" of plants across international borders, whether for commercial, scientific, or personal purposes (American Orchid Society 2024, p. 1). However, this treaty does not regulate any collection or movement of plants within an individual country and also does not seem to be a major deterrent against illegal collectors.

In 2024, the Florida Fish and Wildlife Conservation Commission (FWC) finalized an addendum to the Florida's State Wildlife Action Plan that added almost 600 plant species, including the ghost orchid, to its list of Species of Greatest Conservation Need. However, even with this change, the State Wildlife Action Plan does not ensure specific conservation actions will be accomplished for any particular plant species. Highlighting and focusing attention on the conservation needs of these plant species is important, but it must be followed by species-specific and habitat-level funding in order to be most effective.

3.8.2 Land Protection and Management

Protected lands include lands that are state or federally owned, and private land owned or protected by conservation organizations (e.g., conservation easements). These properties buffer against the impact of habitat loss and at least to some extent, modification due to land use changes. In addition, populations occurring on protected lands are more likely to receive conservation management, such as hydrological restoration, prescribed burning, and non-native invasive species management. Therefore, some threats or potential threats may be reduced for populations that occur on protected land.

Currently, almost all known extant populations are located on public, protected lands often with mixed or combined ownership/management. These include both state and federally managed lands, specifically Florida Department of Environmental Protection State Park lands: Fakahatchee SPSP, Collier-Seminole State Park, and Coastal Transition Site 1; USFWS National Wildlife Refuge land: Florida Panther NWR ; National Park Service land: Big Cypress National Preserve, Florida Forest Service land (historically but not extant): Picayune Strand State Forest; Lee County land: Six Mile Cypress Slough Preserve (historically but not extant); and in Cuba at Guanahacabibes National Park. Additionally, there is also a privately owned but protected site at the National Audubon Society's Corkscrew Swamp Sanctuary.

The level of monitoring and species-specific management at these protected sites varies. For Fakahatchee SPSP, the most recent management plan lists ghost orchid as a known imperiled species within the park. As such, it lists hydrological maintenance/restoration and protection from visitor impacts as the main management actions for the species and "Tier 4" monitoring efforts, meaning a population census designed to count the entire population with demographic analysis, including mortality, reproduction, emigration, and immigration (Florida DEP 2014, pp. 38–56). While ghost orchid is listed as a known species occurring within Collier-Seminole State Park's management plan, no species-specific management or monitoring actions are listed Florida (DEP 2004, p. 84). However, their management goals of controlling invasive exotic plant species and restoring hydrology as near to pre-drainage conditions as possible would be likely to benefit ghost orchid on the property. At Florida Panther NWR, the population is monitored annually for survival and flowering/fruiting/recruitment rates (Danaher 2024, pers. comm.). In their Natural Resource Prioritization Phase II Decision Report, the Panther NWR lists improving and conserving hydrology of forested and herbaceous wetlands as a goal in order to increase and/or maintain ghost orchid populations within water ash slough habitat. It specifies that this may be accomplished through: 1) sampling, studying, propagating, and/or outplanting the orchids; 2) developing and implementing a hydrologic monitoring program to identify optimal ghost orchid hydrologic conditions by assessing surface and groundwater levels, surface flow, hydroperiod, and water quality conditions; and 3) implement early detection, rapid response efforts for non-native invasive species (USFWS 2024, p.11).

3.8.3 Conservation Horticulture

While ghost orchid is known for being difficult to grow in e*x situ* conditions, recent research advancements have made their cultivation in the lab and greenhouse possible. One major step forward was the discovery of a fungal strain, harvested from ghost orchid roots in the wild, that could be used in the lab to greatly increase seed germination and successful seedling development rates (Hoang et al. 2017, p. 383). Like all orchid species, ghost orchid seeds and seedlings require a fungal mycorrhizal symbiont, due to the lack of endosperm (and therefore nutrients) in orchid seeds. Thus, culturing the seeds with its specific *Ceratobasidium* fungal partner has allowed for increased growth success of ghost orchids from seed. Another difficulty with growing ghost orchids in controlled conditions from a young age is the growth pattern and orientation of their roots. When cultivated *in vitro*, their roots tend to grow thick and in different planes, which makes subsequent attachment in *ex vitro* conditions more challenging. Research has shown that careful root pruning of seedlings cultured on media may facilitate attachment to substrates under greenhouse conditions (Rodenius et al. 2014, p. 1). As an epiphyte that must grow on a host tree, attachment is an important step in ghost orchid development and thus this represents an important advancement in ghost orchid cultivation. Additionally, although ghost orchids are considered intolerant of desiccation in their natural, high-humidity environments, they actually appear to be tolerant of desiccation in the greenhouse setting (Coopman and Kane 2019, p. 64). This discovery may allow for the direct use of *in vitro*-derived plants for field restoration and thus for more efficient conservation of the species (Coopman and Kane 2019, p. 69). This may also explain why a fairly wide range of greenhouse misting conditions has been found to be appropriate for ghost orchid acclimatization in the greenhouse (Coopman and Kane 2018, p. 106). In fact, their ability to rapidly acclimatize under sufficient misting and air movement conditions means that they should need no longer than a month in the greenhouse for acclimatization (Coopman and Kane 2018, p. 106). Covering the roots with Spanish moss in the greenhouse also appears to help keep roots sufficiently hydrated while simultaneously allowing them drying out periods, a process which may help stimulate flowering (Davis 2009, p. 412).

Of course, the most significant conservation impact that these research insights can provide is their translation to conservation outplantings of ghost orchids back in the field. Such efforts began in 2015 with the first translocation study in which ghost orchids attached to burlap in the greenhouse were transplanted to host trees at the Panther NWR. Survival of plants was high one year following the outplant at about 90% and still fairly high 20 months later at about 73% (Kane 2023, pers. comm.). Following this success from greenhouse acclimated orchids, 120 plants six years in age were directly outplanted to the Panther NWR from culture. Survival of these plants has gradually decreased over time; in 2023 only 34 plants of the original 120 were still alive. Additionally, although these plants have flowered and even begun to develop seed capsules, the fruits were aborted before fully maturing. One likely explanation for this fecundity failure is inbreeding depression, as all outplants were derived from a single seed capsule collected from the Panther NWR (Herdman 2024a, pers. comm.). Therefore, this population of outplants cannot be considered viable, as reproduction has not thus far not been achieved.

3.9 Summary of Factors Influencing Viability

We reviewed and summarized the factors that are affecting the viability of ghost orchid populations. The primary negative influencing factors currently impacting the species are poaching of mature plants from the wild, habitat degradation due to hydrological changes and the frost and wildfire risks associated with these changes, and climate change, most notably the increased intensity and frequency of hurricanes and impacts from sea-level rise. These threats have all had negative impacts on the ghost orchid's resiliency, representation, and redundancy, especially within the last few decades. Other threats that have impacted the species or may soon impact the species include invasive species, recreational use and unregulated human activities, and pesticide use. While conservation efforts in the form of *ex situ* propagation and *in situ* translocations represent important foundational work, these have not yet advanced to the point of positively impacting the viability of wild ghost orchid populations.

CHAPTER 4 – POPULATION AND SPECIES NEEDS AND CURRENT CONDITION

In this chapter, we consider the historical distribution of the ghost orchid, its current distribution, and what the species needs for viability. We first defined populations of the species. Next, we characterize the needs of the species in terms of population resiliency and species' representation and redundancy (the 3Rs). Finally, we estimate the current condition of ghost orchid using population and habitat metrics used to characterize the 3Rs.

4.1 Populations

Ghost orchid populations occur in southwestern peninsular Florida and Cuba, separated by about 350 miles (mi) (560 kilometers (km)) (Figure 5). As of 2024, populations remained extant in both locations, but with total extent of occurrence reduced, as populations in central and eastern Cuba are thought to be extirpated (Mújica 2021b, pers. comm.) and a population in Lee County, Florida has been extirpated (Greeno 2024, pers. comm.) and two other populations in Florida are likely extirpated.

Florida's ghost orchids occur in the western Greater Everglades ecosystem in about 21 small isolated locations within 10 conservation properties, mostly protected and managed lands, in Collier and Hendry counties, across a small area just over 1,450 square mi (3,757 km). In their most recent global assessment, NatureServe (2021) estimates that there are between 603–704 known reproductively mature individual plants in Florida, though a few populations have had updated census counts since this time (see more below).

In Cuba, fewer than 150 reproductively mature ghost orchid plants are known in Guanahacabibes National Park in the extreme southwestern part of the country (Mújica 2021b, pers. comm.). In addition, two plants were reported from Ciénaga de Zapata National Park about 200 mi (320 km) to the east of Guanahacabibes but were unconfirmed and may be extirpated (Zettler et al 2019, p. 140). Plants have also been recorded or reported in eastern Cuba including the province of Granma (Rio Portillo), Las Tunas, Santiago de Cuba, Guantanamo, and Holguin provinces (Natureserve 2021 p. 3; Zettler et al 2019, p. 140), but none of these populations are believed to be extant (Mújica 2021a, pers. comm.).

We do not have information on what precisely constitutes a biological population for the ghost orchid. For the purposes of evaluating current condition of ghost orchid, we used analysis units to evaluate population resiliency, see "Methods for Estimating Current Condition", below.

Figure 5. Maps showing A) the global range of ghost orchid and B) the range within Florida of extant populations. Note that individual population locations are not displayed due to their highly sensitive nature.

4.2 Methods for Estimating Current Condition

For the purpose of this assessment, we defined viability as the ability of ghost orchid to sustain natural populations in its habitats of strand swamp, dome swamp, and slough ecosystems over time. Using the SSA framework (Chapter 1), we described viability of ghost orchid by estimating the current condition using a variety of demographic and habitat factors. We chose to use the property/management area as our analysis unit (AU) for assessment since 1) many monitoring and management activities take place at this level and 2) with a few exceptions for the larger populations, many managed areas have only one ghost orchid population.

Table 1. Analysis units with ghost orchid populations

Analysis Unit	Monitoring Type/Frequency	Ownership/ Management	Total Population Size	# of Sub-Populations	Known Trends	Last Year Detected	Reference
Florida Panther National Wildlife Refuge	Annual monitoring since 2015	USFWS	275 ± 20	7	Projected to decline 20% by 2034	2023	Danaher 2024, pers. comm.
Fakahatchee Strand Preserve State Park	Annual monitoring of ~ 50% of the population	Florida Department of Environmental Protection	230 ± 50	~20	At least 60% decline over 30 years of monitoring, possibly as much as 77% decline	2023 (about half of subpopulations are monitored annually)	Owen 2024. pers. comm.
Big Cypress National Preserve	Periodic surveys	National Park Service	~ 300	4 (1 large, main population and 3 others with <20% of the ghost orchids combined)	At least 30% decline since 2017, and then subsequent 6% decline	2023	Angelo 2024a, pers. comm.

Analysis Unit	Monitoring Type/Frequency	Ownership/ Management	Total Population Size	# of Sub-Populations	Known Trends	Last Year Detected	Reference
Audubon's Corkscrew Swamp Sanctuary	Periodic surveys	National Audubon Society	2	1	One of three known plants was killed by Irma in 2017	2024	Clem 2024a, pers. comm.
Coastal Transition Site 1	Annual survey	Florida Department of Environmental Protection	19	2 extirpated; 1 in poor condition	Decline	2024	Florida DEP 2024, pers. comm.
Collier-Seminole State Park	Periodic surveys	Florida Department of Environmental Protection	4-5	1(?)	Decline due to disturbances in hydrology, non-native plants, and hurricane. Possibly also poaching	2015	Patel 2024a pers. comm.
Hendry County site	Opportunistic surveys	Undisclosed	6-50	5	Unknown	2023	Nesmith 2024, pers. Comm.; Owen 2024. pers. comm.
Naples urban site	Periodic surveys	Undisclosed	31	1	Approximately 25% decline over 16-year period	2017	Owen 2024. pers. comm.
Guanahacabibes National Park	Annual or near annual monitoring		230	1?	Recent decline and projected to be extirpated by 2040 if hurricane activity is high enough.	2021	Raventós et al. 2015; Mújica 2021b; pers. comm.; Wiegand et al. 2013
Six Mile Cypress Slough Preserve	Periodic surveys	Lee County Parks and Recreation	0	0	Extirpated by frost mortality		Greeno 2024, pers. comm.

Analysis Unit	Monitoring Type/Frequency	Ownership/ Management	Total Population Size	# of Sub-Populations	Known Trends	Last Year Detected	Reference
Picayune Strand State Forest	Opportunistic surveys/searches	Florida Forest Service	0	Historically 4, currently 0	Decline. Four populations previously observed, no ghost orchids when revisited. Possibly lost to wildfire	Pre 2017	Mike Knight 2024, pers. comm.
Ciénaga de Zapata National Park	Unknown		Unclear	1?	Possibly extirpated but more surveys needed	Exact year unclear	Mújica 2021a, pers. comm.

~870 plants in US and ~230 Cuba. Total global population estimate ~1,100 plants

4.2.1 Population Resiliency

Each population/analysis unit of ghost orchid needs to be able to withstand, or be resilient to, stochastic events or disturbances (e.g., hurricanes, drought, frost, etc.). Therefore, we assessed the resilience of each analysis unit by synthesizing the best available information about demographic and habitat conditions.

Based on ghost orchid needs (Chapter 2) and the factors influencing the viability of the species (Chapter 3), the following set of demographic and habitat condition factors was developed to assess the current overall resilience of each population. Each one is discussed in detail below (Table 2).

(1) Abundance – total number of individuals within each analysis unit.
(2) Seedling Abundance– percent of individuals in the population in the seedling stage
(3) Population Reproduction – rate of successful fruit production
(4) Population status- whether the analysis unit is increasing, decreasing, or stable based on monitoring data and/or periodic surveys
(3) Hydrological Conditions – year-long standing freshwater (high salinity water is inadequate for ghost orchid survival)
(4) Poaching – current and historical documentation or suspicion of orchid poaching from the wild
(5) Forest Conditions– intact forest canopy and subcanopy with presence of host trees

Demographic Factors

The demographic factors considered for ghost orchid were: 1) total population abundance, 2) seedling abundance, 3) reproductive output, and 4) changes in population abundance. Ghost orchid needs a sufficient number of individual plants spread out across the different life history stages in order to reproduce, survive over time, and replace individuals that have died in a population (i.e., avoid a net loss or negative growth rate).

We chose total population abundance because populations with more individuals should provide greater resiliency while small, more isolated populations are less likely to persist in the long-term (Barrett and Kohn 1991, pp. 3–30). This factor also represents the simplest, most available demographic data for all populations, at least as an estimate if not an exact count. Seedling abundance was also chosen as an important factor to consider for resiliency based on recent demographic population monitoring and research that has shown that the number of seedlings in a population contributes greatly to its long-term stability (Mújica et al. 2021, p. 5). Additionally, high seedling numbers and robust recruitment rates have often been found to be very important for population growth/stability of other orchid species (Chung et al. 2011, pp. 2034–2036; Ackerman et al. 2020, pp. 677–682). We also chose to include reproductive output because plants that are able to survive long enough (often 15+ years) to flower and fruit not only contribute to the next generation of plants, but also show that sufficiently suitable conditions exist for persistence of plants. This is especially important considering that typically only a small proportion of a population will reach the size and age necessary to reproduce, and only a proportion of those go on to flower and a smaller proportion still go on to fruit. While presence/abundance of pollinators would ideally be directly considered in an analysis of this species' resiliency (see below for habitat factors), the data for this factor for each of the population sites simply are not complete enough to include. However, presence and abundance of fruit capsules can also serve to act as an indicator of past pollinator presence, as ghost orchids require cross-pollination via moths to complete reproduction. Finally, we chose changes in population abundance because whether the number of plants in a population have been increasing, decreasing, or remaining stable are indicative of overall population health and stability. Additionally, changes in population abundance may capture the effects of other, more difficult to quantify or even unknown factors that are otherwise not included here.

For the **Total Population Abundance** factor, we developed three resiliency condition classes and assigned each a resiliency score:

High resiliency had more than 175 orchids present in the population.

Moderate resiliency had 50 – 175 orchids present in the population.

Low resiliency had fewer than 50 orchids present in the population.

Although there currently is not a definition for the minimum population size for a self-sustaining population of ghost orchid, research into population growth rates for different populations of the species have shown positive growth rates for a population with as few as ~190 plants (Mújica et al. 2021, p.4; Raventos et al. 2015, p. 182). Thus, just slightly lower than this was chosen as the high/moderate cutoff point. Given that fruiting rates in many years and at several populations has been observed to be very low, often in the single-digit percentages, we set the cutoff for moderate resiliency as having at least some realistic probability of having at least more than one plant in the population flower and set fruit. To match the fruiting rates that can be as low as 4–5%, as observed in some populations, we set the cutoff for moderate/low resilience at 50 plants so that even at a low percentage of fruiting, more than 1 plant in the population would be likely to fruit. Anything lower than this abundance of 50 plants was said to have low resiliency for this factor, as the population would be unlikely to consistently have fruiting individuals, which are needed for reproduction and long-term health of the population.

For the **Seedling Abundance** factor, we developed three resiliency condition classes and assigned each a resiliency score:

High resiliency had more than 20% of plants within the population in the seedling life stage

Moderate resiliency had 10–20% of plants within the population in the seedling life stage.

Low resiliency had fewer than 10% of plants within the population in the seedling life stage.

Rather than set a total number of individual seedlings needed to be present within a population, we chose to use percentages at the cutoffs between the condition classes. This is because the demographic structures are very different for a smaller vs larger population with the same number of seedlings. A greater percentage of individuals in the seedling stage class indicates successful recruitment and helps lead to positive population growth rates. Based on previous demographic monitoring for ghost orchid, at least 20–25% of plants should be in the seedling stage class to achieve a positive population growth rate (though note that having a percentage above this level does not at all guarantee population growth) (Mújica et al. 2021, p. 4). Thus, we chose 20% as the cutoff between high and moderate resiliency. Note that concrete seedling abundance data was not available for all populations, but in these cases the category could be inferred based on other data, such as overall abundance and/or reproductive output. Fewer than 10% of plants in the seedling stage was chosen as the low resiliency cutoff because populations with such a low abundance of seedlings have not been shown to have positive population growth rates (Mújica et al. 2021, pp. 4–8).

For the **Reproductive Output** factor, we developed three resiliency condition classes and assigned each a resiliency score:

High resiliency had greater than 10% of plants producing fruit.

Moderate resiliency had 5–10% of plants producing fruit.

Low resiliency had <5% fruit production

While annual capsule production in this species may naturally be low, possibly due to the conditions necessary for successful cross-pollination (presence and visitation by one of a few species of moths), some fruit production is necessary each year to ensure successful seedling creation and recruitment, especially if recent declines in populations are to be reversed (see more below). The thresholds established above are based on realistic reproduction rates observed in natural populations (e.g., extremely infrequently if ever above 20%) combined with species expert opinion on what should be considered as high, moderate, and low conditions. While flowering rates were a possible consideration to include for this reproductive output category, it was ultimately determined that evidence of fruit production was much more important for population stability and growth, as often plants can reach reproductive maturity and produce flowers without fruiting and thus not actually contribute to future generations.

For the **Population Trend** factor, we developed three resiliency condition classes and assigned each a resiliency score:

High resiliency had an increasing population trend.

Moderate resiliency had a possibly fluctuating but overall, approximately stable population trend.

Low resiliency had a decreasing population trend.

For a population to be highly resilient, there should be evidence of consistent population growth. Especially when considered alongside the stochastic events that may in the short-term reduce plants numbers (e.g., hurricanes, flooding, etc.), a positive population growth rate will help the population to bounce back from these events in the following years. A fairly resilient population may show some years of population increase and some years of population decrease, but overall has approximately stable numbers. A population that is decreasing can be said to have poor health and/or stability because it is displaying a lack of ability to withstand the natural range of favorable and unfavorable conditions present in its habitat. We chose to weight the population trends factor twice as much as all other factors because 1) population trends demonstrate the actual, current status of populations and 2) this factor may take into account other factors not included in this current condition analysis for a variety of reasons (lack of data, previously unidentified as important to the life history of the species, etc.). Furthermore, even if all other current condition factors are rated as high for the species, if the population is declining then this should take precedence.

Habitat Factors
The habitat factors we considered for ghost orchid were: 1) hydrological condition, 2) past and present poaching, and 3) forest condition (presence of host trees and intact canopy/subcanopy).

One of the most important ecological conditions necessary for ghost orchid survival is appropriate hydrology, defined as yearlong standing water and adequate supply of freshwater in a condition as close to natural, historical conditions as possible. Not only does the nearly year-long presence of standing or very slow-moving freshwater in its slough and swamp habitats protect against the otherwise occasional frost conditions, but it also seems to provide the necessary conditions for seedling recruitment, likely because moist bark allows for the growth of its mycorrhizal fungal partner and also allows for seed germination (Mújica et al. 2018, p. 583; Mújica et al. 2021, p. 8). The long hydroperiods also protect against intense wildfires from burning into the interior of these swamps and sloughs which could damage or kill host trees. We also chose to include evidence of poaching because of how frequently this has been observed for several populations and the high degree to which it can reduce population numbers and therefore resiliency. Poaching almost invariably involves the taking of reproductively mature plants, thus reducing the reproductive output of populations (see above) and having long-term demographic impacts. Indeed, a harvesting rate of anything over 5% of the reproductive individuals in a large population of another epiphytic orchid species has been shown to elevate extinction risk to 100% within 100 years when otherwise without harvest the risk would be 0% (Mondragon 2009, pp. 35–39). Forest condition, as measured by an intact canopy/subcanopy and presence of host trees, has also been included as a habitat factor for this analysis because of how highly dependent ghost orchids are on their host trees and an intact canopy for survival. Damage to the forest canopy and host trees from several hurricanes over the last few decades has had significant impacts on ghost orchid habitat.

4.3 Current Condition Results

4.3.1 Current Population Resiliency

A summary of the results of our current condition analysis for population resiliency are displayed in Table 3. Considering the demographic factor of total abundance, only four analysis units fit the criteria to be classified as having high resiliency: the Panther NWR, Fakahatchee SPSP, Big Cypress National Preserve, and Guanahacabibes sites, all of which at last count/approximation have over 200 plants. All other sites were classified as having low resiliency for this factor because plants numbered less than 40 at each location. For seedling abundance, only the Panther NWR and Guanahacabibes could be categorized as moderate or moderate-high resiliency based on recent demographic monitoring surveys. The number of seedlings and percent of seedlings in the populations can vary from year to year, thus, in order to capture this variation, we considered recent seedling abundance data collected over a six-year period (2015 to 2020) for Florida Panther NWR. Overall, we categorized the Florida Panther NWR as moderate-high because the first 4 years of monitoring seedling abundance was high (range 24–44%), but the last 2 years of monitoring seedling abundance was moderate (14%) and low (0%) (Mújica et al. 2021, p. 4). Therefore, for this six-year period, capturing interannual variation, we consider overall seedling abundance to be moderate-high for this population.

For the Guanahacabibes population,18.7% of plants were in the seedling stage in 2021, the year data is most recently available (Mújica 2021, pers. comm.) and thus was classified as moderate resiliency for this category.

While an exact percentage is not available, consistent annual observations have led to the conclusion that the Fakahatchee SPSP populations have very low recruitments rates and seedlings numbers, as well as seedling survival rates (Owens 2024, pers. comm.). The other sites of ghost orchid occurrence have such low total abundance that they fit into the low resiliency category for seedling abundance. For the same reason, these very low total abundance sites can also be categorized as having low resiliency for reproductive output. However, a few sites have displayed enough successful fruit production to be classified as having moderate resiliency for this category. At the Guanahacabibes National Park AU, fruiting rates have been extremely variable over the years monitored, spanning the range from zero fruits produced within a year (e.g., 2007–2008) to high fruit production the year directly following (2008–2009) (Raventos et al. 2015, p. 182). Interestingly, this population has displayed the opposite pattern compared to the Fakahatchee SPSP ghost orchids in that fruit production has historically decreased after hurricane activity (instead of increasing for the latter), possibly due to loss of pollinators in the region (Raventós et al. 2015; pp. 182–184; Wiegand et al. 2013, p. 447). Thus, we classified Guanahacabibes as, on average, having moderate resiliency for reproductive output.

At the Panther NWR analysis unit, the average number of flowers per number of plants has ranged from 0.22 to 0.59 between 2015 and 2020 and the percent of mature plants fruiting has ranged from 4% to 17.1% (Mújica et al. 2021, p. 4). The average of these fruiting percentages over this time span is 9.5% and in fact was on the lower end in the two most recent years of data collection with only 5 and 2 fruits produced in 2021 and 2022 respectively (Danaher 2024, pers. comm.). Thus, on average this population fits the criteria for having moderate resiliency for reproductive output in the 5–10% level. Considering Fakahatchee SPSP, in most years the populations here can be said to have low reproductive output as evidenced by the extremely low fruit production rates of 1–2 seed capsules amongst the 45–120 plants annually monitored. It is important to note, however, that after a hurricane, fruiting rates will increase substantially to 6–7 total capsules, likely due to the combined effects of increased flowering rates and increased pollinator activity. Thus, to capture this inter-annual variation in fruit production rates, we categorized Fakahatchee SPSP as having low-moderate reproductive output.

Considering the hydrological condition habitat factor, all sites in Florida have been affected to some degree by hydrological changes, largely due to anthropogenic environmental modifications such as canals, roads, and ditches (see more in Chapter 3). Therefore, none of the Florida sites could be classified as having high resiliency for this factor. However, some sites have been impacted more than others, or are naturally more susceptible to change given their geographic and landscape position. For example, the Coastal Transition Site 1 is the most vulnerable to saltwater intrusion given its proximity to the coast and indeed, surface water salinities have already increased to concerning levels for host tree survival. At the end of the dry season, surface water salinities in the general area of ghost orchid presence at Coastal Transition Site 1 were 1.4-2.0 ppt and canopy/host trees start to die off at the upper end of this salinity range (Florida DEP 2024, pers. comm.). Thus, this site was scored as having poor resiliency for hydrology. The Panther NWR was classified as having moderate resiliency for this category because although hydroperiod has been impacted by surrounding roads and canals, there has been some mitigation of these effects from culverts and bridges. On the other hand, Big Cypress National Preserve received a low resiliency score for this factor because conditions have been observed to be much drier in recent years, to the point of intense wildfires burning in extremely close proximity to ghost orchid populations, areas that given historical hydrological conditions would normally not burn (Angelo 2024 pers. comm.). The population in Cuba was the only site to receive an "NA" resiliency score for this factor because hydrology is not nearly as relevant for plants at this location where there is typically no standing water and also no possibility of frost or fire.

There was great variability in the degree to which sites experienced poaching and thus in the resulting scores. Four sites scored as having high resiliency for this factor due to a lack of history of any poaching activity and/or due to the degree of protection afforded the plants which deters poachers. For example, at the Panther NWR, there has been limited public access for thirty-five years and the access that is available only includes short public hiking trails in one part of the refuge. Additionally high fences on the eastern and southern boundaries and a camera trap grid of over 40 trail cameras helps to protect the ghost orchid populations. As a consequence, there have not been any documented ghost orchid poaching incidents on the Panther NWR (Danaher 2024, pers. comm.). Similarly, the Audubon Corkscrew Swamp Sanctuary site has tightly controlled public access, cameras on site, and as an added obstacle, the ghost orchids are located unusually high on their host trees, making them out of reach without climbing equipment (Clem 2024a, pers. comm.). On the opposite end of the spectrum, Fakahatchee SPSP is infamous both for having ghost orchids and for being a place where people have poached ghost orchids, as is highlighted in popular media such as the book *The Orchid Thief* and the movie *Adaptation*. Public access is not very restricted at this location and given the size of the park and the number of park staff, it would be impossible to provide constant surveillance. Unfortunately, at least 8% of ghost orchids from Fakahatchee SPSP have been poached in the last twenty years. Thus, it received a rating of low resilience for this category. In between these two extremes of resiliency scores for poaching, we felt that both the Collier-Seminole population and the Cuba population should receive a moderate rating for this category. In the case of the former, poaching has been suspected but not definitively documented and in the case of the latter, other orchid species have been poached from the park, but there has not been evidence of poaching specifically of ghost orchids, though they would be highly desirable by these same collectors.

Table 2. Current condition categories and criteria for each. The demographic variables are highlighted in a light blue and the habitat variables are highlighted in a light green.

Condition Category	**Total Abundance**	**Seedling Abundance**	**Reproductive Output**	**Known Trends**	**Hydrological Condition**	**Habitat Threat: Poaching**	**Forest Conditions**
High	>175 orchids	>20% seedlings	>10% fruiting	Population stable to increasing	Yearlong standing freshwater; freshwater hydrological conditions same as historical	No evidence or history of poaching	Intact canopy/subcanopy; host trees present
Moderate	50–175 orchids	10–20% seedlings	5–10% fruiting	Population fluctuating but overall stable	Some evidence of hydroperiod shortening and/slightly inadequate freshwater conditions	Poaching has been documented but threat has been reduced and/or is minimal	Some open canopy; some host trees present
Low	<50 orchids	<10% seedlings	<5% fruiting	Population decreasing	Obvious hydroperiod shortening and/or inadequate freshwater condition	Poaching has been documented and is ongoing	Open canopy; host tree availability minimal

The last habitat factor for population resiliency, forest condition, considers the condition of host trees and surrounding canopy/subcanopy. The forest condition, as defined by the presence of host trees and an intact canopy/subcanopy, has been reduced in most sites due to the high frequency of severe hurricanes in the Southwest Florida region coupled with the very limited range extent of ghost orchids, resulting in most sites receiving a low or moderate rating in this category. Most impactful in recent history was Hurricane Irma in 2017 which made landfall in southwestern Florida as a major, Category 3 hurricane. Big Cypress National Preserve, Fakahatchee SPSP, and the Panther NWR all suffered extensive damage, instant reduction of canopy cover, and felling of many host trees and thus these were all rated as having low resiliency for this factor. At the Audubon Corkscrew Swamp Sanctuary, one of the three ghost orchids was lost due to the host tree falling from the strong winds. The Coastal Transition Site 1 analysis unit was difficult to assess for this category because the one remaining extant population was only discovered after these recent major hurricanes took place. Additionally, an area where ghost orchids previously occurred at Coastal Transition Site 1 was affected by both Hurricane Irma and Hurricane Ian (2022), but it’s possible that ghost orchids were extirpated from this area previously and not because of the hurricanes. Thus, we scored the habitat condition for this site as moderate to high to encompass this uncertainty, while recognizing that impacts to host trees do not seem to be as severe as other locations. Going back a little further in time, Hurricane Ivan was a devastating Category 5 hurricane that hit western Cuba in September 2004. The extremely strong winds from the storm damaged nearly 60% of ghost orchid host trees in Guanahacabibes

National Park and 59% of ghost orchids were negatively affected. Even six years post-storm, the population had not recovered (Wiegand et al. 2013, pp. 444–447). Additionally, a population viability analysis and hurricane simulation analysis conducted for this population concluded that it would almost certainly become extirpated within just a twenty-five-year time frame if annual probability of hurricanes exceeded 14% and extirpation probability would only remain under 50% if hurricane annual probability remained at 2% or lower (Raventós, et al. 2015, pp. 182–86). However, it must be noted that this simulation assumes similar impacts to the ghost orchid population as that observed with Hurricane Ivan, which given the unusual strength of the storm would not be the case with every hurricane to hit the area. Still, with the damage already observed to both phorophytes and the ghost orchids themselves from Hurricane Ivan and the danger future intense hurricanes bring to the population, we rated the Guanahacabibes National Park as having low resiliency for forest condition due to the impacts to ghost orchids and their habitat.

Table 2. Summary of Current Conditions using the resiliency categories from Table 2

Analysis Area	**Total Abundance**	**Seedling Abundance**	**Reproductive Output**	**Known Trends**	**Hydrologic al Conditions**	**Habitat Threat: Poaching**	**Forest Conditions**
Florida Panther NWR	High	Moderate-High	Moderate	Low	Moderate	High	Low
Fakahatchee Strand Preserve SP	High	Low	Low-Moderate	Low	Moderate	Low	Low
Big Cypress NP	High	Low	Low	Low	Low	Low	Low
Audubon's Corkscrew Swamp Sanctuary	Low	Low	Low	Low	Low-Moderate	High	Low-Moderate
Coastal Transition Site 1	Low	Low	Moderate	Low	Low	Moderate	Moderate
Collier-Seminole SP	Low	Low	Low	Low	Moderate	Moderate	Low-Moderate
Hendry County	Low	Low	Low	Unkno wn	Moderate	High	Unknown
Naples Urban site	Low	Low	Low-moderate	Low	Moderate	Moderate	Unknown
Guanahacabibes National Park	High	Moderate	Moderate	Low	NA	Moderate	Low
Six Mile Slough	Low	Low	Low	Low	Low	Extirpated	Low
Picayune State Forest	Low	Low	Low	Low	Low	Likely Extirpated	Low
Ciénaga de Zapata National Park	Low	Low	Low	Low	NA	Likely Extirpated	NA

The numerical resiliency scores (high = 3, moderate = 2, low= 1) for each population and each factor can be seen in Table 5. The average resiliency score for the population is shown in the last column, with known changes in abundance weighted twice the amount of the other factors. How these overall numerical scores can be translated to overall resiliency categories is shown in Table 4.

Table 3. Overall weighted resiliency score categories.

Low	Low-Moderate	Moderate	Moderate-High	High
1–1.49	1.5–1.74	1.75–2.24	2.25–2.50	2.51–3.0

Table 4. Numerical resiliency scores for each factor by analysis unit. Average composite score is shown in the last column, with known trends being weighted twice as heavily as all other factors. *Extirpated/possibly extirpated populations are shown at the bottom of the table and scores filled in where possible and relevant but receive "NA" for current condition.

Analysis Area	Total Abundance	Seedling Abundance	Reproductive Output	Known Trends	Hydrological Conditions	Habitat Threat: Poaching	Forest Conditions	Composite Condition Score	Overall Resiliency
Florida Panther NWR	3	2.5	2	1	2	3	1	1.94	Moderate
Fakahatchee Strand Swamp SP	3	1	1.5	1	2	1	1	1.44	Low
Big Cypress NP	3	1	1	1	1	1	1	1.38	Low
Audubon's Corkscrew Swamp Sanctuary	1	1	1	1	1.5	3	1.5	1.38	Low
Coastal Transition Site 1	1	1	2	1	1	2	2.5	1.44	Low
Collier-Seminole SP	1	1	1	1	2	2	1.5	1.31	Low
Hendry County	1	1	1	Unclear	2	3	3	Range between 1.6—1.9 depending on trends)	Low-Moderate
Naples Urban Site	1	1	1.5	1	2	2	Unknown	1.42	Low
Guanahacabibes National Park	3	2	3	1	NA	2	1	1.93	Moderate
Six Mile Slough*	1	1	1	1				Extirpated	
Picayune Strand SF*	1	1	1	1				Presumed Extirpated	
Ciénaga de Zapata National Park	1	1	1	1				Presumed Extirpated	

Based on this analysis, no extant populations of ghost orchid can currently be considered to have high resiliency. This is largely due to the fact that all have experienced declines in abundance in recent years and all are in low condition for at least one if not multiple habitat factors. Ranked the highest for overall resiliency is the Florida Panther NWR which still only scored high enough to be considered moderately resilient. The total population size here is on the larger end and seedling abundance and fruit production are okay in most years with little to no threat of poaching, but recent trends have still shown a decline and habitat condition has been reduced. Additionally, hydrological conditions have been reduced due to the widespread alteration of natural water flow from surrounding roads and canals. On the higher end of overall resiliency is the Guanahacabibes National Park population in Cuba, which can also be categorized as having overall moderate resiliency. The population receives high scores for its population size, demographic structure, and hydrological condition due to the different type of habitat utilized by the species in Cuba; however, like the Panther NWR, there has been a significant decline in habitat condition documented this century, largely caused by hurricane impacts (Wiegand et al. 2013, entire). Additionally, at least one large ghost orchid has been poached from this population in the last decade (Zettler 2024, pers. comm.) and other orchid species from the National Park have also been poached. These factors preclude it from being scored as high for population resiliency. Although the Fakahatchee SPSP population is one of the larger populations, it's low seedling abundance, seedling survival rates, and in most years low reproductive output decreases its overall resiliency. This paired with steep declines over the last 30 years of approximately 60–77% and the perennial problem of poaching at this site gives it a low population resiliency. Similarly, the Big Cypress National Preserve population, although larger in size, does not have much seedling abundance or fruit production and suffered large losses after Hurricane Irma in 2017. Additionally, plants here face the threat of poaching and several have in fact been poached in recent years. The habitat has also been much drier recently and an intense 2020 wildfire reached dangerously close to ghost orchid occupied areas. These factors taken together indicate an overall low resiliency for Big Cypress National Preserve.

The Hendry County site proved to be difficult to score for some factors, as the presence of this population is known from only one survey in 2023. We know the population is low in abundance (<50 plants, but likely between 10 and 20 plants (Owen 2024, pers. comm.)) and poaching does not seem to be an issue at this location (no evidence of poaching to date), but other data is lacking. Still, the abundance data alone suggests a low to moderate resiliency given how few plants remain. Coastal Transition Site 1 consists of just one small population with little seedling abundance/survival and has significantly decreased in size. Two other populations were recently extirpated from this analysis unit: one population was likely extirpated due to substantial canopy loss after Hurricane Irma as well as impacts from Hurricane Ivan (in 2004) that resulted in storm surges, and the other population was likely lost due to poaching, but frost events in 2010 could have also resulted in extirpation (Florida DEP 2024, pers. comm). Additionally, this population is extremely susceptible to saltwater intrusion and resulting host tree/canopy die-off affecting its hydrological and habitat condition; already, measured surface water salinities have reached concerning levels close to the remaining ghost orchid occupied areas. Thus, this population is considered to have low resiliency.

While one of the most well-known populations for its high flowering rates (plants flower regularly with many flowers on each plant), unusually high height in its host trees and easy accessibility, the Audubon Corkscrew Swamp Sanctuary population is very small with only two individuals and has suffered both from drier hydrologic conditions and impaired habitat condition due to recent hurricane damage, giving it an overall low resiliency. The Collier-Seminole State Park analysis unit scored low for every demographic factor, as the population consists of only about five plants and is thought to be on the decline (Patel 2024a, pers. comm.). This combined with the reduced hydrologic and habitat conditions it results in low overall resiliency. Lastly, the Naples urban site scored low for total abundance because it consists of only 31 plants, though many reproductively mature. It has experienced a decline recently (approximately 25% from 2001 to 2017), though more recent information is lacking since it has not been visited in the last seven years and only infrequently visited before then, thus making hurricane damage difficult to assess. However, with the information known/assumed for this population, it can be said to have low-moderate resiliency.

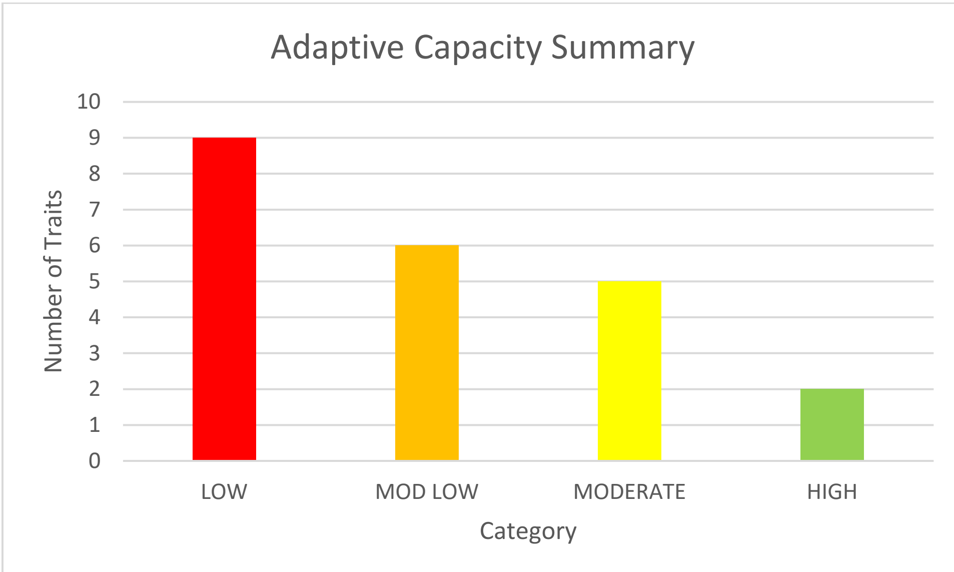
4.3.2 Current Species Representation

Representation reflects a species' adaptive capacity to respond to changing near-term and long-term environmental conditions and can be characterized by the breadth of genetic and ecological diversity within and among populations. A species' adaptive capacity is essential for viability, as species need to adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269).

For ghost orchid, we do not have information on the genetic diversity within or among the populations across the species' range, though the need for such studies has been highlighted (Danaher et al. 2019, p. 682; Houlihan et al. 2019, p. 7) and some genetic work has begun but is not yet available (Danaher 2024, pers. comm.; Herdman 2024a, pers. comm.). Therefore, for the purposes of this analysis, we evaluated whether there are other types of diversity that could potentially indicate some ability to adapt to change, such as morphological or phenological differences, or different habitat types within the species' range. The greatest difference in these adaptive components comes from examining the two geographic regions where ghost orchids are found, in Florida and in Cuba. For example, one of the biggest distinctions between Florida and Cuba populations is the type of habitat occupied in these two locations. While all current ghost orchids in Florida occur in long hydroperiod subtropical dome swamps, strand swamps, and cypress sloughs, plants in the extant population in Cuba occur in a tropical semi-deciduous forest with soils characterized as fractured reef limestone, with little or no standing water present (Raventos et al. 2015 p. 180; Mújica et al. 2018, p. 573). It is possible that at least some of this difference in occupied habitat may be attributable to the difference in climate between the two regions, with subtropical southwest Florida occasionally experiencing frost conditions while tropical western Cuba never experiences frost. The southwest Florida populations may require long hydroperiod environments to protect the ghost orchids from these frost events, while the Cuba population does not have such a requirement due to the lack of any frost. Another critical difference comes in the form of host tree occupation, with a majority of Florida ghost orchids principally found growing on just two species of trees (Florida water ash and pond apple) while a similar proportion of Cuban ghost orchids can be found growing on five species of host trees, though 18 in total have been recorded (Mújica et al. 2018, p. 577). There is no overlap in host tree species between the two regions, as nearly all the trees that ghost orchids grows on in western Cuba do not occur in Florida and the host trees of Florida are much less common in Cuba. Moreover, there is a difference in the phenology of ghost orchids in Florida compared to Cuba. While flowering typically occurs during the summer from May to August in Florida populations, flowering in Cuba occurs later in the year, typically from October to December (Mújica et al. 2018, p. 575). Consequently, there is also a distinct difference in fruiting times, with Florida populations typically fruiting in January to April and Cuba plants fruiting from May to June (Mújica et al. 2018, p. 575). Interestingly, ghost orchids within the Coastal Transition Site 1 population appear to flower slightly later than at most other locations in Florida, with the peak occurring in August to September. The reason for this phenological distinction is unclear but could be due to microclimate and/or genetic differences (Florida DEP 2024, pers. comm.).

One morphological difference between ghost orchids in these two regions is nectar spur length, which on average appears to be several centimeters longer in the Cuba population compared to orchids in Florida, which could mean there is a genetic component causing this distinction (Zettler 2024, pers. comm.). Along with these regional differences in ghost orchid habitat, morphology, and phenology, it is also important to recognize the ways in which the species life history and ecological associations remain more constant across its range. For example, in both Florida and Cuba plants appear to prefer growing on trees with corrugated or semi-corrugated bark on average about 3–6 ft (0.9–1.8 m) above the ground, though Florida plants may grow slightly higher, probably to accommodate the higher water levels (Mújica et al. 2018, p. 581). Additionally, flowers in both regions are pollinated primarily by species of hawk moths (family *Sphingidae).* While the presence/absence of frost distinguishes the two regions, other climatic conditions such as average total annual rainfall and average annual temperature are quite similar between the two (Mújica et al. 2018, p. 575). Taken altogether, it seems likely that there is some representative diversity present between the two main regions of occurrence (Florida and Cuba), but little if any representative diversity within these two regions.

We can also utilize the attributes of adaptive capacity developed by Thurman et al. (2020, entire) to assess the ability of ghost orchid to cope with or adjust to possible environmental changes. These researchers organized adaptive capacity into 7 ecological complexes further subdivided into 36 individual attributes, though not all apply to sessile organisms and non-animals organisms such as plants. For each attribute, species can be evaluated on a scale of low, moderate, or high, with low indicating less adaptive capacity and high indicating greater adaptive capacity. Of those attributes that did apply to ghost orchid, nine were found to be of low adaptive capacity for the species, six were moderately low, five were moderate and only two were categorized as high. See Appendix A for further explanation of traits and how they were scored for ghost orchid. This summary of ghost orchid's innate adaptive capacity provides additional support to the idea that its representation may be limited. In the future, research into the in vitro germination of ghost orchid seeds could reveal information about the species' adaptive capacity to environmental change, as has been completed for another species of native Florida orchid, *Calopogon tuberosus* var.*tuberosus* (Kauth et al. 2011 pp. 151–154 ; Kauth and Kane 2009 pp. 336–442).



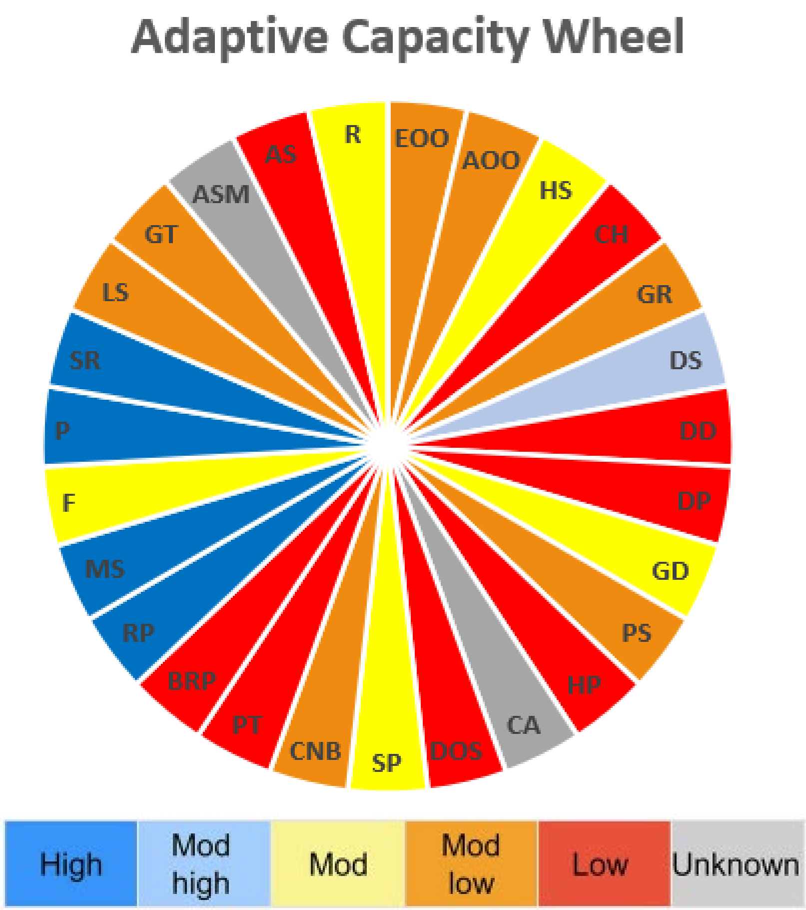


Figure 6. Adaptive capacity wheel results for traits relevant ghost orchid life history.

4.3.3 Current Species Redundancy

Redundancy is defined by the number of populations, their resiliency, and their geographic distribution and connectivity for the species. Because ghost orchid has a low number of populations most of which have low or low-moderate resiliency, distributed in a narrow geographic area, redundancy for this species is inherently limited. A single catastrophic event, such as a Category 3–5 hurricane, could very plausibly impact a large percentage of the species range at one time and cause significant declines at multiple sites simultaneously. In fact, this has already been observed with the occurrence of Hurricane Irma in 2017 in which several populations (Big Cypress National Preserve, Fakahatchee SPSP, Audubon Corkscrew Swamp Sanctuary, Coastal Transition Site 1, and Florida Panther NWR) and the Guanahacabibes National Park population in Cuba were negatively affected at the same time. With hurricane frequency and intensity projected to increase in the near future, this could easily happen again.

Uncertainties relating to current condition

While we have worked to gather as much relevant information for each of the ghost orchid populations as possible, certain uncertainties related to current condition remain. Firstly, only some populations have had detailed, demographic monitoring conducted in recent years so some of this critical information is lacking. Additionally, it is not clear if there are any extant populations in Cuba aside from the Guanahacabibes National Park population, for example at Zapata Swamp from which there have been reports of ghost orchid. Additionally, it is possible that unsurveyed locations with suitable habitat in Florida harbor undocumented ghost orchid populations, especially on private properties where many fewer rare plant surveys are conducted. Similarly, we lack updated survey data for numerous populations that could have been impacted from recent hurricanes. We are also lacking information on the genetic diversity within the species to inform our assessment of representation. Furthermore, while presence of hawk moth pollinators is known to be extremely important to the pollination ecology and reproduction of the species, detailed insect surveys and data on their presence and abundance do not exist for most ghost orchid sites.

4.4 Current species viability

Ghost orchid occurs in 12 analysis units, 10 of these are in Florida and 2 are in Cuba. In Florida, two analysis units are considered to be recently extirpated, six analysis units are considered to have low resiliency, one analysis unit is considered to have low to moderate resiliency, and one analysis unit is considered to have moderate resiliency. In Cuba, only one analysis unit has an extant ghost orchid population and is considered to have moderate resiliency, while other historical populations are considered to be extirpated. All analysis units have declining populations. Overall, the species has low abundance within each analysis unit with no more than approximately 300 individuals within an analysis unit, though most have less than 40 plants.

With declining population health (overall low resiliency due to low abundances and declining habitat conditions) coupled with relatively small geographic extent (low redundancy) and relatively low adaptive capacity, the species now possesses limited ability to withstand inherent stochasticity (environmental, demographic, and genetic), catastrophic events (hurricanes, wildfire, frost), and other changing environmental conditions (sea level rise and saltwater intrusion).

CHAPTER 5 – FUTURE VIABILITY CONSIDERATIONS

5.1 Introduction

We have determined that the current condition of the ghost orchid is characterized by low resiliency, representation, and redundancy. Thus, we did not fully evaluate the future condition, including scenario planning for this species. If the ghost orchid warrants listing under the Act, future scenario planning should be included in recovery planning efforts.

Here, we provide a summary of the primary threats to the species and how these threats may evolve and continue to impact the species in the future. We expect poaching, hydrological changes, and climate change to continue to reduce the species overall viability in the future. We provide a summary of each threat below and the projected continued impact of these threats to ghost orchid viability.

Poaching

We expect illegal collection of ghost orchids to continue in the future. Poaching has been documented or suspected at over half of the analysis areas where ghost orchids occur. While all poaching events affect the ghost orchid at an individual level, these past poaching events have had negative effects at the population and species level. Because the species is long-lived and exhibits life-history traits characterized by slow growth rates, limited reproductive capacity, and slow development to reproductive maturity, these poaching events are more likely to have a negative impact on the population compared to plant species that flower and fruit abundantly and are able to do so early on in their life cycles. The length of time needed to replace lost, mature individuals is likely measured in the tens of years and thus the demographic harm done to a population is likely felt for several years after the original poaching incident. Thus, the full effects of poaching events that have taken place within just the last few years may still not be realized. Indeed, demographic analyses of other orchid species has shown that even low levels of adult whole plant collection (as opposed to just pseudobulb collection) can have large negative demographic effects and not be viable for orchid populations (Ticktin et al. 2020, p. 7). A recent review of wild orchid harvesting and what life history characteristics may lend the species to sustainable collection practices reveals that ghost orchid fits almost none of the criteria for possible sustainable harvest and working through the provided decision tree leads to a conclusion of "Do not harvest; enforce conservation" (Ticktin et al. 2023, pp. 4–7). Thus, any future scenario where illegal ghost orchid harvesting continues will negatively impact the species. In fact, if populations continue to decline as they have been (see previous chapter), the negative effects of any level of poaching will only become more impactful. Furthermore, despite some concerted efforts to curb poaching through restricting access to areas where ghost orchid occurs and despite at least some availability of plants in the commercial horticultural trade, poaching continues. More recently, an efficient in vitro clonal propagation protocol for ghost orchid via protocorm like body formation (PLB) has been developed which could help to increase commercial availability and possibly reduce poaching events from the wild (Hoang 2016, pp. 184–189). However, it is unlikely that this will completely mitigate the risk of poaching in the near-term and we still see this continuing to act as a major threat.

Hydrological changes

As a part of the Comprehensive Everglades Restoration Program (CERP), a number of water restoration projects are either underway or planned for southern Florida, with the common goals of returning pre-drainage watershed flow patterns, improving wetland habitat conditions, and increasing groundwater levels. One project that could have a positive future impact within the historical range of ghost orchid is the Picayune Strand Restoration Project (PSRP). In an effort to restore over 55,000 acres (22,258 hectares) of natural areas in Collier County, this project is conducted as a partnership between the South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers. It has thus far involved the removal of roads and logging trams and the plugging of several canals, with further road and canal work planned over the next two years (SFWMD 2024, entire). These efforts should improve water flow in Picayune Strand State Forest, Collier-Seminole State Park, and Coastal Transition Site 1 (US Army Corps of Engineers 2024, entire). However, it must be noted the ghost orchid population at Picayune Strand State Forest is possibly extirpated, likely due to a fire in 2018 (Knight 2024 pers. comm.; Sowell 2024 pers. Comm). Therefore, improved habitat conditions at this location would only benefit ghost orchid if concerted, species-specific conservation efforts were made to return ghost orchid plants to this site as a reintroduction. It is significant that attempts at improving the hydrology of this location are being made, as the prior ghost orchid population was likely extirpated as a result of wildfires that were able to burn due to drier conditions. Another project planned as a part of CERP is the Western Everglades Restoration Project (WERP), which aims "to improve the quantity, quality, timing and distribution of water in the Western Everglades in the effort to re-establish ecological connectivity, reduce the severity and frequency of wildfires, and restore low nutrient conditions" (US Army Corps of Engineers 2024, p. 1). This project would have the largest impact on Big Cypress National Preserve, with project models showing an increase in hydroperiod for the area with the largest ghost orchid population increasing from 180 days to 365 days (Angelo 2024, pers. comm.). The first phase of this project, the installation of the L-28 culverts, was only very recently initiated in July 2024. Thus, the effects on ghost orchid populations in Big Cypress National Preserve from this project have yet to be seen.

Concentrated on southwest Florida and the Big Cypress Basin watershed, the Southwest Florida Comprehensive Watershed Plan (SFCWP) seeks to accomplish much the same goals as CERP for watershed management. As a part of this Plan, one of the projects that may have the most impact on restoring hydrological regimes in areas with current ghost orchid populations is the SR 29 Barron River Flow-way Restoration project. Through the use of canal plugs and weirs, goals of this restoration include improved sheet-flow and groundwater levels within Big Cypress National Preserve, Fakahatchee Strand, and the Florida Panther NWR conservation sites, all home to extant ghost orchid populations (Southwest Florida Comprehensive Watershed Plan 2015, pp. 94–95). Other functional group projects identified in the SFCWP that are likely to benefit ghost orchid habitat within its range include the Camp Keais Strand, Coastal Fakahatchee, and Belle Meade Flow-way Restoration projects. Concentrated on the Corkscrew Watershed in northern Collier and southern Lee counties, the Corkscrew Watershed Initiative Public Planning Project began in 2024 and seeks to develop a comprehensive strategy to achieve ecological restoration of the Corkscrew system by improving wetland hydroperiods and natural flows (SFWMD 2024, p.1). Positive effects on the hydroperiod at the conservation sites within the scope of these projects should benefit ghost orchid habitat, though by exactly how much and whether this will be enough to help already declining ghost orchid populations is difficult to say. As for Collier-Seminole, improved hydrology within the park could benefit the ghost orchid population, however it is already so small in size that even restored hydrological conditions may not be sufficient alone to allow for a viable population. Additionally, this population and the Coastal Transition Site 1 population are low-lying enough that improved water flow will likely be superseded by pending sea level rise which threatens to raise surface water salinities and inundate ghost orchid habitat at both of these locations before the end of the century.

The potential improvements from these hydrological restoration projects may be somewhat mitigated from possible future increases in groundwater extraction that would be expected with the region's projected population growth. In Collier County alone, the population is projected to increase by as much as 59% from 2023 to 2050 (Rayer 2023, p. 4). Another aspect that may dampen the positive effects of these projects is the issue of the quality of additional water entering these natural areas. Water within the sloughs and swamps of ghost orchid habitat was historically oligotrophic (low-nutrient), but phosphorus levels in the Everglades have increased almost twenty-fold from precolonial times (Zacharias and David Kaplan 2022, pp. 3–4; McCormick et al. 2000, entire). In order to achieve the desired reduction in total phosphorus levels, more aggressive Best Management Practices (BMP) and larger stormwater treatment areas may need to be implemented than currently specified in the WERP plan (Khare et al. 2020, entire; Julian & Davis 2024, pp. 80–82). Aside from phosphorus, pesticide contamination from agricultural and landscaping runoff is another water quality issue for Everglades restoration (Perry 2008, pp. 571–574).

Another factor that may lessen the potential positive effects of hydrological restoration is the increased levels of evapotranspiration that are expected from climate change. Higher air temperatures with little to no increases in rainfall are projected to increase evapotranspiration rates and reduce wetland hydroperiods and wetland water depths by 2050 in southwest Florida (South Lee County Watershed Initiative Hydrological Modeling Project Final Report 2021, pp. 27–28). Thus, negative effects of hydrological change associated with climate change must also be considered for future ghost orchid viability and future habitat suitability.

Hurricanes

The frequency and intensity of major hurricane and tropical storm activity has already increased during this century compared to historical levels within the range of ghost orchid occupancy (Kossin et al. 2020, entire; Gilliam 2021, entire). In fact, while the probability that a cyclone becomes a major storm (Category 3 or higher) has globally increased by about 8% per decade, the North Atlantic has experienced the greatest changes with a 49% increased probability per decade (Kossin et al. 2020, p. 11977). As discussed in the previous chapters, the effects from these storms can cause both immediate and gradual declines in ghost orchid populations due to host tree mortality/damage, canopy loss, and storm surge. Therefore, it is necessary to consider how the damaging effects from hurricanes and storms may change and in fact worsen in the future and how this may impact ghost orchid viability.

A National Oceanic and Atmospheric Administration (NOAA) review of scientific literature examining tropical storm projections in light of expected climate change concluded that the proportion of intense tropical cyclones (i.e. the overarching category for both tropical storms and hurricanes) is projected to increase even further in the coming decades, leading to more damaging wind speeds, higher storm surges, and more extreme rainfall rates (Knutson et al., pp. 310–312). Specifically, increased sea surface temperature will cause more intense hurricanes with increased wind speeds (Balaguru et al. 2016, p. 106). Of all studied locations in the eastern U.S., one investigation found that the Gulf Coast will see the greatest increases in storm surge heights (Salarieh et al. 2023, pp. 9–15). Additionally, the most intense storms are also the ones projected to move at 20–30% slower translation speeds compared to historical speeds, causing higher rainfalls and worsening surges (Hall and Kossin 2019, entire; Gori et al. 2022, p. 175). Over the rest of this century, Florida is among the locations at the greatest risk for increased tropical cyclone sequential landfall, meaning multiple major storms making landfall at a particular location within a short time period (Xi and Lin 2021, pp. 4–5). Thus, there is an increased risk for areas to be struck by a storm before recovering from the last one. Even only projecting into the very near future (2030's), Florida's Gulf coast is predicted to see increased tropical cyclone activity, with the greatest increases of the highest intensity storms (Hall et al. 2021, pp. 1327–1328).

All of the above highlights the extreme and unique vulnerability of the ghost orchid geographic distribution, being nested within one of the highest risk locations for future storm activity and impacts. In simulations of hurricane effects specifically pertaining to the Cuban ghost orchid population, one of the larger ones still in existence, even just a moderate increase in annual hurricane probability compared to the present level would lead to high likelihood of population extirpation (Raventos et al. 2015, pp. 182–184). Increases in storm surge inundation will almost certainly increase the frequency with which ghost orchids become submerged under water for prolonged periods of time during and after storms, as ghost orchids most often grow only a few feet above the ground. Increases in wind speed will most likely lead to increases in the damage and mortality of host trees, upon which ghost orchids rely for survival. These winds can be expected to cause increased canopy damage as well, decreasing the naturally shady conditions ghost orchids prefer and subjecting them to desiccation from increased sun exposure. In summary, the future conditions created by increased tropical storm and hurricane intensities over the remainder of this century can be expected to have even greater detrimental effects to ghost orchid populations than that already documented.

Frost

The infrequent frost events that occur during the winter in Southwest Florida can directly kill ghost orchids and is thought to be the cause of extirpation of a population in Lee County. With climate change and generally warmer temperatures projected for the future, these frost events would be expected to become less likely which could benefit ghost orchid plants. One study examined the potential future frequency of "chilling events", which are not exactly equivalent but are similar to frost conditions, in southeast Florida, only about 30 miles further south than the center of ghost orchid occupancy in southwest Florida. On the low end of climate emissions scenarios, chilling events would be predicted to occur in this region once every 3.4 years, a decrease in frequency from the current 1.9-year average, while on the high end of emissions scenarios, chilling may be expected to occur only once every 32.5 years (Ross et al. 2009, pp. 1821–1825). Thus, chilling and frost, while certainly will be less common, should still be expected to occur in the future. Additionally, southern Florida is expected to experience the least amount of change in frost conditions compared to the rest of the Unites States (Zhong et al. 2017, p. 55). Future wintertime relative humidity is projected to decrease everywhere in the United States, which could help to make frost events more likely or cause more damage to ghost orchid plants when the frosts to occur, since high humidity levels are thought to protect ghost orchids against the effects of frost (Liu et al. 2012, pp. 123–124).

Sea level rise and saltwater intrusion

Across the state of Florida, sea levels are already as much as 8 inches (20.3 cm) higher than the levels measured in the 1950s (Florida Climate Center 2024, p. 2), with shifts in vegetative structure and composition of coastal habitats already evident (Williams et al. 1999, pp. 2050–2059). Looking to the future, sea level rise is expected to not only continue but accelerate in pace. The predicted amount of future sea level rise along Florida's coastlines depends on different greenhouse gas emission scenarios, but even just a low-intermediate sea level rise scenario shows a 1.64 ft (0.3 m) further increase in the sea level around the Naples area by 2080, but under an intermediate-high sea level rise scenario there is a 3.38 ft (0.91 m) predicted further increase (The Florida Climate Center 2024, p. 7). The current elevation of extant ghost orchid populations ranges approximately from 2.1 ft (0.64 m) to 20.2 ft (6.17 m) (USGS National Map Viewer 2024, entire). Thus, some populations are nearly certain to become inundated with saltwater during this century. In fact, the Coastal Transition Site 1 ghost orchid population is already experiencing higher surface water salinity levels. In the case of this location, it is a question of when and not if the canopy and ghost orchid host trees begin to die off from these salinity levels (Florida DEP 2024, pers. comm). While other, higher elevation populations may not experience permanent inundation from the sea level rise by itself, sea level rise paired with the already elevated storm surge levels to be expected from higher hurricane intensities will worsen storm surge in the future; this could impact all ghost orchid populations.

Sea level rise is projected to continue to impact ghost orchid habitat becoming unsuitable due to the intrusion of saltwater in normally freshwater habitats

Pest Control

As discussed in Chapter 4, mosquito control may be a threat to the moth pollinators of ghost orchid flowers, and thus to the reproductive viability of ghost orchids themselves. This may become an even larger threat in the future with a recently planned expansion of the Collier Mosquito Control District (District). Beginning in October 2024, the District will greatly expand in size from 401 square miles (1039 square kilometers) to 730 square miles (1891 square kilometers) (Fox 4 Southwest Florida 2024, p. 1) and will include parts of Picayune Strand State Forest (location of possibly extirpated ghost orchid population) and Coastal Transition Site 1 (location of an extant ghost orchid population) (Collier Mosquito Control District 2024, pp. 1–3). Not only will the overall area increase and begin to include managed lands with ghost orchids, but the perimeter length of the District boundaries bordering protected lands with ghost orchid populations will greatly increase. Previously, none of the Florida Panther NWR boundary occurred along the District boundary. With this expansion, all Florida Panther NWR northern and western boundaries will occur along the new Mosquito Control District boundaries, making unintended pesticide application effects within the Florida Panther NWR much more likely. Similarly, the Audubon Corkscrew Swamp Sanctuary will see a much greater percentage of its perimeter bordered by the District boundary. While only it's southern boundary was bordered before, now the entire eastern side will be bounded by the District as well. Just as the District has stated "mosquitoes do not respect human-made boundaries", moths do not follow anthropogenic lines either. Thus, individuals of these night-time flying pollinators that travel between the District and protected lands may be harmed.

5.2 Future condition viability summary

Nearly all the negative factors currently affecting viability of ghost orchid populations will continue to affect the species in the future. In the case of some factors such as poaching, this may be at a similar level to the present, while for other factors like climate change associated sea level rise and hurricane impacts, these are expected to worsen. Hydrological conditions within the species' natural habitats may improve as a result of regional large-scale restoration projects, but these may not be sufficient to bolster ghost orchid populations, especially the smallest and least reproductively successful populations.

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Appendix A.

Description of Adaptive Capacity traits as defined by Thurman et al. (2020) and edited for brevity, ranking or each trait for ghost orchid, and justification on ranking based on current knowledge of the species' life history traits.

Abbreviation	**Trait Name**	**Trait Description**	**Ghost Orchid Ranking**	**Justification**
EOO	Extent of Occurrence	Area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence	MODERATELY LOW	Natureserve 2021 estimate of 3,757 sq. km
AOO	Area of Occupancy	A scaled metric that represents the area of suitable habitat currently occupied	MODERATELY LOW	Natureserve 2021 approximately 190 sq km
HS	Habitat Specialization	The use of a relatively restricted subset of habitats, with narrow or well-defined physical or biotic characteristics, for important life-cycle processes	MODERATE	In Florida restricted to three main habitat types which range from G2 to G4 in commonness. Different habitat type in Cuba
CH	Commensalism with Humans	Degree of tolerance of human interactions and infrastructure	LOW	All the areas where ghost orchid is persisting have low amounts of anthropogenic infrastructure present
GR	Geographic Rarity	Takes into consideration that some species may be broadly distributed in their spatial extent but simultaneously exhibit patchiness in their occurrence, or low local abundance	LOW	Ghost orchid is endemic to Southwest Florida and Cuba and populations are mostly isolated from one another

Abbreviation	Trait Name	Trait Description	Ghost Orchid Ranking	Justification
DS	Dispersal Syndrome	The degree of flexibility in either the timing or mechanism of dispersal; for sessile organisms, dispersal syndrome refers to the morphological characteristics of seeds that are correlated with particular seed dispersal agents	MODERATELY HIGH	Not dependent on animal vectors, but mostly reliant on gravity and dispersal tends to be localized.
DD	Dispersal Distance	The distance an individual or propagule can move from an existing population	LOW	Severely restricted dispersal or movement capability (< 10 m per dispersal event). Even sparse forests have restricted seed shadows and dense forests have very restricted seed shadows.
DP	Dispersal Phase	The phase or life-stage in which individuals or propagules disperse	LOW	Short period or discrete phase because fruiting is infrequent.
GD	Genetic Diversity	The diversity of genotypes (or genetic variability) within a species.	MODERATE	No direct measure but small number of mature individuals and occurrences. Total occupied area has been greatly reduced in the last 500 years
PS	Population Size	The number of individuals in a population, including those who contribute offspring to the next generation (ie all the breeding adults in that population) and non-breeding individuals.	MODERATELY LOW	< 2500 mature individuals, or estimated population decline by ≥ 20% within two generations. Both apply to ghost orchid
HP	Hybridization Potential	Existence of closely related species, subspecies, or allopatric populations for interbreeding, with much consideration of fitness consequences such as outbreeding depression	LOW	No evidence of hybridization in ghost orchid

Abbreviation	Trait Name	Trait Description	Ghost Orchid Ranking	Justification
CA	Competitive Ability	The acquisition of a resource that is essential to growth and reproduction when it occurs in limited supply	Unknown	Not clear
DOS	Diversity of Obligate Species	The number of obligate species interactions, including mutualists, pollinators, dispersers, etc, that a focal species relies on to complete some aspect of its life cycle	LOW	Mycorrhizal associations are necessary and highly specific
SP	Seasonal Phenology	The timing of periodic life cycle events that are influenced by seasonal and interannual variations in climate.	MODERATE	Usually flowers may-august in Florida but flowers have been seen during a much wider range of the year
CNB	Climatic Niche Breadth	Measure of niche specialization and reflective of the range of abiotic conditions to which a species is adapted, and their degree of flexibility in responding to changing conditions potentially outside of that range	MODERATELY LOW	Species is moderately (50–90% of occurrences or range) restricted to a particular climatic (or hydrological) condition that may be lost or reduced in the assessment area as a result of climate change. All but one extant population are located in SW florida, some of which may be vulnerable to SLR and all of which are vulnerable to hurricanes
PT	Physiological Tolerances	The degree to which a species (or population) is restricted to a narrow range of abiotic conditions (eg temperature, hydrology)	LOW	Rainfall and temperatures are very similar between Florida and Cuba populations, probably can't tolerate much outside the natural range, also evidenced by the difficulty of growing ex situ.
BRP	Behavioral Regulation of Physiology	The ability of individuals to change their behavior in effort to reduce exposure to climate stressors	LOW	Minimal or no behavioral flexibility and reduction in exposure; species is restricted in expression of behavior by access to essential resources or other physiological limitations

Abbreviation	Trait Name	Trait Description	Ghost Orchid Ranking	Justification
RP	Reproductive Phenology	The timing of reproductive events within a species life cycle that are influenced by seasonal and interannual variations in climate.	HIGH	Does not seem like ghost orchid has a strict environmental cue to flower/fruit and flowering, while usually occurring May-August, has been seen widely outside this time period
MS	Mating System	Group structures within populations related to reproductive behaviors; in plants, reproductive systems reflect varying degrees of outcrossing, which can range from asexual or cloning systems to cross-fertilization among multiple individuals	HIGH	Cross-fertilization (allogamy)/sexual reproduction
F	Fecundity	The number of offspring, seed sets, or asexual propagules produced on average by reproductive individuals of the species	MODERATE	Although many seeds are produced per capsule, typically only a few capsules are produced within an entire population.
P	Parity	The number of times an organism reproduces within its lifetime (ie reproductive rate); in plants, species are either monocarpic (single flowering cycle), plietesial (grow for a number of years then flower gregariously or synchronously once), or polycarpic (multiple flowering cycles)	HIGH	Polycarpic; individuals capable of multiple reproductive events per lifetime
SR	Sex Ratio	How resources to produce offspring of either sex are used	HIGH	Plants are bisexual

Abbreviation	Trait Name	Trait Description	Ghost Orchid Ranking	Justification
LS	Life Span	The average lifespan or average life expectancy	MODERATELY LOW	Plants can live 15 or more years but there is not a clear average life span
GT	Generation Time	Average time between two consecutive generations in the lineages of a population	MODERATELY LOW	Plants in the wild that have been tracked since seedling stage have not flowered til about 15 years of age, but can occur much sooner in ex situ greenhouse conditions
ASM	Age of Sexual Maturity	Time to reproductive maturation, relative to overall lifespan	Unknown	More information about total lifespan of individual plants is required to accurately assess this trait but likely either low or moderate since reproduction does not occur within the first few years of life.
AS	Age Structure	A summary of the number of individuals of each age (or age class) in a population	LOW	This is hard to generalize because it varies by year and by population, but overall it does seem like seedling numbers are lacking outside of Cuba
R	Recruitment	Proportion of juveniles surviving to adulthood (maturity) in a population	MODERATE	In demographic research presented in Mújica et al. 2021, consistently about half were either in the seedling or juvenile stage