Varronia rupicola (no common name)
5-Year Review: Summary and Evaluation

Photo by Omar A. Monsegur-Rivera, USFWS

U.S. Fish and Wildlife Service
South Atlantic–Gulf and Mississippi Basin Regions
Caribbean Ecological Services Field Office
Boquerón, Puerto Rico

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5-YEAR REVIEW
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I. GENERAL INFORMATION

A. Methodology used to complete the review:

The U.S. Fish and Wildlife Service (Service) completed this review using information obtained from the *Varronia rupicola* final listing rule and designation of critical habitat under the Endangered Species Act (ESA), the recovery outline, peer-reviewed scientific publications, several unpublished research projects reports, unpublished field observations by the Service, State and other experienced biologists, and personal communications. The Service's lead Recovery biologist for this species prepared this review.

On June 20, 2019, the Service published a notice in the Federal Register (84 FR 28850) announcing the initiation of the 5-year review for 53 southeastern species, including *V. rupicola*. At that time, the Service opened a 60-day comment period and requested new information concerning the biology and status of the species. No information was received from the public during the comment period. The Service sought peer review from four individuals familiar with this species and its habitat (see Appendix A). Comments were incorporated into the final document and are summarized in Appendix A.

B. Reviewers

Lead Regional: Carrie Straight, Recovery Coordinator, Southeast Atlantic-Gulf and Mississippi-Basin Regions, Atlanta, Georgia.

Lead Field Office: Omar A. Monsegur-Rivera, Caribbean Ecological Services Field Office, Boquerón, Puerto Rico, omar_monsegur@fws.gov.

C. Background

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

2. Listing history
Original Listing
Federal Register Notice: 79 FR 53303
Federal Register Notice date: September 9, 2014
Entity listed: Species
Classification: Threatened

3. **Associated rulemakings**
   Critical Habitat
   FR notice: 79 FR 53315
   Date: September 9, 2014

4. **Review History**
   The final listing rule and designation of critical habitat published on September 9, 2014, and Dr. Martin A. Hamilton PhD thesis (2016) on the biogeography, systematic placement and conservation genetics of *V. rupicola* are the most recent comprehensive analyses of the status of this species. In addition, we referenced the Hamilton et al. (2018) which consists of the IUCN Red Listing Assessment of *V. rupicola*. Moreover, there is ongoing research funded by the Puerto Rico Department of Natural and Environmental Resources (PRDNER), "Safeguarding the unprotected population of the endangered species *V. rupicola*". All these documents were used as reference point documents for this 5-year review.

5. **Species' Recovery Priority Number at start of review: 8c**
   At the time of listing, *V. rupicola* was recognized as a species with a moderate degree of threat and a high recovery potential with conflict due to the threats of development projects. Recovery potential is considered high because the species has a wide distribution throughout the Puerto Rican bank (biogeographical unit comprising Puerto Rico, the US Virgin Islands and the British Virgin Islands) (Figure 1.), it shows no germination problems, develops as reproductive individuals in a relatively short time period (1-2 years under nursery conditions). Furthermore, it is currently under research and conservation efforts by several institutions, including the Royal Botanical Garden (Kew); University of Puerto Rico, the British Virgin Islands National Park Trust (NPT), the Vieques NWR, and the Caribbean Ecological Services Field Office (CESFO). These research efforts will provide key information on the species reproductive biology and biogeography and will provide propagation protocols for the development of recovery goals. Nonetheless, the recovery of *V. rupicola* is in conflict with development projects (e.g., utility rights of way, housing projects, hotels, landfills, rock quarries) or other forms of economic activity. Therefore, the recovery priority number acquires the letter "c".

6. **Recovery Plan**

   At present, there is no final recovery plan approved for the species.

II. REVIEW ANALYSIS

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

The Endangered Species Act (Act) defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate wildlife. This definition limits listing DPSs to only vertebrate species of fish and wildlife. Because the species under review is a plant, the DPS policy is not applicable.

B. Recovery Criteria

1. Does the species have a final, approved recovery plan containing objective, measurable criteria? No

C. Updated Information and Current Species Status

1. Biology and Habitat

a. Summary of new information of species biology and life history:

Varronia rupicola has been reported flowering and fruiting in December-January (Breckon and Kolterman 1996), and in June-July (Monsegur and Breckon 2007). Under nursery conditions, seed germination has been reported as not less than 67% (Wenger et al. 2010). In addition, germination in the wild has also been observed to be high (O. Monsegur, Service, pers. obs. 2013). However, there is a high mortality at seedling stages associated with drought stress, and only few individuals make the transition (natural thinning) to sapling stages (O. Monsegur, Service, pers. obs. 2013). Monsegur and Breckon (2007) reported numerous seedlings (>140) and various saplings at the Guánica Commonwealth Forest (GCF). Nonetheless, overall seedling recruitment in mainland Puerto Rico and Vieques Island seems to be fairly low when compared to Anegada Island (British Virgin Islands [BVI]), where the species shows a more widespread and uniform distribution (Hamilton 2016; Monsegur and Breckon 2007).

The range wide distribution of the species (southern Puerto Rico to Anegada) (Figure1) suggests a former animal disperser. Currently, despite the showy red fruits of *V. rupicola*, its dispersion in Puerto Rico (including Vieques) seems to be almost limited to gravity as the majority of the seedling recruitment occurs under the parent tree or downslope (Hamilton et al. 2015; O. Monsegur, Service, pers. obs. 2013). This may be an effect of habitat fragmentation and small population size, which may result in deterrence of dispersers; as dispersers may focus on more reliable and abundant plant species for foraging, and therefore, provide minimal help with seed dispersion (Hamilton 2016). There is ongoing research using trap cameras aiming to address information on the species phenology, pollinators, and seed dispersers, as well as potential predation by exotic animals. Some observations of seed dispersal by an undetermined vector have been reported at Anegada (Hamilton, Kew, pers. comm. 2013), and there is an ongoing research by Dr. Martin Hamilton (Kew) and Kelly Bradley (Fort Worth Zoo) to address the role of the Anegada rock iguana (*Cyclura pinguis*) on the dispersal and distribution of *V. rupicola* at the island of Anegada (Hamilton 2016). Patterns of plant-animal interactions were probably altered due to the former extensive deforestation of the island of Puerto Rico associated to agricultural land use.

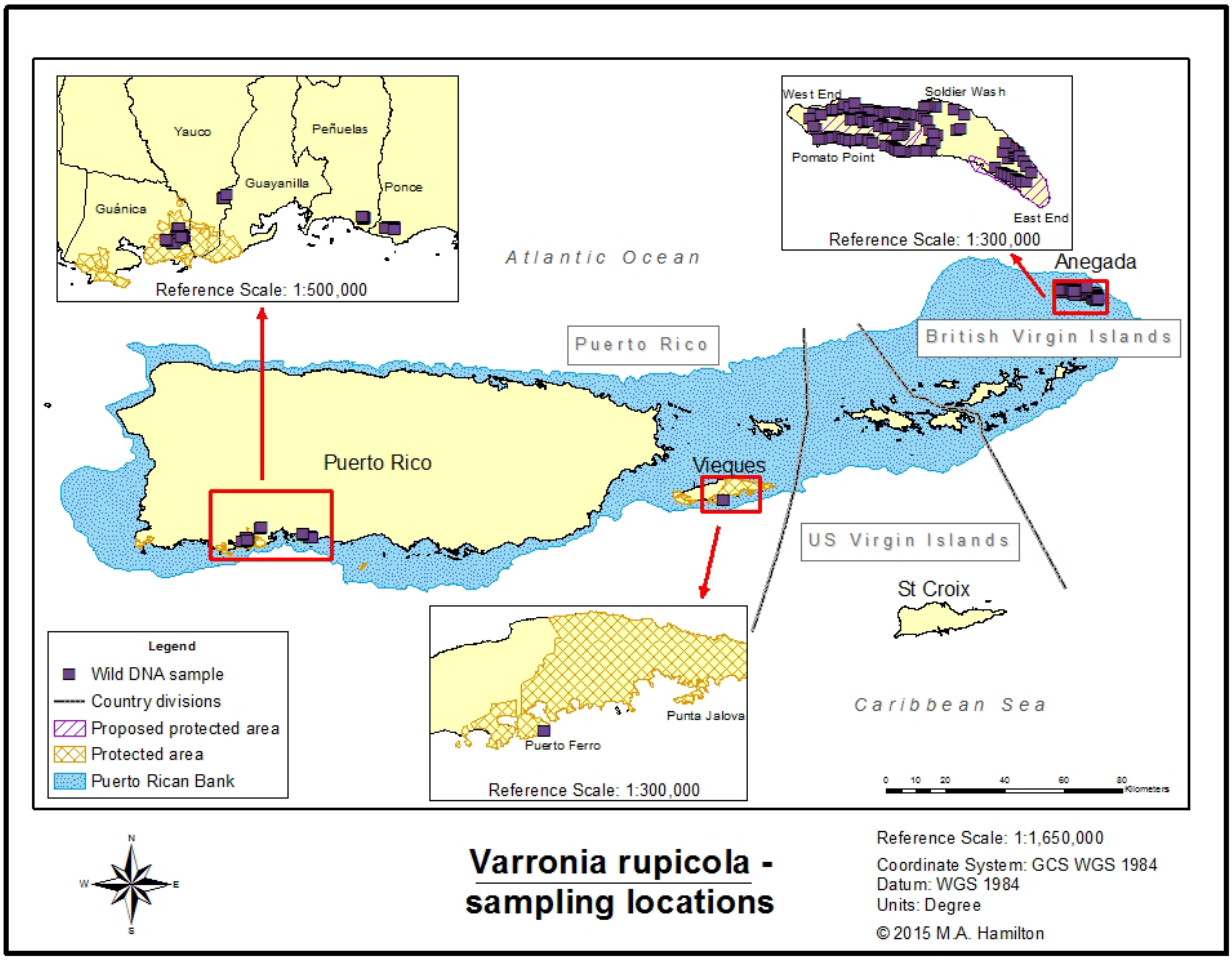

Figure 1. Map showing the known distribution of *Varronia rupicola* in southwestern Puerto Rico, Vieques Island, and Anegada (British Virgin Islands), and DNA samplings sites across the species distribution. From Hamilton 2016.

Material of *V. rupicola* germinated at Cabo Rojo National Wildlife Refuge tree nursery were flowering and producing fruits about a year after germination (O. Monsegur, Service, pers. obs. 2013). The species' ability to rapidly reach a reproductive stage and the finding of individuals along recently disturbed sites (recently opened dirt roads) and natural forest gaps (canopy openings), suggest that *V. rupicola* is an early colonizer or pioneer species (consistent with other species of *Varronia spp.*).

b. Abundance, population trends, demography:

As of the time of this review, *V. rupicola* populations are estimated to contain approximately 1,247 adult individuals across the 5 known genetically unique populations: Guánica (193), Ponce (83), Vieques (12), Anegada West (629) and Anegada East (330). In addition, approximately 335 seedlings and 262 saplings have been recorded as part of ongoing monitoring efforts (2012-2021) (Table 1). These numbers are based on herbarium records and observation points (validated

with photos) by species experts. In defining the above population estimates, we only considered adult individuals, as seedlings and saplings are subject to natural thinning due to environmental stochasticity (e.g., droughts). The number of individuals for the Puerto Rico populations is currently higher with approximately 288 adult individuals, when comparing to the number of individuals known at the time of listing in 2014 (109 adults and saplings) and the 165 individuals estimated by Hamilton (2015).

The individuals of *V. rupicola* on Anegada have been located in 69% of 104 sampling points along 27 random transects situated in and around the Western Salt Ponds of Anegada RAMSAR site (Convention on Wetlands of International Importance) (Clubbe et al. 2004). At the time of listing in 2014, *V. rupicola* was considered common and widespread in the northwest section of Anegada. However, despite the recent extensive surveys for the species on this Island, the number of known adult individuals is estimated to be 629 for Anegada West, and 330 adult individuals for Anegada East (Table 1). However, a long-term monitoring effort is needed to determine a population trend for the species.

Table 1. Population status of *Varronia rupicola* across the species range as of March 2021. The information is based on extensive habitat surveys since 2012 as part of research and conservation efforts led by Dr. Martin A. Hamilton.

Population	Country	Number of Saplings	Number of Seedlings	Number of Adults (Population Size)
Guánica	Puerto Rico	38	167	193
Ponce	Puerto Rico	144	160	83
Vieques	Puerto Rico	0	1	12
Anegada West	British Virgin Islands	33	4	629
Anegada East	British Virgin Islands	47	3	330
Total		**262**	**335**	**1247**

c. Genetics:

Based on the findings from cyto-, phylo- and population genetic, and when compared with biogeographical analysis, *V. rupicola* remains as a distinct (valid) species endemic to Caribbean islands where five discrete populations were identified (Hamilton 2016; represented in Table 1). These populations consist of three populations in Puerto Rico (Guánica, Ponce, Vieques), and two in Anegada, BVI (Anegada West, and Anegada East) (Hamilton 2016). The species has lost genetic diversity in the wild through a reduction in population size with allelic diversity proportional to the size of the population, and all five populations showing lower than expected levels of heterozygosity as well as significant genetic differentiation and evidence of inbreeding (Hamilton 2016).

Twenty-four (26.1%) of the 92 alleles for diploid acting loci are unique to the Anegada populations (BVI), and twenty (21.7%) of the 92 alleles unique to Puerto Rico, three of these only found on the island of Vieques (Hamilton 2016). Of the remaining 17 private alleles from Puerto Rico, four are only found in the population defined as Guánica (municipalities of Guánica and Yauco); seven are only found in the Ponce population (municipalities of Peñuelas and Ponce); four are shared between Guánica and Ponce; one shared between Guánica and Vieques; and one shared between Ponce and Vieques (Hamilton 2016). The above information highlights the importance of the Puerto Rico populations (including the small population at Vieques) for the conservation of the species genetic diversity. Preserving genetic diversity found in all five populations will help support species redundancy and the ability of the species to adapt to both near-term and long-term changes in its physical and biological environment.

The genetic evidence shows a link between patterns of allelic richness and population size, with the Vieques population showing the lowest allelic richness (Hamilton 2016). This is probably the result of the small size of the known population caused by former deforestation associated to agricultural practices and military maneuvers. The number of private alleles (Pa) also follows this trend with the exception of the Ponce population that has slightly more Pa than the larger Guánica population. All the Puerto Rico populations had larger inbreeding values compared to the BVI, suggesting the smaller and isolated populations from Puerto Rico are exchanging less genetic material when compared to the Anegada populations (Hamilton 2016).

d. Taxonomic classification or changes in nomenclature:

Varronia rupicola is a woody shrub in the family Boraginaceae Jussieu (Hamilton 2016; Hamilton et al. 2015). The taxonomy of the group is fully discussed in the listing rule for *V. rupicola* (USFWS 2014a). We have no new taxonomic information for the species.

e. Distribution and trends in spatial distribution:

Varronia rupicola is currently known from five genetically unique populations across its range; Guánica, Ponce, Vieques, Anegada West and Anegada East (Figure 2) (see Section II.C.1.c., above; Hamilton 2016; Hamilton et al. 2018). Based on Hamilton 2016, the core of the Guánica population occurs within the East Unit of the GCF (municipality of Guánica, Yauco and Guayanilla), and it also extend to a small locality at the West Unit of the GCF at the area known as Montalva (municipality of Guánica). Another recorded locality for the *V. rupicola* Guánica population extends to a privately owned property located at Montes de Barina in the municipality of Yauco (USFWS 2014a; USFWS 2014b). At this site the species was originally reported by Alcides Morales (Sociedad Ornitológica Puertoriqueña, Inc., pers. comm. 2012) from a private property known as Finca

Catalá. The Montes de Barina locality (boundary of the municipalities of Yauco and Guayanilla) was later vouchered by Dr. Hamilton, and subsequent genetic analysis confirmed that these individuals are part of the Guánica population. The Barinas locality is in the proximity of the general area where the type specimen was collected by Paul Sintenis in 1886 (USFWS 2014a). In early 2020, the type locality at Indios Ward in the municipality of Guayanilla was rediscovered (Hamilton et al. 2020) and herbarium vouchers prepared. Due to the proximity, the individuals at Indios Ward are expected to be genetically similar to the Guánica population, however, further research is needed to validate this information.

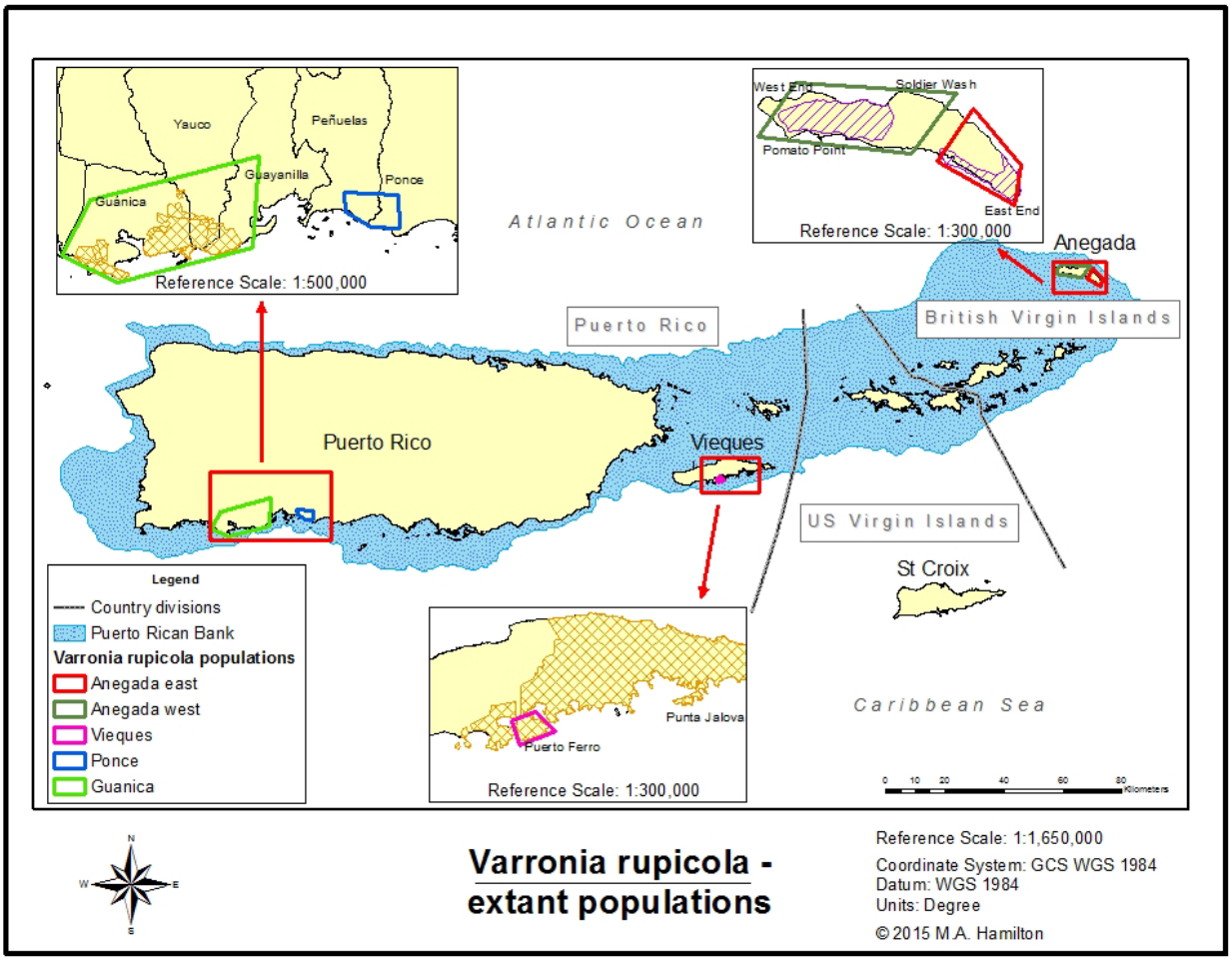

Figure 2. Map showing the genetically unique extant populations of *Varronia rupicola* . From Hamilton 2016.

The distribution of *V. rupicola* extends slightly east along the southern coast of Puerto Rico to the area of the Ponce population (boundary of the municipalities of Ponce and Peñuelas (Hamilton 2016). Prior to the listing of the species, Monsegur and Breckon (2007) reported a single individual in a ravine just on the west side of El Peñón (historical site) at the municipality of Peñuelas. By 2013, the Service confirmed the presence of approximately eight clusters of individuals in an area

just north of the hotel Ponce Holiday Inn in the municipality of Ponce (USFWS 2014a). Extensive habitat assessment surveys confirmed the presence of multiple clusters on the hills just northwest of the Monsegur and Breckon 2007 record (Hamilton 2016). In addition, ongoing efforts has confirmed that the Ponce population extends west to the hills near the entrance to the Peñuelas Valley Landfill (Hamilton et al. 2020).

The distribution of *V. rupicola* extends to the island of Vieques (Puerto Ferro) where recent work carried by Martin Hamilton (Royal Botanic Garden, Kew) confirmed the occurrence of the species within the Vieques National Wildlife Refuge (VNWR) (Hamilton 2016), and the population is yearly monitored by refuge staff. Nonetheless, the record of the species from Punta Jalova in Vieques remains questionable as there is no limestone parent material on the area, and the overall site was part of the Eastern Maneuver Area of the U.S. Navy at Camp Garcia and the area was later cleared of vegetation for the investigation for unexploded ordinance (UXO) (Hamilton 2016). In fact, the Punta Jalova is an old herbarium record from 1978 by Roy Woodbury and it is likely an error on the specimen label, thus, making challenging confirming this locality (Hamilton 2016).

As previously mentioned, the easternmost distribution of the species extends into the island of Anegada, BVI, where two populations have been identified (Anegada west and Anegada east), where approximately 959 adult individuals are estimated to exist (Hamilton 2016; Table 1). In summary, the overall species distribution is similar today to what was known at the time of listing. In fact, the type locality in the municipality of Guayanilla was rediscovered in early 2020.

f. Habitat or ecosystem conditions:

All sites where *V. rupicola* has been described lie within the subtropical dry forest life zone overlying a limestone substrate (Ewel and Whitmore 1973). Subtropical dry forest life zones receive a mean annual rainfall ranging from 24 to 40 in (600 to 1110 mm), and its vegetation is deciduous on most soils, with tree species dropping leaves during the dry season. The vegetation usually consists of a nearly continuous single-layered canopy, with little ground cover. The leaves of dry forest species are succulent or coriaceous, and species with spines and thorns are common. Tree heights usually do not exceed 49 ft (15 m) and crowns are typically broad, spreading and flattened (Ewel and Whitmore 1973).

Varronia rupicola has been recorded in forested hills with open to relatively-dense shrublands/shrublands 6.5 to 9.8 ft (2 to 3 m) in height; in low forest with canopy from 8 to 15 ft high (3 to 5 m); and at the edge of a dense low coastal shrubland forest. In the island of Anegada, *V. rupicola* was found in open limestone pavement and sand dunes. Woody species associated to *V. rupicola* prime habitat in southern Puerto Rico (GCF) include; *Gymnanthes lucida* (Yaití), *Exostema caribaeum* (Albarillo), *Pisonia albida* (Corcho), *Pictetia aculeata*

(Tachuelo), *Thouinia portoricensis* (Serrazuela), *Coccoloba krugii , Pilosocereus royenii* (Sebucán), *Bursera simaruba* (Almacigo), *Erithalis fruticosa, Guettarda krugii* (Cucubano), *Tabebuia heterophylla* (Roble), *Hypelate trifoliata*, *Coccoloba diversifolia* (Uvilla), *Cassine xylocarpa* (Coscorrón), *Krugiodendron ferreum* (Palo de hierro), *Jacquinia berteroi, Bourreria succulenta* (Palo de vaca), *Crossopetalum rhacoma* (Pico de paloma), *Anthirea acutata* (Quina), and *Amyris elemifera* (Tea) (Murphy and Lugo 1986). The populations of *V. rupicola* in Puerto Rico are also found in close proximity to populations of the endangered plants *Eugenia woodburyana* and *Trichilia triacantha* (Bariaco), and other rare plants such as *Myrtus bellonis, Passiflora bilobata*, and *Nashia inaguensis* (Breckon and Kolterman 1996, Monsegur and Breckon 2007, Hamilton 2016). At the island of Anegada, *V. rupicola* is also found associated to the endemic *Acacia anegadensis* (Hamilton 2016). In a comprehensive study of the vegetation of Anegada, *V. rupicola* was found in higher abundance (based on percentage occurrence across plots) on limestone but also widespread within the sand dunes (Clubbe et al. 2004).

Varronia rupicola is considered restricted to areas where the underlying geology is limestone and has been recorded growing in sandy substrate, pockets of loam and unconsolidated mineral substrate (Hamilton et al., 2015). The majority of the suitable habitat and known populations of *V. rupicola* in Puerto Rico lie within the Ponce limestone formation, a Mid-Tertiary pink to white, fine-grain limestone (Lugo et al. 1996). In Puerto Rico, this formation extends from the western end of the GCF, east toward the Municipality of Ponce (El Tuque). The soils at the GCF are described as shallow, alkaline, and derived from limestone rock (Molina and Lugo 2006). According to Murphy and Lugo (1986) these soils are nutrient-rich, but only a small fraction of the total phosphate and potassium is readily available. These soil factors increase the effects of low rainfall and its seasonality on the vegetation. Based on the information above, we identified shallow and alkaline soils derived from limestone rock, and an average rainfall of 860 mm (34.5 in) as physical or biological features for this species' critical habitat.

Across its range, *V. rupicola* plants are found in extremely limited areas of intact habitat (<90 km^2 [34.7 mi^2]), overlying substrates that cover <200 km^2 (77.2 mi^2) across the three islands (Hamilton 2016). Protected areas contain less than a third (<30 km2 [11.6 mi^2]) of the remaining intact habitat that supports the species (Hamilton 2016). Since the species listing and critical habitat designation in 2014, the species habitat continues to decline due to ongoing deforestation for development and maintenance of power lines (Hamilton et al. 2020) (see discussion under Factor A).

On September 9, 2014, the Service published the final rule designating critical habitat for *V. rupicola* (Figures 3 and 4) and identified the primary constituent elements of the critical habitat for the species (USFWS 2014b). The Service designated 2,648 ha (6,547 ac) in seven units as critical habitat for *V. rupicola*. The seven units are: (1) Montalva, (2) Guánica Commonwealth Forest, (3)

Montes de Barina, (4) Peñon de Ponce, (5) Punta Negra, (6) Puerto Ferro and (7) Cerro Playuela (Figures 1 and 2).

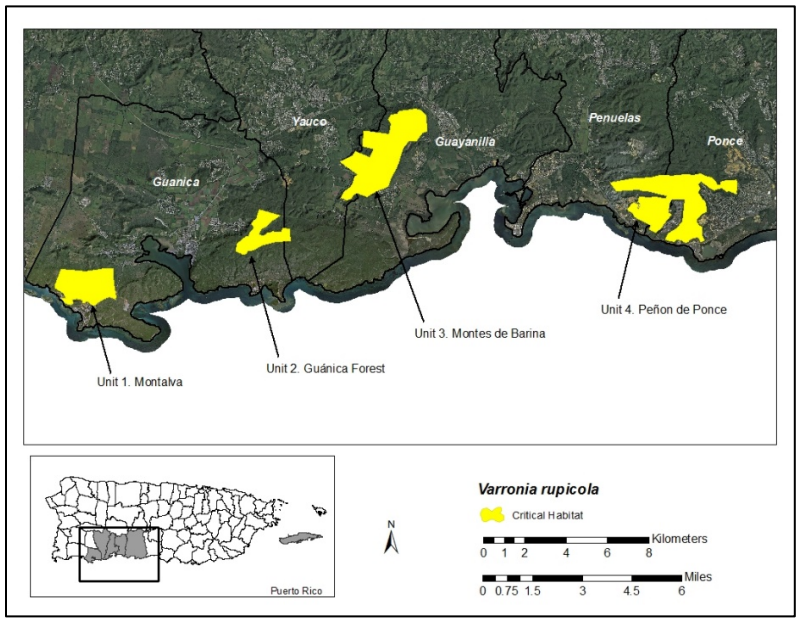

Figure 3. *Varronia rupicola* designated Critical Habitat along the southwestern coast of Puerto Rico (79 FR 53315).

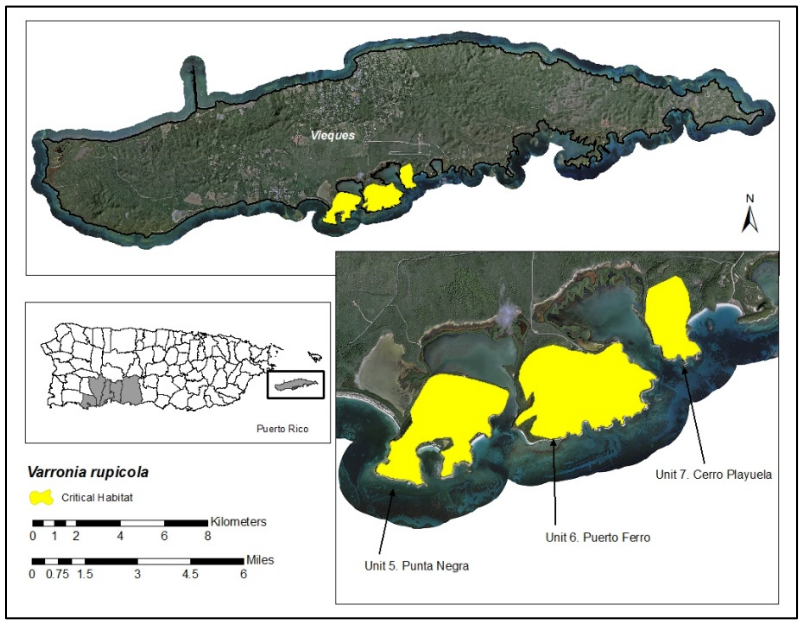

Figure 4. *Varronia rupicola* designated Critical Habitat at Vieques Island (79 FR 53315).

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

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

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

The species rarity and restricted distribution makes it vulnerable to habitat destruction and modification (Hamilton 2016, Hamilton et al. 2018). About 50 percent of known *V. rupicola* individuals in Puerto Rico occur on private lands currently subject to urban development (i.e, Yauco, Guayanilla, Peñuelas, and Ponce). Moreover, the habitat at Peñuelas and Ponce remains underestimated, resulting in a reduced of the distribution and abundance of the species at these areas, as recent surveys within these areas has confirmed additional localities (Hamilton et al. 2020). The habitat in the municipalities of Peñuelas and Ponce has been severely fragmented for urban development (i.e., housing projects, hotels, jails, landfills, rock quarries, and Puerto Rico Highway Number 2). The habitat has been further fragmented by the use of these forested areas by the Puerto Rico Energy and Power Authority (PREPA) as a right of way for power lines, and habitat was impacted for the construction of a gas pipeline that was later canceled (Gasoducto Sur). Future development projects may threaten these populations with becoming fragmented (reducing the amount of suitable habitat available for natural recruitment), and possibly extirpating currently known individuals. Despite the species biology suggests its ability to colonize disturbed areas, it is very likely that once the habitat is fragmented. *V. rupicola* will be outcompeted by exotic plant species (see Factor E).

In the municipality of Peñuelas, the species is found in an area that is currently under urban development. Breckon and Kolterman (1996) reported a healthy population of *V. rupicola* in this area located at El Peñón, which is part of a residential development called “Urbanización El Peñón”. At this site, *V. rupicola* plants were growing within residential lots, and although the lots are large in size, current and ongoing construction and deforestation threaten all individuals at this locality. In fact, by 2007, Monsegur and Breckon were able to locate only one individual adjacent to the historical site “Urbanzación El Peñon”, and the individual was later extirpated by the improvement to Highway PR 2.

In the municipalities of Yauco and Guayanilla (Montes de Barina), the species occurs within private properties that may be subject to urban development. These areas are also threatened by deforestation for agricultural practices such as cattle, and for the extraction of fence posts (O. Monsegur, pers. obs. 2005). The known population at Yauco was recorded just at the edge of an existing dirt road, therefore, road expansion or bulldozing will result in habitat modification, and may result in the extirpation of individuals, and in further intrusion of exotic plant species. At present, habitat modification at Montes de Barina continues, and the recently rediscovered type locality (Indios Ward at the municipality of Guayanilla) is threatened by maintenance of power lines and ongoing deforestation (Hamilton et al. 2020).

In the GCF and the VNWR, *V. rupicola* is found at the edge of trails and roads, making the species prone to impacts from management activities (e.g., maintenance or widening of trails, and road repairs). Additionally, several individuals of *V. rupicola* are found underneath power lines of PREPA at the GCF, where they are threatened by maintenance activities such as cutting or the use of herbicides. PREPA has the right to access the power lines for maintenance and service in case of emergencies. Damage to individual plants caused by power lines maintenance activities has been observed in the past (O. Monsegur, Service, pers. obs. 2009). This makes a significant part of the Guánica populations prone to extirpation despite the existence of regulatory mechanisms (see Factor D).

Furthermore, despite being a National Wildlife Refuge, the Vieques site (Puerto Ferro) is considered as an active ammunition site due to the previous use of Vieques Island as a bombing range by the U.S. Navy (http://public.lantops-ir.org/sites/public/vieques/default.aspx). Although there are no current plans to conduct vegetation removal to investigate the ammunitions in Puerto Ferro (F. Lopez, Service, pers. comm. 2021), the investigation process at Vieques has proved to be dynamic and there is a possibility that clearing of native vegetation may be required for future removal of ammunitions.

Although the *V. rupicola* population in Anegada Island appears to be healthy with an estimated population of 1,000 individuals (Hamilton et al. 2015; Hamilton 2016). However, despite efforts to maintain biodiversity and promote conservation on that Island, *V. rupicola*, along with other rare plant species and their preferred limestone habitat, face threats of habitat fragmentation, habitat modification, and invasive species (Hamilton 2016, Hamilton et al. 2015, Pollard and Clubbe 2003, McGowan et al. 2006). Anegada is under heavy pressure for residential and tourism development (McGowan et al. 2006), resulting in the construction and improvement of roads, which increases habitat loss and fragmentation. Furthermore, about half of known *V. rupicola* populations and suitable habitat are within privately owned land, which is being modified or proposed to be modified for urban development. Moreover, *V. rupicola* has no legal protection in BVI and there is no protected habitat for the species either

(Hamilton 2016). Hamilton (2016) reported high levels of habitat disturbance across the island, including the operation of heavy machinery to clear vegetation, and anthropogenic development within the boundaries of proposed conservation areas in West Anegada, including the extirpation of significant numbers of *V. rupicola*.

The discussion above emphasizes the risk of almost all individuals and populations of *V. rupicola* in areas outside of protected lands through habitat loss, encroachment of invasive exotics, and direct removal of individuals. For example, the entire Ponce population remains in private lands vulnerable to extirpation. Even on protected lands there are forces that continue to threaten individual plants (e.g., Vieques NWR).

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

There is scientific interest in *V. rupicola* from local and international botanists including an ongoing research by the Royal Botanic Gardens (Kew) related to the reproductive biology, propagation, and genetics of this species, including the populations from Puerto Rico and the BVI (Puerto Rican biogeographical platform). However, the current available information does not suggest that overutilization for commercial, recreational, scientific, or educational purposes have contributed to a decline of *V. rupicola*. The ongoing research is the only known utilization of the species, and it targets the species conservation. Therefore, despite its rarity, we do not have any evidence suggesting that collecting for scientific purposes is adversely affecting *V. rupicola*.

c. Disease or predation:

At the time of listing, disease or predation were not considered to be a factor in the decline of *V. rupicola*. No pests had been identified in wild populations of the species at that time. However, Malumphy et al. (2015) identified the lesser snow scale (*Pinnaspis strachani*) and the seagrape flatid plant-hopper (*Petrusa epilepsies*) as pests affecting individuals of *V. rupicola* in Anegada Island. Malumphy et al. (2015) suggested that *V. rupicola* may be vulnerable to the lesser snow scale because of observations of plant mortality and the absence of a control mechanism for this pest in the wild. So far both pests: *P. strachani* and *P. epilepsies*, have only been recorded in Anegada. In addition, minor to moderate infestation by glasshouse whitefly (*Trialeurodes vaporaroirum*) was observed on cultivated material of *V. rupicola* at the Royal Botanical Garden, Kew (Wenger et al. 2010). However, this was suspected to be the result of the proximity of the *V. rupicola* material to a species that is highly susceptible to this insect pest.

Due to the low number of individuals and populations of the species, disease and predation could certainly be threat. This is particularly important for the Vieques population, which is composed by less than 15 individuals (not including

seedlings) clustered within a small area. Nonetheless, there is only slight evidence suggesting that *V. rupicola* might be vulnerable to *P. strachani*, and recent monitoring has not detected it as a widespread pest in Anegada. Furthermore, populations of *V. rupicola* continue recruiting individuals, thus, we consider this threat as low and non-imminent.

d. Inadequacy of existing regulatory mechanisms:

Commonwealth of Puerto Rico

In 1999, the Commonwealth of Puerto Rico approved Law No. 241-1999, also known as the New Wildlife Law of Puerto Rico ("Nueva Ley de Vida Silvestre de Puerto Rico"). The purpose of this law is to protect, conserve, and enhance both all native and migratory wildlife species (including species not classified as threatened or endangered), including plants; declare all wildlife species within its jurisdiction as property of Puerto Rico; and to regulate permits, hunting activities, and nonnative species, among others. However, as we mentioned above under Factor A, some individuals of *V. rupicola* have been pruned, and in some cases eliminated as the result of unauthorized activities such as vegetation removal within the Commonwealth forests and privately owned lands (Monsegur and Breckon 2007). Therefore, we believe that protection provisions under Law No. 241-1999 are not being appropriately enforced.

Moreover, when *V. rupicola* was listed, the Service identified the inadequacy of existing regulatory mechanisms as one of the factors affecting the continued existence of the species. At that time, the species had no legal protection under PRDNER's Regulation 6766 (Regulation to govern the management of threatened and endangered species in the Commonwealth of Puerto Rico [se below]) because it was not part of the Commonwealth's list of protected species. However, once *V. rupicola* was federally listed, legal protection was immediately provided under the ESA, and by virtue of an existing Section 6 Cooperative Agreement with the Commonwealth of Puerto Rico. Listing under the ESA assured the addition of *V. rupicola* to the Commonwealth list as a protected species. Species listed under Commonwealth regulations remains protected even if these are later removed (delisted) from the ESA.

In 1998, the Commonwealth of Puerto Rico approved the Commonwealth Law No. 150-1998, known as Puerto Rico Natural Heritage Law (Ley del Programa de Patrimonio Natural de Puerto Rico). The purpose of this law was to establish the PRDNER Natural Heritage Program. This program has the responsibility to identify and designate as critical elements some rare, threatened, or endangered species that should be considered for conservation, because of their contribution to biodiversity and because of their importance to the natural heritage (PRDNER 1988). Currently, *V. rupicola* is considered as a critical element by the PRDNER Natural Heritage Program. Although Law No. 150-1988 does not provide penalties for actions that may adversely affect critical elements, it triggers other

Commonwealth laws and regulations, such as Law No. 133-1975 and Regulation No. 6769 (see below), that provide protection to critical elements.

Moreover, the GCF is protected by Law No. 133-1975 (12 L.P.R.A. sec. 191), as amended, known as the Puerto Rico Forest Law ("Ley de Bosques de Puerto Rico"), as amended in 2000. Section 8(A) of Law No. 133-1975 prohibits cutting, killing, destroying, uprooting, extracting, or in any way damaging any tree or vegetation within a Commonwealth forest without authorization of the PRDNER Secretary. Although management plans for Commonwealth forests should include the protection and conservation of species classified under PRDNER regulations as critical element, endangered, or threatened, on occasions the location of such species in the forests makes enforcement of these regulations a difficult task. As previously mentioned, *V. rupicola* occurs along trails, near access roads, and below power lines. According to PRDNER forest managers, on several occasions, coordination between forest personnel and field staff from PREPA has not been effective to avoid damaging species protected by Commonwealth laws, including *V. rupicola* (M. Canals, PRDNER, pers. comm. 2008).

In 2004, PRDNER approved Regulation 6766 to regulate the management of threatened and endangered species in the Commonwealth of Puerto Rico ("Reglamento para Regir el Manejo de las Especies Vulnerables y en Peligro de Extinción en el Estado Libre Asociado de Puerto Rico"). Article 2.06 of Regulation 6766 prohibits collecting, cutting, and removing, among other activities, listed plants within the jurisdiction of Puerto Rico. *Varronia rupicola* is not included in the list of protected species under Regulation 6766. However, as indicated above, Law No. 241 provides protection to all wildlife species (including plants) under Commonwealth jurisdiction, even those on private lands.

Although the protection of existing laws extends to populations of *V. rupicola* through Puerto Rico, the enforcement of such laws and regulations continues to be a challenge (see discussion under Factors A and E). Accidental damage or extirpation of individuals of *V. rupicola* has occurred due to lack of knowledge of the species within the GCF and privately owned lands. Therefore, despite *V. rupicola* is now protected by the Commonwealth laws and regulations, we consider the implementation of existing regulatory mechanisms as a challenge for the long-term conservation of the species

Federal

One of the currently known populations of *V. rupicola* is located at Puerto Ferro within the VNWR. Collecting and managing plant material (including seeds) within a National Wildlife Refuge are regulated and require a Section 10 (a)(1)(a) permit and a Special Use Permit from the refuge (FWS Form 3-1383-R). The National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd-668ee, as amended by the National Wildlife Refuge System Improvement Act of 1997) provides guidance for management and public use of the refuge system,

thus providing mechanisms for the management and conservation of endangered species, including *V. rupicola*.

Anegada Island (British Virgin Islands)
On the island of Anegada, there are various conservation and education efforts taking place for the protection of rare plant and animal species (Wenger et al. 2010). However, we are unaware of any formal regulatory mechanism currently protecting *V. rupicola*. On November 3, 1999, a portion of western Anegada (2,646 ac (1,071 ha)) was designated as a Ramsar site and added to the List of Wetlands of International Importance (Western Salt Ponds of Anegada). A portion of the preferred limestone habitat of *V. rupicola* lies within this site, which is owned by the British government. Although this designation does not necessarily provide legal protection status, the purpose of a Ramsar site is to ensure the perpetuation of ecological functions of the site by means of a wise-use approach. More recently, the Government of the BVI has undertaken public consultations about proposals for the establishment of conservation areas that will include terrestrial habitats in Anegada Island (Hamilton 2016).

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

Factor E is analyzed as a variety of direct and indirect impacts on the species, impacts that can be exacerbated by the effects or exacerbate the effects of other Factors such as A, C, and D.

Invasive Species
Invasive plant species can affect native ecosystems at three levels: genetic, where the number of individuals of native species can be reduced below the minimum necessary for persistence; species diversity, where the number of species present and their distribution can be reduced; and ecosystem, where the functioning of the ecosystem can be changed (Rippey et al. 2002). Nonnative species can be very aggressive and compete with native species for sunlight, nutrients, water, and ground cover. Once established, these nonnative species typically dominate the landscape, and that novel forest is characterized by a reduced diversity and a decrease in the number of endemics (Lugo and Helmer 2003). Therefore, the impacts of invasive species are among the greatest threat to the persistence of rare endemic species and their habitats (Thomson 2005).

Habitat modification by urban development has promoted the invasion of *V. rupicola* habitat by nonnative plant species (e.g., grasses) that are typically fire-adapted and, therefore, increase the chances of fires by providing a higher fuel load in the ecosystem. Studies conducted within the GCF indicate that some nonnative tree species (e.g., *Leucaena leucocephala*) can persist as a dominant canopy species for at least 80 years (Wolfe 2009). The same is expected to occur with nonnative grass species (e.g., *Megathyrsus maximus*) that once stablished persist in the ecosystem. As observed in several localities (e.g., Ponce and Peñuelas), these invasive species invade recently disturbed (naturally or by human

impacts) areas and occupy the suitable habitat of *V. rupicola*. Despite the quality and overall diversity of the habitat that harbors *V. rupicola* populations in the southern coast of Puerto Rico, recent developments and habitat fragmentation have served as corridor for invasive species (e.g., right-of-way for the former Gasoducto Sur; O. Monsegur, Service, pers. obs., 2013). On the island of Anegada, numerous invasive plants have been documented in the town of The Settlement, three of which have been observed moving towards natural habitats (McGowan et al. 2006), further promoting the risk of wildfires that may affect *V. rupicola*.

Human-induced Fires

Fire is not a natural event in subtropical dry or moist forests in Puerto Rico and the U. S. Virgin Islands. The vegetation in the Caribbean is not adapted to fires, because this disturbance does not naturally occur on these islands (Brandeis and Woodall 2008; Santiago-García et al. 2008). Human-induced fires may lead to destruction of the native vegetation seed bank and may create conditions favorable for the establishment of nonnative plant species adapted to fires (e.g., *Leucaena leucocephala* and *Megathyrsus maximus*) that may outcompete *V. rupicola*. In some cases, fires may maintain extensive areas of young forest and grasslands, slowing the recovery of ecosystems and, therefore, impairing the delivery of ecosystem services (Brandeis and Woodall 2008). For example, the nonnative *Megathyrsus maximus* is well adapted to fires and can take advantage of disturbances caused by fire to takeover areas previously covered by native vegetation. Furthermore, the presence of this species increases the amount of fuel and the intensity of fires. Therefore, damage caused by fires to the ecosystems, particularly to juvenile plants, might be irreversible (Santiago-García et al. 2008).

Varronia rupicola is threatened primarily by human-induced fires within its prime habitat. The *V. rupicola* populations occur along the municipalities of Yauco, Guayanilla, Peñuelas, and Ponce are susceptible to wildfires, particularly on private lands where fires are accidentally or deliberately ignited. Evidence of recent fires within the habitat and adjacent to known populations of *V. rupicola* in Peñuelas and Ponce have been observed by Service biologist Omar Monsegur (2011 and 2013). *Varronia rupicola* populations within the GCF may be protected, as this conservation area has an active fire control program (M. Canals, PRDNER, pers. comm. 2008). Nonetheless, Miguel Canals (former GCF manager) indicated that fires still occur within the forest, particularly on the periphery along roads (Canals, PRDNER, pers. comm. 2008). Moreover, accidental fires have been reported below the PREPA power lines adjacent to known populations of *V. rupicola*. Recent fires have been recorded in the proximity of known populations with the GCF (Montalva) and private lands adjacent to the Ponce Holiday Inn (Hamilton 2016; Omar A. Monsegur, Service, pers. obs. 2015).

Hurricanes and Climate Change

The islands of the Caribbean are frequently affected by hurricanes. The U.S. Virgin Islands have been hit by several major hurricanes in the past three decades: Hugo (1989), Luis and Marilyn (1995), Lenny (1999), Omar (2008), Irma (2017) and Maria (2017). Examples of the visible effects of hurricanes on the ecosystem include massive defoliation, snapped and wind-thrown trees, large debris accumulations, landslides, debris flows, altered stream channels, and transformed beaches (Lugo 2008). Successional responses to hurricanes can influence the structure and composition of plant communities in the Caribbean islands (Van Bloem et al. 2003, Van Bloem et al. 2005, Van Bloem et al. 2006, Lugo 2000). Hurricanes can produce sudden and massive tree mortality, which is variable among species (Lugo 2000). As endemic to the Caribbean, *V. rupicola* would be expected to be well adapted to tropical storms and the prevailing environmental conditions in this geographical area. However, the resilience of rare and endangered native species populations may be limited or constricted by the reduced number of populations and individuals, which may result in inbreeding depression and a reduced reproductive output (e.g., low seed production and dispersal, and reduced seed viability), making the populations vulnerable to stochastic events. Such is the case of the Vieques population, which is composed of only few individuals. For example, hurricanes cause disturbance that result in changes in the habitat structure (e.g., gaps). As stated above, invasive plants capitalize such habitat disturbance colonizing the gaps. This is the case of Puerto Ferro in Vieques Island where the *V. rupicola* population is very small and is being encroached by exotic plant species (Bermúdez-Carambot 2019). In fact, conservation efforts at the VNWR have included removal of exotic plants following Hurricane Maria to avoid the encroachment of *V. rupicola* individuals (Bermúdez-Carambot 2019).

Populations of *V. rupicola* may be threatened by climate change, which is predicted to increase the frequency and strength of tropical storms and can cause severe droughts (Hopkinson et al. 2008). Rather than assessing climate change as a single threat, we examined the potential consequences to species and their habitats that arise from changes in environmental conditions associated with various aspects of climate change. For example, climate-related changes to habitats or conditions that exceed the physiological tolerances of a species, occurring individually or in combination, may affect the status of a species. In fact, vulnerability to climate change impacts is a function of sensitivity, exposure, and adaptive capacity of species (IPCC 2007, Glick and Stein 2010). For instance, severe droughts may reduce seedling recruitment, as they may result in deaths of small plants, or may compromise flower and fruit development, and the viability of seeds. In areas in the Caribbean, the warming trend will continue, with increasing number of days per year over 35°C (95°F), and there is observed increase in droughts, which is expected to increase into the future (IPCC 2021). Despite the wide distribution of *V. rupicola* and the number of populations, the number of individuals per population (excluding Anegada Island) may be too low to sustain a positive recruitment rate of individuals. This may explain the low

number of intermediate-sized, non-reproductive individuals of *V. rupicola* observed from Guánica to Ponce in southern Puerto Rico, when compared to the high numbers of young seedlings (Omar A. Monsegur, Service, pers. obs. 2013). In fact, despite the high number of seedlings reported at Ponce (PRDNER 2013), entire clusters of seedlings have been extirpated due to thinning associated to severe drought events at this population (Omar A. Monsegur, Service, pers. obs. 2020). Thus, populations of *V. rupicola* that are reduced to a small area, and with few individuals, may be susceptible to extirpation due to severe drought events. Such is the case of the Vieques population where natural recruitment is reduced and there are only few clustered individuals (Table 1.). As stated above, this site is managed for exotic plants removal, and there is an ongoing program to secure *ex-situ V. rupicola* material (Bermúdez-Carambot, 2019).

On the island of Anegada, climate-induced sea-level rise could lead to the extirpation of *V. rupicola*. The preferred habitat of this species on that island is at lower elevations, and more than 40 percent of the island is less than 9.8 ft (3 m) above sea level (Wenger et al., 2010). Sea level rise modeling by Hamilton (2016), anticipates significant impacts to the populations of *V. rupicola* in Anegada within a one-hundred-year scenario, and highlights the indirect impacts to populations and suitable habitat due to development further inland and up slope. The most recent climate report indicates continued increase in sea level rise and associated coastal flooding and erosion as well as more extreme tropical cyclones with higher precipitation into the future (IPCC 2021). Therefore, we believe that cyclonic surges and coastal erosion associated with hurricanes, may affect the populations located along the coastal areas in Anegada as the sea level rises in the future. Considering the low elevation of the entire island of Anegada, the future impacts from sea level rise coupled with ongoing development may have a significantly adverse impact on the species conservation.

D. Synthesis

When *V. rupicola* was listed (2014) the number of known individuals in Puerto Rico (including Vieques) was estimated at approximately 109 adults and saplings, and by 2015, that number increased to 165 individuals. As of the time of this review, the *V. rupicola* populations are estimated at approximately 1,247 adult individuals (Puerto Rico: Guánica (193), Ponce (83), Vieques (12); BVI: Anegada West (629) and Anegada East (330)). In addition, approximately 262 saplings and 335 seedlings have been recorded as part of ongoing monitoring efforts (2012-2021). Nonetheless, the increase in the number of known individuals might not necessarily be the result of a population increasing trend or expansion, instead, it could likely be the result of increased survey efforts.

Varronia rupicola is currently known from five genetically unique populations across its range; Guánica, Ponce, Vieques, Anegada West and Anegada East (Hamilton 2016). In early 2020, the type locality at Indios Ward in the municipality of Guayanilla, Puerto Rico, was rediscovered (Hamilton et al., 2020). Due to proximity, the individuals at

Indios Ward are expected to be genetically similar to the Guánica population, however, further research is needed to confirm this.

At present, the species rarity and restricted distribution continue to make it vulnerable to habitat destruction and modification, as approximately 50 percent of known *V. rupicola* individuals in Puerto Rico occur on private lands subject to development. Many individuals in the past have been lost due to urbanization and incompatible habitat management of roads, trails, and rights-of-way. The habitat in the municipalities of Peñuelas and Ponce has been severely fragmented for urban development (i.e., housing projects, hotels, jails, landfills, rock quarries, and Puerto Rico Highway Number 2), and at Anegada Island, there is evidence of habitat modification, including vegetation clearing that resulted in the extirpation of significant numbers of *V. rupicola* individuals. In fact, we are unaware of any formal regulatory mechanism currently protecting the species in Anegada.

Despite that at the time of listing disease or predation were not considered to be threats contributing to the decline of *V. rupicola*, the species might be vulnerable to insect pests (e.g., *P. strachani*), suggesting the need for a broader monitoring to track this potential threat. Also, *V. rupicola* and its habitat continue to be affected by invasive plant species, which also promote favorable conditions for human induced fires. In addition, the impacts from hurricanes promote colonization of invasive plants that encroach *V. rupicola*. Thus, the reduced number and small size of *V. rupicola* populations in Puerto Rico, make the species susceptible to hurricanes and droughts events. Consequently, despite a higher number of *V. rupicola* individuals has been recorded, our analysis on the above threats indicates the species continues to meet the definition of a threatened species.

III. RESULTS

A. Recommended Classification:

____ **Downlist to Threatened**
____ **Uplist to Endangered**
____ **Delist***:*
__X_ **No change is needed**

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

- Validate the existing germination and propagation protocols to support reintroduction and population enhancement efforts and to provide guidelines to partners regarding the management of propagated material (e.g., avoiding mixing material from the different genetically unique populations).

- Secure *ex situ* collections from the five genetically unique populations (i.e., Guánica, Ponce, Vieques, Anegada West and Anegada East) by banking seed material and establishing living material collections in collaboration with other institutions (e.g., Fairchild Tropical Botanic Garden, Atlanta Botanical Garden, the Royal Botanic Garden, Kew).
- Enhance (augment) of the natural populations (Vieques, and Guánica) to numbers that secure its viability. The minimum number of individuals should be at least 250 reproductive individuals per population, showing evidence of natural recruitment on a 5 to 10-year timeframe, and that recruitment supports a stable or improving population growth rate. Site selection must provide connectivity with existing individuals and the area must provide conditions that minimize risk of habitat modification, human induced fires, and habitat intrusion by exotic plants). Based on the availability of research-based data on the species' population genetics, planting material from different sources is not recommended to enhance natural populations.
- Establish new populations to secure the genetic diversity of natural populations (i.e. Ponce, Vieques, Guánica, Anegada West, and Anegada East). The minimum number of individuals should be at least 250 reproductive individuals per population, showing evidence of natural recruitment on a 5 to 10 year timeframe, and that recruitment supports a stable or improving population. Site selection must provide connectivity with existing populations and the area must provide conditions that minimize risk of habitat modification, fires, and intrusion by exotic plants).
- Develop a habitat suitability model by incorporating data on forest cover, geology, elevation, and the species current distribution, to identify remnants of suitable habitat that may harbor extant populations or that may serve as future reintroduction sites.
- Develop a methodology using camera trapping to identify possible seed disperser and their role on the current distribution and abundance of *V. rupicola*, as well as to identify possible seed predators.
- Expand ongoing research on the species population genetics to include samples from recently discovered localities (e.g., type locality from Indios Ward in Guayanilla).
- Monitor for the presence and potential impacts from insect pest across the species range.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Varronia rupicola* (no common name)

Current Classification: Threatened.

Recommendation resulting from the 5-Year Review:

_____ Downlist to Threatened
_____ Uplist to Endangered
_____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Omar A. Monsegur-Rivera, Caribbean Ecological Services Field Office.

FIELD OFFICE APPROVAL:

Field Supervisor, Caribbean Ecological Services Field Office, Fish and Wildlife Service

Approve MARELISA RIVERA Digitally signed by MARELISA RIVERA Date: 2021.08.27 17:20:26 -04'00' Date _____

LEAD REGIONAL OFFICE APPROVAL:

Assistant Regional Director – Ecological Services, Fish and Wildlife Service

Approve JOHN TIRPAK Digitally signed by JOHN TIRPAK Date: 2021.09.27 09:07:32 -05'00' Date _____

APPENDIX A: Summary of peer review for the 5-year review of *Varronia rupicola* (no common name)

A. Peer Review Method/Charge:

The Service requested peer review of this 5-year status review from three independent reviewers outside the Service who are knowledgeable about *Varronia rupicola*. The request was sent via electronic mail and a 30-day review period was provided to all reviewers.

B. Peer Reviewers:

José A. Sustache-Sustache
State Botanist and Curator of the SJ herbarium
PR Department of Natural and Environmental Resources
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C. Summary of Peer Review Comments/Report:

We received comments from one of the three requests for peer review that were sent out. The reviewer recommended no changes to the 5-Year Status Review document. He further acknowledges that the information provided on the status of Varronia rupicola is the best available information.