

**Management Plan for the Bermuda White-eyed  
Vireo  
(*Vireo griseus bermudianus*)**



Government of Bermuda  
Ministry of Home Affairs  
Department of Environment and Natural Resources

# **Management Plan for the Bermuda White-eyed Vireo (*Vireo griseus bermudianus*)**

**Prepared in Accordance with the Bermuda Protected Species Act 2003**

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Cover photo: Adult Bermudian White-eyed Vireo  
Photo credit: Richard Brewer

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*“To conserve and restore Bermuda’s natural heritage”*

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## DISCLAIMER

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Management plans delineate reasonable actions that are believed to be required to manage or recover listed species. We, the Department of Environment and Natural Resources, publish management plans, sometimes preparing them with the assistance of field scientists, other government departments, and other affected and interested parties, acting as independent advisors to us. Plans are submitted to additional peer review before they are adopted by us. Objectives of the plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved. Management plans may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than our own. They represent our official position only after they have been signed by the Director of Environment and Natural Resources as approved. Approved plans are subject to modifications as dictated by new findings, changes in species status, and the completion of described actions.

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An electronic version of this plan will also be made available at [www.environment.bm](http://www.environment.bm)



Andrew Pettit  
Director  
Department of Environment and Natural Resources  
Bermuda Government



Date

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## EXECUTIVE SUMMARY

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This management plan addresses the need for actions to conserve the endemic subspecies of White-eyed Vireo (*Vireo griseus bermudianus*) on Bermuda.

### **Current Species Status**

Legal protection for this subspecies was first granted under the Protection of Birds Act in 1975 followed by the Protected Species Act in 2003. Bermuda's White-eyed Vireos are currently listed as 'Vulnerable' under the Protected Species Amendment Order (2016). Although a local population estimate has yet to be ascertained for this subspecies, birdwatching observations (since 2011) and active leg ringing (since 2017) by the author suggests the population comprises a conservative estimate of at least 2000 individuals, across the archipelago.

### **Habitat Requirements and Threats**

The White-eyed Vireo inhabits woodlands, copses, gardens, thickets, and overgrown fields. In precolonial times, the Bermuda White-eyed Vireo would have inhabited mixed forest stands of entirely native trees and shrubs. At present, it maintains a relatively large and stable population on Bermuda, where native forests have been largely replaced with introduced flora, forming horizontal, dense woodlands and thickets. Vegetation that supports food items, such as berries, insects, spiders, and caterpillars, are important for foraging. Branches which terminate with a stable fork that are at least 1m off the ground are crucial for nest cup placement. Important nest material includes palm fibers, bark, lichen, spider web silk, and caterpillar silk. Unfortunately, nest cup collapse is prevalent among Bermuda's vireos, suggesting suitable nesting material is a limiting factor. Adult males require a fairly large and intact area of woodland for stable pair formation and good breeding success. Although some males defend extremely fragmented and small territories, they appear less successful in attracting and keeping a mate, thus limiting their breeding opportunities. Consequentially, indiscriminant, large scale removal of wooded habitat through human development could threaten the vireo population in Bermuda. Nest contents of White-eyed Vireos are also predated by introduced pest species e.g. the Black Rat (*Rattus rattus*), Great Kiskadee (*Pitangus sulphuratus*), Argentine Ant (*Linepithema humile*), and possibly large anoles (Dactyloidae).

### **Management Objective**

The primary goal of this plan is to provide crucial ecological and biologically relevant data to inform management activities for the Bermuda White-eyed Vireo, as well as layout essential guidelines needed to preserve, protect, and facilitate population growth of this songbird. It is currently recognized as the only avian, terrestrial, endemic subspecies on the island and is thus of extreme conservation importance. It is with hope that this document will also encourage additional research and monitoring, mitigation of threats, and make the public aware of the practices they can adopt that will be beneficial to our local vireo.

### **Management Criteria**

A positive conservation status for the Bermudian White-eyed Vireo can be maintained with:

- Evidence that the local population remains stable or increases in abundance.
- Mapping vireo territories to understand home range areas necessary for survival and breeding.
- Identifying and mitigating introduced predators that threaten vireo nest success.
- Conducting population and threat assessments of other species known to provide important nesting resources for breeding vireos. E.g. Golden silk orb-weaver
- Increasing public awareness of this songbird and champion conservation efforts to protect it.

### **Actions Needed:**

1. Estimate population size, adult survival, and juvenile recruitment, through long-term monitoring of colour-ringed vireos.
2. Map territories and site fidelity of wild, colour-ringed vireos.
3. Encourage the public to practice vireo nest predator control to improve breeding success.
4. Conduct a field study on the ecology, distribution, and threats faced by the Golden silk orb-weaver.
5. Public awareness campaign on Bermuda vireo breeding behavior, nesting threats, and habitat management.

### **Management Costs**

The total cost of management actions cannot be defined at this point. Funding needs to be secured through non-governmental organizations (NGO's), overseas agencies, and other interested parties for implementing the necessary research and monitoring studies. Developing budgets for each action are the responsibility of the leading party as outlined in the work plan.



## PART I: INTRODUCTION

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### A. Brief Overview

The genus *Vireo* is currently comprised of 33 recognized species distributed from Alaska to South America, including the Caribbean and Bermuda (Slager et al. 2017, Winkler et al. 2020, Mejías and Nol 2020). Most species exhibit some shade of green in their plumage, hence the Latin word “*Vireo*,” which means “I am green.” Vireos are primarily insectivorous songbirds that inhabit vegetated habitats of varying degrees of thickness, ranging from dense boreal and deciduous forests to open fields with sparse bushes, shrubs, and thickets (Mejías et al. 2020). The International Union for the Conservation of Nature (IUCN) considers the extinction risk of most vireo species as being “Least Concern” (i.e. unlikely in the near future), including the North American White-eyed Vireo (*Vireo griseus*), the primogenitor of Bermuda’s vireo.

The North American White-eyed Vireo is native to the south-eastern United States. In this region, the bird is quite cryptic and is usually heard more than seen, as it vocalizes loudly within the tangles of dense shrubs and thickets. Migratory individuals return to their northern breeding sites by mid-April (Hopp et al. 1995) before their September-October winter migration to the Caribbean and Central America. Unlike their shy mainland counterpart, Bermudian White-eyed Vireos (*Vireo griseus bermudianus*) are bold and approachable, commonly venturing outside the thicket tangles to sing from exposed perches. In Bermuda, the earliest recorded specimen dates back to 1874-75. The collector provided the following account that reemphasizes its tameness: “*I have touched one with my gun in the thick bushes before it would bunch an inch*” (Reid 1884). The two races also differ in that *bermudianus* spends considerably less time on the wing, preferring to move with short, flutter hops, as opposed to the long, lopping flight of North American vireos.

This island subspecies is not migratory, but rather a year-round resident. Breeding on Bermuda begins in late February, with the last chick rearing occurring in September (Mejías, unpubl. data). Although an official population estimate of Bermuda White-eyed Vireos is unavailable, their presence in almost all remaining wooded habitats suggests they are fairly abundant.

This management plan highlights the ecology and natural history of the Bermuda White-eyed Vireo, and discusses proposed necessary steps needed to protect and conserve this subspecies. More specifically, Part I briefly outlines information on taxonomy, distribution, habitat requirements, biology, and threats towards this songbird. Part II lays out the proposed management objectives and gives specific work plan actions in a step-down narrative form. Part III concludes the document with a summary table which lists the priority tasks required to complete the management objectives.

## B. Taxonomy and Description of Species

**Kingdom:** Animalia

**Phylum:** Chordata

**Class:** Aves

**Family:** Vireonidae

**Genus:** *Vireo*

**Species:** *griseus*

**Subspecies:** *bermudianus*

**Common name:** White-eyed Vireo; better known in Bermuda as “*Chick-of-the-Village*,” or “*Chick-de-willy*.” Historically known as “White-eyed Greenlet,” (Jones 1859).

The White-eyed Vireo belongs to the family Vireonidae and genetic evidence suggests this species is most closely related to the Thick-billed Vireo (*Vireo crassirostris*; Slager et al. 2017, Mejías et al. 2020). Bangs and Bradley (1901) were the first to describe the Bermudian White-eyed Vireo and suggested it was a subspecies of the North American White-eyed Vireo. An updated phylogeny, where the Bermudian White-eyed Vireo was treated as a separate species, supports their hypothesis, with *V. griseus* and *V. g. bermudianus* emerging as sister species. The short branches on the phylogenetic tree between them suggests that *V. g. bermudianus* is a relatively recent arrival to Bermuda (Mejías et al.; in review). Although the North American White-eyed Vireo is a scarce, fall migrant to Bermuda, it does not breed with Bermudian White-eyed Vireos. Therefore, *V. g. bermudianus* could one day reach species-level endemism through reproductive isolation.

Physically, the Bermuda White-eyed Vireo (hereafter, “Bermuda vireo”) is a tiny songbird with green, yellow, grey, and sometimes brown, plumage colouration (Fig. 1). Total body length ranges from 115–130 mm (Mejías, unpubl. data) and body mass from 9.5-12.5 g (Table 1). Adults can be recognized by their white irises and black pupils, enclosed by lemon-yellow spectacles. They have a greyish hood, whitish throat, and a greyish-white belly boarded by yellow flanks. Their upper parts are uniform green, sometimes showing a vague yellow wash. Wings are marked with two bold yellowish-buff wing bars. Tail is green, notched, and moderate in length; undertail coverts are whitish. The Bermuda vireo has a bulbous, black, hooked-tip bill; it shares this bill shape with the rest of Vireonidae (Mejías et al. 2020). The Bermuda vireo is similar in appearance to the North American White-eyed Vireo, but *bermudianus* has noticeably longer tarsi that are black, as opposed to the bluish-grey tarsi typical of continental vireos (pers. obs). Bangs and Bradley (1901) also noted the longer tarsi in the Bermuda birds, as well as bearing shorter wings than the North American race. Table 2 summarizes morphology measurements taken from 10 Bermuda vireo specimens collected from Hamilton during the early twentieth century (Bangs and Bradley 1901). The wing chord, tarsus length, and bill length (i.e., “exposed culmen”) measurements of present-day are congruent with historical measurements (see Tables 1 and 2; Mejías, unpubl. data).

Bermuda vireo fledglings are similar in appearance to adults, with the exception of a dark iris and less brightly coloured plumage (Fig. 2). Compared to adults, many physical features of young Bermuda vireos are muted. Most obviously, young birds lack the

quintessential white eyes of adults. With maturity, the eye colour gradually changes from coffee-brown, to dark grey, to greyish-white, to pure white, from 1 year (Mejías, pers. obs.) to two (Pyle 1987). The spectacles and flanks of juvenile vireos are also drab yellow compared to adults.



**Figure 1:** Photograph of an adult Bermuda vireo. Note the diagnostic white eye from which the species' common name is derived. Other noteworthy traits include the bright yellow spectacles, flanks, greenish upperparts, and two bold buffy-yellow wing bars. Photographed by Luke Foster.



**Figure 2:** Photograph of a juvenile Bermuda vireo. Photographed by Richard Brewer.

**Table 1:** Morphology measurements taken from Bermuda vireos captured and colour-ringed in 2017. \*Bill length represents exposed culmen.

Body Mass (g)	Wing Chord (mm)	Bill Length* (mm)	Tarsus Length (mm)
12.5	57	8.9	24.7
11	60	9.4	26
9.5	60	9.4	24.9
11.5	60	9.2	23.3
11	59	10.8	22.4
11.5	61	9.8	23
12	62	11.2	25.7
11.5	62	9.4	24.7
12.5	61	10.2	23.9
11	60	9.6	25.1

**Table 2:** Summary of historical morphology measurements taken from Bermuda vireos.  
*Measurements.*

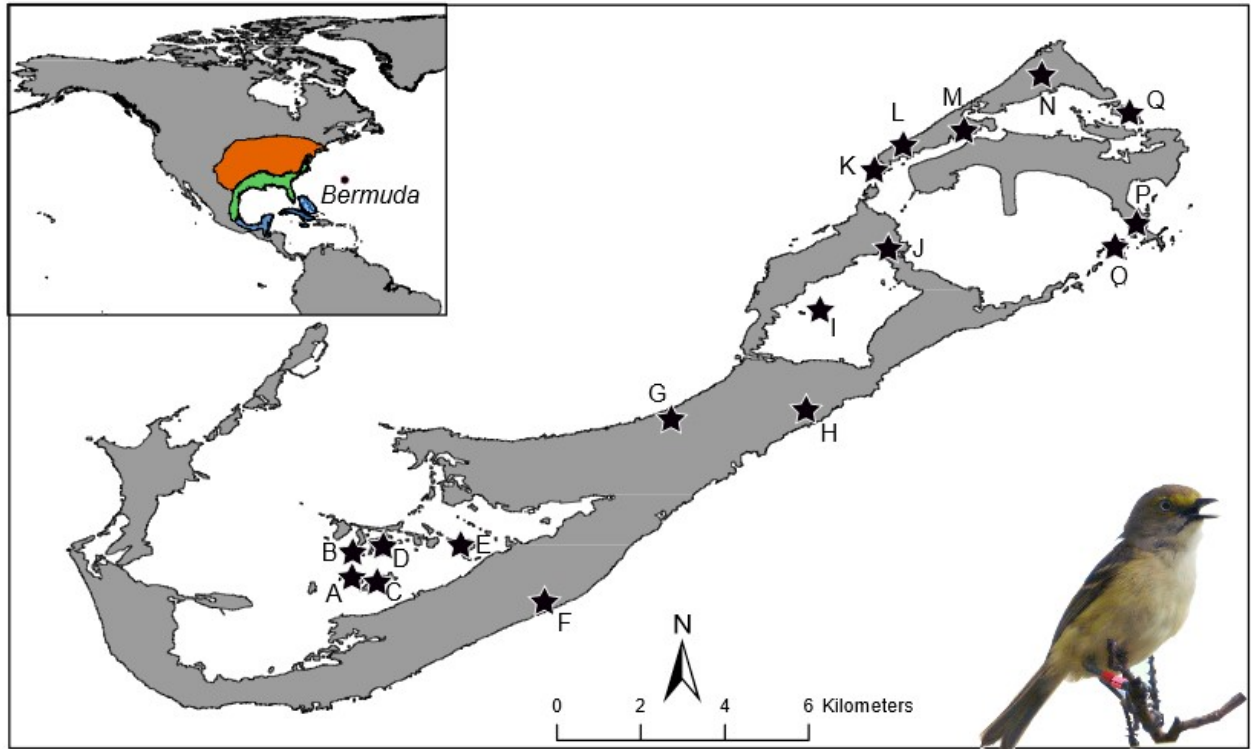
No.	Sex.	Wing.	Tail.	Tarsus.	Exposed Culmen.
39131 Mus. Comp. Zoöl. Type.	♂	58	46	20.4	10.6
1 Bradlee Coll.	♂	59	46.5	20.4	11
2 "	♂	59	47	20.2	11
3 "	♂	58	45	20.6	10.4
4 "	♂	59	46.5	20.2	10.4
8 "	♂	59.5	47	20.2	10.4
10 "	♂	58	45	21	10.6
11 "	♂	59.5	47	20.4	10.8
4162 Bangs Coll.	♂	59.5	47	21	11
4161 "	♂	59	48	21	10.6

Vireo vocal displays are the loudest and most conspicuous of any of Bermuda's native terrestrial avifauna. The primary song of this species, performed only by males, is often described as "explosive" (Bradley 1980, Borror 1987), with song elements comprised of chips, buzzes, and whistles uttered rapidly. A Bermudian rendition of this song, "*Chick-of-the-Village*," gives the bird its nickname. Additional song interpretations include "*ginger-beer-quick*" and "*chick-choo-willio*" (Bangs and Bradley 1901). If compared to the English language, each song can be thought of as a single sentence, with each song having a fixed/predictable structure lasting about one second long. Male Bermuda vireos appear to have a repertoire of about 7-10 songs (Mejías, unpubl. data). Males use these songs for mate attraction and territory defense (Bradley 1987, Mejías, unpubl. data). A second vocal display typical of this species are scolding calls, which are nasally, harsh, whining notes that are uttered either singly or in quick succession. These calls are used by both sexes, usually during territorial conflicts, perceived threats, and even directed at birdwatchers who use "pishing" calls (Mejías, pers. obs).

## C. Current Status

### **Subspecies Range**

The Bermuda vireo is only found on the Bermuda archipelago. Although sedentary like the White-eyed Vireo subspecies in the southern United States and Mexico (Hopp et al. 1995, Somershoe et al. 2005), *bermudianus* likely descended from the North American, migratory subspecies, *V. griseus griseus*, which breeds in the northern states during the spring and summer (Nolan and Woldridge 1962, Somershoe et al. 2005) and migrates to the Caribbean and the Yucatan Peninsula for the winter (Hopp et al. 1995, Somershoe et al. 2005; Fig. 3). Bermuda's proximity to the eastern seaboard makes the island an occasional stopover site for migrant vireos (Fig. 3).



**Figure 3:** A map of the Bermuda archipelago depicting all sites (“stars”) where Bermuda vireos have been captured and colour-ringed, between 2015 and 2021: A: Burt’s Island (N = 3 birds ), B: Gamma Island (2); C: Darrell’s Island (18); D: Port’s Island (16); E: Hinson’s Island (17); F: ABS Nature Reserve (2); G: Oceanview Golf Course (8); H: Spittal Pond (16); I: Trunk Island (3); J: Blue Hole/Tom Moore’s Tavern (7); K: Ferry Point Park (102); L: Lover’s Lake (5); M: BIOS (3), N: St. George’s Golf Course (34); O: Nonsuch Island (6); P: Cooper’s Island (1) and Paget Island (4). Note, while the Bermuda vireo is indeed found across the archipelago, stars only denote sites where birds were captured and colour-ringed. The inset map depicts the ranges of the North American White-eyed Vireo; orange represents the breeding range of migratory individuals, green represents the year-round range of non-migratory individuals, and blue represents the wintering range of migratory individuals. Photo of colour-ringed Bermuda vireo by Neal Morris.

## **Local Distribution**

### Historical Distribution

Historical records suggest the Bermuda vireo was abundant island-wide. Reid (1884) described it as “*one of the commonest resident Bermuda birds.*” It was often seen foraging 3-12 feet from the ground among cedars, mangroves, “holly” pomegranate, and lemon trees, with most sightings occurring in cedars (Reid 1884). Jones (1859) described it as “*found in abundance all the year round.*” Bowditch (1904) echoed these testaments, stating “*this bird ranks with the Cardinal and the Catbird in point of numbers; everywhere one goes, he hears its characteristic song, translated into ‘chick-of-the-village’ by the negroes.*” Even towards the end of the 20<sup>th</sup> century, which marked a drastic increase in human development and increased forest fragmentation (Dobson 2002), this tiny vireo was still considered abundant island wide by local birdwatchers and naturalists (Amos 1991).

### Contemporary Distribution

The Bermuda vireo can be readily found in almost all wooded areas across mainland Bermuda and offshore islands; some of these sites allowed several to be readily captured, colour-ringed, and studied (Fig. 3). It is easily the most abundant native songbird on the island, with local birdwatchers reporting sightings of them year-round (eBird, Bermuda sightings database). They are most abundant in large, intact wooded areas, such as Ferry Point Park, Spittal Pond, Hog Bay Park, and Southlands (Mejías, pers. obs). In contrast, they appear virtually absent in the center of the heavily developed city of Hamilton and city parks, but become readily apparent in wooded areas on city boundaries, and beyond (Mejías, pers. obs).

## **Species Protection**

Following IUCN criteria, the Bermuda White-eyed Vireo is listed as ‘Vulnerable’ (D1 + 2) under the Protected Species Amendment Order (2016). Current legal protection is provided by the Protected Species Act (2003) which considers the willful destruction, damage, removal or obstruction of habitats, and the taking, importing, exporting, selling, purchasing, or transporting this species an offence. Offenders are liable to a fine of up to \$25,000 or two years imprisonment.

## **Habitat Protection**

Some woodlands inhabited by vireos occur in Government owned nature reserves and parks and are therefore afforded protection under the Bermuda National Parks Act (1986). Others occur within privately owned lands that have varying levels of protection depending on how they are zoned by the Department of Planning (i.e. Nature Reserve, Woodland Reserve, and Open Space Reserve).

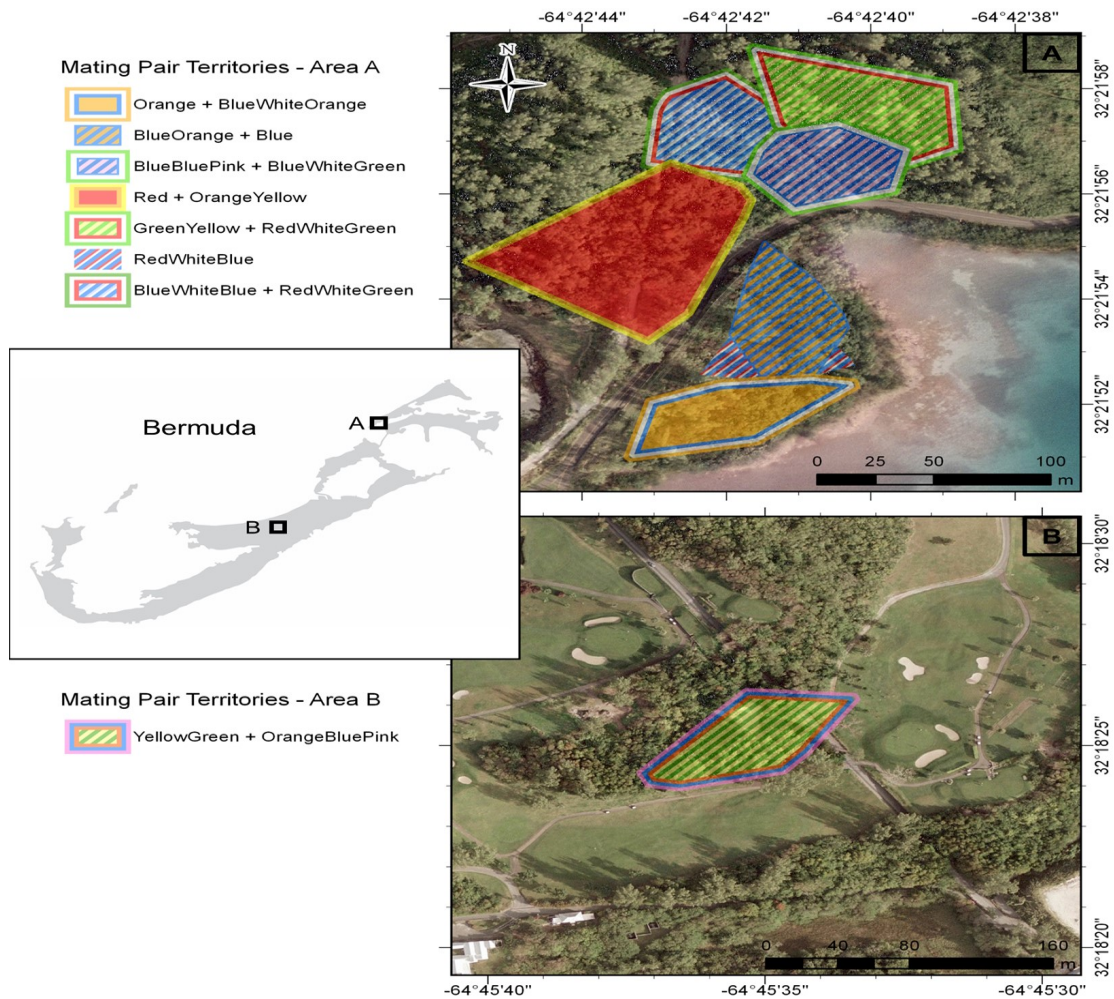
## D. Ecology

### Habitat Requirements

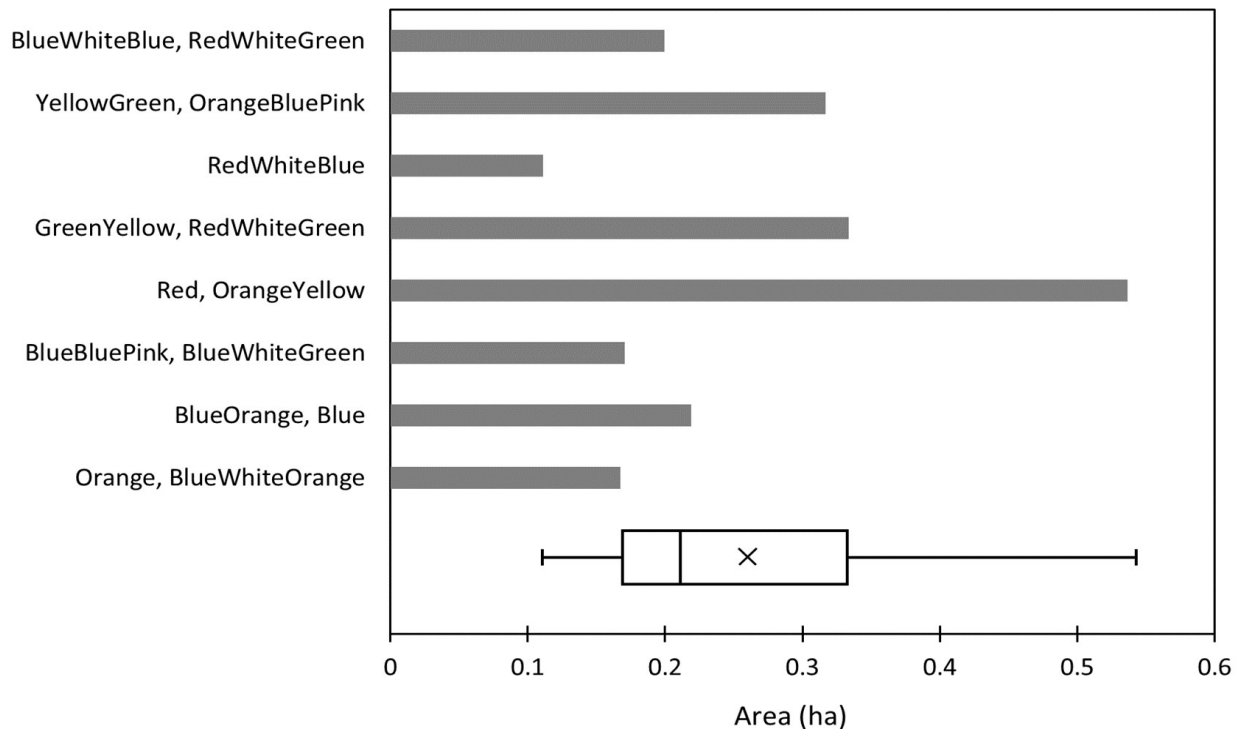
The White-eyed Vireo nests within thickets as well as in sparse, shrubby, open habitat (Winkler et al. 2020). In North America, this species is found nesting in scrubby, second growth forest and marsh edge, with birds sometimes distributed patchily (Bradley 1980). Continental vireos are considered habitat generalists (Peake and Ritchison 1998, Kovar 2015). Prior to human settlement, the Bermuda vireo would have inhabited woodlands and thickets comprising mostly native, evergreen flora. A typical precolonial woodland would have had Bermuda Cedar (*Juniperus bermudiana*), Bermuda Olivewood (*Elaeodendron lananum*), Bermuda Palmetto (*Sabal bermudana*), Southern Hackberry (*Celtis laevigata*), and Yellowwood (*Zanthoxylum flavum*) as canopy trees, and shrubs such as Bermuda Sedge (*Carex bermudiana*), Bermuda Snowberry (*Chiococca alba*), and Bird Pepper (*Capsicum baccatum*) dominating the understory (Britton 1918, Bermuda Plant Finder 2016). In present-day Bermuda (21st century) the majority of the woodlands and thickets across the island are second growth forests made almost entirely of introduced and invasive trees. Arguably the most drastic changes in Bermuda vireo habitat was the loss of the Bermuda Cedar dominated forests during the middle of the 20th century, following excessive logging and accidental introductions of two scale insects (Challinor and Wingate 1971, Tucker 1970). Woodland species now include Casuarina (*Casuarina equisetifolia*), Brazilian Pepper (*Schinus terebinthifolia*), Chinese Fan Palm (*Livistona chinensis*), and Allspice (*Pimenta dioica*) as canopy trees, and Asparagus Fern (*Asparagus densiflorus 'Sprengeri'*), Asparagus Wedding Fern (*Asparagus setaceus*), and sapling Suriname Cherry (*Eugenia uniflora*), as the lower shrubby layer. Bermuda vireos are also habitat generalists, and are found nesting and defending territories comprised largely of introduced trees and shrubs (Mejías and Nol 2020). Bermuda Cedar and Southern Hackberry are the most commonly used native nesting trees, whereas Brazilian Pepper and Suriname Cherry are the favoured introduced trees (Mejías, pers. obs).

Bermuda vireo territories require sufficient size to have an ample supply of plants that provide food and nesting material. Preliminary territory mapping revealed neighboring males occupy well-defined, largely non-overlapping territories, varying in size from approx. 0.1-0.5 acres (average 0.26 acres) (Mejías and Musiuk unpubl. data; Fig2 4 and 5). These territories are defended by the males year-round. It is also important for the tree species that make up the territory to attract sufficient insect prey items and produce adequate berries and fruits for consumption (see “Diet and Feeding” below for more details). Similarly, various tree species that provide nesting material and attract silk-producing spiders and caterpillars (see “Reproduction” below for more details) are essential for nest construction. For these reasons, a mixed woodland would be more productive than a monoculture woodland.





**Figure 4.** Preliminary territory data of 8 neighbouring colour-ringed male Bermuda White-eyed Vireos at Ferry Point Park (top panel) and 1 male at Oceanview Golf Course (bottom panel) studied between 2016 and 2017. GPS points were collected with a Garmin handheld GPS unit (3m accuracy) corresponding to multiple sightings of banded individuals.



**Figure 5.** Histogram depicting territory size of the same 8 colour-ringed male Bermuda White-eyed Vireos in Fig. 6. Ring colour on the left and right of comma represent banded male and female vireos, respectively. Male (Red + White/Blue) had the smallest territory, and was the only male who was unable to attract a female. The “X” marks the average territory size among males.

## Reproduction

Bermuda vireos can usually be found travelling in pairs, with both sexes sometimes shadowing one another year-round. Unpaired males generally ascend to higher perches and sing tirelessly until paired, at which point males sing primarily in the understory (Mejías, unpubl. data). Their nesting season spans February — September, marking the start and end of nest building and fledgling feeding, respectively (Mejías, unpubl. data). Local colour-ringing revealed that vireos can breed as early as their first year of life and can live to at least 6 years of age. Their neat, bowl or cup-shaped nests are constructed with plant matter and trash, which carry their small (length:  $\bar{x} = 18.9$  mm, width:  $\bar{x} = 14.5$  mm,  $n = 2$  eggs, 1 clutch), white and brown eggs (Fig. 6). Bermuda vireos appear to produce only one brood a year, although pairs have been observed building as many as 5 successive nest cups in a season, each following nest failure (Mejías, unpubl. data). Their nest construction usually begins with the male securing the first bit of nest material, most commonly a piece of polyphil cotton (Fig. 7), suggesting the male selects the nest-site. Both sexes then begin adding bits of plant matter to build an outer wall, comprised largely of loose tree bark and leaves collected from plants, like Bermuda Palmetto,

Allspice, and Cow Cane (*Arundo donax*), and then dotted with tufts of green moss and lichen (*Ramalina denticulata*), presumably for camouflage. Silk collected from spiders and caterpillars help bind this nest material together. The incredibly durable webbing from the Golden silk orb-weaver, known locally as the “Hurricane Spider,” was once commonly used in nest construction (Wingate, pers. comm). There was also an account of a Bermuda vireo within the Hungry Bay mangrove trees with thick webbing (likely from the Golden silk orb-weaver) completely covering its right eye (Bowditch 1904). Finally, the nest is lined with fine, reddish-brown straw fibers, collected from the trunk base of both Bermuda Palmetto and Chinese Fan Palm, which the vireos smooth out via foot stomping. Peake and Ritchison (1998) outline three important criteria for nest cup placement for continental White-eyed Vireos, and these are also practiced by Bermudian vireos (Mejías, pers. obs): (1) nests are suspended at least 1 m of the ground, (2) branches of nest trees should terminate with a strong, “Y-shaped” fork that can support a hanging nest cup, and (3) some degree of foliage concealment for the nest cup. Their tendency to use almost any tree species that exhibit these characteristics undoubtedly favoured their survivability on the heavily developed and populated Bermuda archipelago.

Breeding data is based on a subset of the author’s doctoral thesis. Nest construction takes about 4-12 days ( $n = 4$  nests,  $\bar{x} = 7$  days), with the male often quitting during the final few days of nest building, where he closely shadows the female on collecting trips, whilst constantly flicking his wings (Mejías, pers. obs); wing-flicking is recognized as a copulatory display in some songbirds (Dunham 1964, Brooker and Saffer 1996). Bermuda vireos may abandon a nest if it’s in close proximity to busy foot traffic or if the nesting pair discovers someone too close to their nest, although abandonment appears less likely when eggs or chicks are present (Mejías, pers. obs.). Egg laying usually begins 3-4 days after nest cup completion. Clutch size ranges from 1-4 eggs, with 3 being the average. Both sexes partake in incubation (about 14 days,  $n = 2$  clutches,  $\bar{x} = 14$  days) and chick rearing in the nest (9-12 days,  $n = 2$  broods,  $\bar{x} = 11$  days). After fledgling, the male and female split the brood, the former often looking after most of the young (as many as 3 at once), and proceed to feed them in different parts of the territory (Mejías, pers. obs). While males usually feed their fledglings inside his territory, females commonly guide their young beyond her mate’s boundaries, usually feeding them inside neighbouring territories (Mejías, pers. obs). At this stage, fledglings can be heard giving insistent begging calls, which sound like a primitive version of this subspecies’ scolding calls. Throughout fledgling feeding, adult plumage becomes oily and unkempt, as feeding duties take precedence over preening (Mejías, pers. obs). Parents rear fledglings for 21 – 55 days ( $n = 4$  feeding fathers,  $\bar{x} = 41$  days) before young disperse (several kilometers) from natal territories.



**Figure 6.** Photographs of Bermuda White-eyed Vireo nest (left) and a 3 egg clutch from a different nest cup (right). The nest cup is suspended from an Allspice (*Pimenta dioica*) tree.



**Figure 7.** A piece of polyphil debris suspended from a Brazilian Pepper (*Schinus terebinthifolia*) branch by an unpaired male Bermuda vireo, decorated with the lichen, *Ramalina denticulata*. This is likely a “bachelor pad” nest that unpaired males sometimes build to attract a prospecting female.

### **Diet and Feeding**

Continental White-eyed Vireos in the breeding season mainly consume insects and spiders (Nolan and Wooldridge 1962). During the non-breeding season they switched to a primarily plant-based diet (Greenberg et al. 1995). Similarly, Bermuda vireos in the breeding season primarily eat insects and spiders, with their most common prey being bright, lime green caterpillars (Fig. 8). This is most notable during the chick-rearing period, when their facial feathers become soiled, matted, and stringy from the bodily fluids of pulverized caterpillars (Mejías pers. obs). Additional spring and summer prey items include small flies (Arthropoda), spiders (Arthropoda), dragonflies (Anisoptera), moths (Lepidoptera), anoles, and nestling fecal sacs (Mejías pers. obs). Bermuda vireos locate their prey by methodically peering at the surface and undersides of branches, twigs, and leaves, while busily flutter-hopping. They primarily hunt amongst perches 2-5 meters above ground (Mejías pers. obs). This vireonid is quite versatile in its foraging behaviour. They seize aerial prey with quick bill snaps, a sound reminiscent of a “twig snap,” either by extending their head whilst perched, hovering in mid-air, or in passing

flight between perches. Foraging birds may sometimes abruptly fall several meters to a lower perch following an aerial bill snap. Larger prey items (i.e., moths, caterpillars, and anoles) are often held in the bill and beaten against a hard perch or secured between the feet where they are pecked and dismembered prior to consumption. Bermuda vireos also capture prey by hanging from them with just their bill (Fig. 8). A small Jamaican Anole (*Anolis grahami*) on the underside of a branch was seen captured in this manner, where the vireo swung from the anole's neck, until the lizard lost its grip, and the two tumbled to a lower branch, with the vireo landing upright, and proceeded to peck and dismember the lizard held between its feet, prior to feeding it to a fledgling (Mejías pers. obs). In the winter, Bermuda vireos incorporate more plant matter in their diet. Reid (1983) reports them eating the white berries of "*Tournefortia*" and Bird Pepper (*Capsicum baccatum*). Fruits from Bermuda Snowberry, Poison Ivy (*Toxicodendron radicans*), Turkey Berry (*Callicarpa americana*), and Brazilian Pepper are likely additional sources of winter food.



**Figure 8.** Photographs of Bermuda vireos consuming caterpillars. The bright green species depicted in the left panel is likely a Green Looper (*Chrysodeixis eriosoma*). Right panel depicts the “hanging” prey capture method this subspecies uses to secure wedged or secured food. Photographs by Richard Brewer.

## E. Current Threats

### Local

The Bermuda vireo is largely threatened by anthropogenic factors. As early as 1982, new housing units were erected at a rate of 300 units/yr, making present-day Bermuda, whose population surpassed 62,000 people, one of the most densely populated oceanic islands in the world (1,275 people/km<sup>2</sup>; Wingate 1990, Dobson 2002). The replacement of wooded areas with urban development has resulted in approximately 14% of the archipelago being covered by impermeable surfaces (Dobson 2002). Consequently, development has diminished and fragmented woodlands the vireo requires for foraging, shelter, and reproduction (Fig. 9).

Introduced nest predators threaten eggs and developing chicks (Mejías, unpubl. data). For example, Argentine Ants (*Linepithema humile*) can devour down-free nestlings. The Great Kiskadee (*Pitangus sulphuratus*) was observed attacking a Bermuda vireo brooding recently hatched nestlings, and the nest was found destroyed a few days later. The Black Rat (*Rattus rattus*), a common predator of seabird eggs and chicks in Bermuda (Mejías et al. 2017), were sighted frequently on the ground directly underneath vireo nests, and nestlings often disappeared a few days following daytime rat sightings. Large Antiguan Anoles (*Anolis leachii*) occasionally approached vireos inside nest cups, causing the latter to spread its wings and tail, but have yet to be seen consuming nest contents; this anolis lizard has been documented eating Eastern Bluebird (*Sialia sialis*) eggs in Bermuda (Dobson, pers. obs.).

Lastly, nest collapse was observed to be fairly high, with almost every pair studied experiencing at least one nest cup falling apart throughout each breeding season. At no point did any nesting pair attempt to repair damage after nest cup completion. Observed nest collapse may be because of insufficient nesting material availability, specifically the scarcity of the highly durable webbing from the Golden silk orb-weaver, which was not found in any of the collected nest cups (~ 50 nests). Ironically, this same webbing has led to the ensnarement of Bermuda vireo fledglings (Reid 1884), which would undoubtedly kill the young birds if they couldn't escape. Direct sources of mortality of adults are scant at this time, although their tendency to remain in higher perches among dense thickets, as opposed to feeding openly on the ground, appears to greatly reduce their vulnerability to cats and wintering raptors.



**Figure 9.** A bulldozed upland hillside at White Crest Hill in Hamilton Parish where Bermuda vireos are known to abundantly occur.

## F. Current Conservation Actions

Local conservation effort towards the Bermuda vireo has been sporadic and scant. In 1972, Dr. David Wingate captured and translocated several individuals in an attempt to reestablish breeding pairs on the recently reforested Nonsuch Island (Wingate 1990). In 2015 a local birdwatcher, Paul Watson, began colour-ringing Bermuda vireos under license from the Department of Environment and Natural Resources in an effort to understand their survival and site fidelity. In 2017 a doctoral study investigating their singing behaviour, breeding biology, and nesting threats was initiated by the author of this management plan. Indirectly, the Bermuda vireo has received long-term benefits through habitat protection granted by the National Parks Act (1986) which has preserved various tracts of woodland across Bermuda.



## PART II: MANAGEMENT

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### A. Management Goal

The ultimate goal of this management plan is to promote the persistence and population growth of the only remaining endemic, terrestrial, subspecies of bird on the Bermuda archipelago, the Bermuda White-eyed Vireo. This plan presents crucial information on the ecology, natural history, and threats pertaining to the Bermuda White-eyed Vireo, and this data should prove useful in driving proactive measures to protect this vireonid. This can ultimately be achieved by doing a census study on Bermuda vireo numbers, obtaining legislative protection for currently unprotected wooded sites known to support vireos, making landowners aware of available nest predator control resources, proposing alternative invasive tree management practices, and increasing the general public awareness of this endemic subspecies.

**The short-term (5 years):** To expand capture and colour-ringing field survey sites of adult and juvenile Bermuda vireos and perform a population assessment based on these marked birds. Identify privately owned large tracts of woodland (> 0.5 ha) capable of supporting multiple vireo pairs and liaise with landowners on habitat management practices that will benefit the vireo. Begin advocating for better nest predator control and woodland management among homeowners. Initiate field studies investigating the abundance, distribution, and threats facing the Golden silk orb-weaver in Bermuda, whose strong webs are likely a limiting resource for nest building vireos. Finally, spread local awareness of this vireonid through public lectures and local advertisements.

**Long-term (20 year):** Monitor and publish findings on the stability, size, and distribution of the Bermuda vireo population across the island. Establish legislative protection for large, privately owned woodlands. Using field data collected during the short-term period, produce a report on the biology, abundance, and threats, facing Bermuda's Golden silk orb-weaver, as well as any interactions between this arachnid and Bermuda vireos. Assess Bermuda vireo nesting success in areas where predator control efforts have been implemented annually to establish how it varies from unmanaged sites. Finally, continue to present current data pertaining to the ecology, population status, threats, and conservation efforts aimed at this subspecies.

## B. Management Objective and Criteria

### **Management Criteria**

A positive conservation status for the Bermudian White-eyed Vireo can be maintained with:

- Evidence that the local population remains stable or increases in abundance.
- Mapping vireo territories to understand home range areas necessary for survival and breeding.
- Identifying and mitigating introduced predators that threaten vireo nest success.
- Conducting population and threat assessments of other species known to provide nesting resources for breeding vireos. E.g. Golden silk orb-weaver
- Increasing public awareness of this songbird and champion conservation efforts to protect it.

### **Actions Needed:**

1. Estimate population size, adult survival, and juvenile recruitment, through long-term monitoring of colour-ringed vireos.
2. Map territories and site fidelity of wild, colour-ringed vireos.
3. Encourage the public to practice vireo nest predator control to improve breeding success.
4. Conduct a field study on the ecology, distribution, and threats faced by the Golden silk orb-weaver.
5. Public awareness campaign on Bermuda vireo breeding behavior, nesting threats, and habitat management.

This management plan acknowledges both the straightforward and difficult efforts deemed necessary to ultimately favour population stability and growth of the Bermuda vireo. Traits that facilitate their management include their present-day island-wide abundance, tame nature, conspicuous vocal displays, catchability with mist nets, and their willingness to breed in a broad diversity of tree species, both native and introduced. In contrast, several aspects of their breeding present significant management obstacles. Not only are their nests extremely small and cryptic, they are prone to human-induced abandonment, and have contents that are vulnerable to a diverse array of superabundant, introduced predators that overlap extensively with breeding sites. Despite these challenges, if the proposed actions in this management plan are implemented, even at suboptimal levels, it will undoubtedly favour the persistence of nesting Bermuda vireos across the archipelago.

## C. Tools Available for Strategy

### **Mist Netting and Banding/Ringing**

Mist netting is a capture technique that uses a fine meshed net suspended between two tall poles. Mist nets can be raised in a narrow clearing in a wooded habitat or in a sparse, open area, depending on the habitat of the target species. Ideally, mist nets are installed in places where the environmental background and lighting conditions reduce visibility of the mesh to target birds. Mist nets are lined with shelves or “pockets” where captured birds fall and hang from (Fig. 10). Birds can either be captured passively, by waiting for individuals to fly into the net, or, actively, by placing a speaker and audio device that broadcasts the songs/calls near the net to lure birds in; both mechanisms have proven to be extremely effective in capturing Bermuda vireos (Mejías, pers. obs.). The latter method, however, is more likely to skew capture rate towards male Bermuda vireos, because they respond more aggressively towards playbacks of the species’ song and calls (Mejías, unpubl. data). It is imperative that active mist nets are monitored closely so that captured birds can be readily and safely removed, thereby reducing stress and risk of injury. A pair of bird banding/ringing pliers should be used to fit a single metal identification ring on one leg, as well as the addition of colour-ring(s) on either leg for individual recognition from afar (Fig. 10).



**Figure 10.** Bermuda vireo captured via mist netting (left) and banded (right).

The uttermost care should be taken to ensure the leg colour ID sequence is not repeated for individuals belonging to the same species. Colour-rings are tiny, hollow, plastic cylinders made of celluloid or darvic. Caution should be taken when stacking colour-rings onto birds to avoid tarsal swelling; this symptom was always seen with the stacking of darvic colours, not celluloid (Mejías, pers. obs.). Leg irritation can be greatly reduced by using one colour ring, per leg. Mist netting and ringing of birds requires extensive training from an experienced and licensed bird bander. Experienced individuals may apply for a local bird banding permit at the Department of Environment and Natural Resources. This

permit will be necessary to purchase mist nets, birding banding pliers, and leg rings from an overseas supplier. There is an extensive literature on the methodology on safely mist netting and ringing captured songbirds (see Stamm et al. 1960, Dunn and Ralph 2004, Avinet Research Supplies 2019).

### **Point Count Surveys**

Point counts are another standard methodology used to census wild birds during which an observer stands in a single spot for a specific time period and records the presence and numbers of individuals and species seen or heard within a specified radius (Hutto et al. 1986, Leu et al. 2017, Campomizzi et al. 2020). Despite its popularity in field ornithology, the technique comes with inherent biases and limitations (see Simons et al. 2009). For example, although radius point counts were effective in estimating Bermuda vireo abundance in wooded habitats across the island (Mejías and Nol 2020), most individuals were detected by their song, a signal only produced by males, thus underestimating the species' true abundance by excluding females. Furthermore, their singing rate changes with respect to whether or not males are paired with a female (Mejías, unpubl. data). In light of this limitation, radius point counts should be combined with other surveying techniques in order to get a more accurate abundance estimate for this subspecies. Nonetheless, point counts are, at the very least, appropriate for presence and absence vireo surveys.

### **Nest Predator Control**

At least three predators have been recognized as threats to Bermuda vireo nests: Argentine Ant, Black Rat, and Great Kiskadee. All are introduced pests. Although these threats can be readily managed on small, wooded, offshore islands where Bermuda vireos nest, their superabundant presence on mainland Bermuda makes total eradication highly improbable. Nonetheless, limited measures can be taken to ease predation pressure on mainland nesting pairs. Both ants and rats can be controlled with poison bait. The number of poison bait required will ultimately depend on the size of the wooded areas, as well as the estimated abundance of vireos, rats, and ants. Inquiries about the handling, distribution, and purchase of rodenticides should be directed to Bermuda Vector Control. Ant poisons can be locally purchased from a variety of hardware stores. Controlling kiskadees will prove to be more challenging. Live capture using letterbox (aka ladder) traps has shown some promise and should be used in the future.

### **Bermuda Audubon Society and Bermuda Natural History Museum**

Additional information and live encounters of the Bermuda vireo can be acquired through the Bermuda Audubon Society. This local charity hosts several birdwatching, photography walks, and lectures throughout the year, both of which provide ideal opportunities to observe the Bermuda vireo in their habitat. Experienced, local birders also routinely attend these events, serving as an additional source of information on the local vireo. The Bermuda Natural History Museum is also an excellent resource for local publications on the Bermuda vireo, as well as study skins available for research purposes.

## E. Step-down Narrative of Work Plan

Abbreviations used in Section E and Part III:

DENR – Department of Environment and Natural Resources

BAMZ – Bermuda Aquarium Museum and Zoo

BAS – Bermuda Audubon Society

BVC – Bermuda Vector Control

BBB – Buy Back Bermuda

MM – Miguel Mejías

The actions needed to achieve effective management are as follows:

### ***1. Estimate population size, adult survival, and juvenile recruitment, through long-term monitoring of colour-ringed vireos.***

Actions proposed:

- Mist net and colour-ring adult and fledgling Bermuda vireos,
- Revisit field sites at least twice a year, once in the breeding season and once in the non-breeding season, and document recaptured or re-sighted vireos,
- Map general localities of where colour-ringed vireos were captured, recaptured, and re-sighted,
- Encourage public to report or photograph encountered colour-ringed vireos.

**Work Team:** MM and DENR

**Team Leader:** MM

**Assistance:** BAMZ, volunteers, graduate students, visiting researchers

**Outputs:** A long term dataset comprised of recaptured and re-sighted colour-ringed vireos which can be statically analyzed for estimates of population abundance and survival.

**List of equipment required:** Vehicle to get to sites, mist nets, metal and colour rings, banding pliers, breathable, cotton bags to hold captured vireos, binoculars, and a computer with appropriate statistical/survival analysis software installed.

### ***2. Map territories and site fidelity of wild, colour-ringed vireos.***

Actions proposed:

- Visit all field sites several times a year, and use a handheld GPS unit to collect GPS points where colour-ringed birds were seen/recaptured,
- Plot these GPS points onto a map and calculate territory sizes,
- Monitor breeding activities of individuals being mapped.

**Work Team:** MM, DENR, BAS, BAMZ

**Team Leader:** MM

**Assistance:** BAMZ, volunteers, graduate students, visiting researchers

**Outputs:** A report containing a series of maps outlining site fidelity, territory size, and temporal changes in said territory size, and its implications on nesting Bermuda vireos.

**List of equipment required:** A vehicle to get to study sites, a handheld GPS (Garmin units, with ~3m accuracy are sufficient), a physical or digital fieldbook, binoculars, and a computer with appropriate mapping software.

**3. *Encourage the public to practice vireo nest predator control to improve breeding success***

Actions proposed:

- Promote effective methods of predator control on private properties to reduce rat and ant abundance (e.g. poisons and trapping)
- Promote proper sanitation methods at home by reducing shelter and food sources available to rats and ants,
- Discuss and collaborate with BVC to achieve realistic poison control efforts, for a property,
- Follow-up with landowners on whether or not they still detect rats and ants, after practicing predator control,
- Monitor the number of vireo fledglings heard or seen (a measure of vireo productivity) in the property, before and after predator control efforts.

**Work Team:** MM, DENR, BVC

**Team Leader:** MM, DENR

**Assistance:** BAS, landowners, hired groundskeepers of managed sites

**Outputs:** The extermination of rats and ants on small, wooded, offshore island residential properties that also support breeding Bermuda vireos. A reduction in predation on the Bermuda mainland. A revitalized obligation and appreciation in the steps island residents can take to protect our local vireo, and other native species.

**List of equipment required:** Binoculars, physical or digital fieldbook, rat/ant poison, poison bait boxes, mist nets, and letterbox traps.

**4. *Conduct a field study on the ecology, distribution, and threats faced by the Golden silk orb-weaver, whose strong webs were known to be used by nesting Bermuda vireos, and is likely a limited resource, due to a perceived drastic decline in this local arachnid.***

Actions proposed:

- Encourage the general public to report sightings of Golden silk orb-weavers,
- Conduct field surveys to quantify the abundance and distribution of Golden silk orb-weavers across the island,
- Use field observations to document habitat preference, interactions with nesting vireos, and threats

**Work Team:** DENR and MM

**Team Leader:** MM

**Assistance:** General public, local school students, volunteers, graduate students, visiting researchers.

**Outputs:** A report, possibly even a management plan, for the Golden silk-orb-weaver, outlining the status of this species, its ecological interactions with other species,

especially with nesting vireos, current threats, and proposed steps that might be needed for their rebound in numbers.

**List of equipment required:** A vehicle to travel to different sites, a physical or digital fieldbook, a handheld GPS unit, trail cameras, and binoculars.

**5. *Increased public awareness on Bermuda vireo breeding behavior, nesting threats, and habitat management.***

Actions proposed:

- Research lectures on the breeding biology and threats faced by Bermuda vireos,
- Create a “Backyard Vireo Management” pamphlet for public dissemination,
- Make these pamphlets available for landowners with small (i.e., at least 0.5 - 1 ha) and large ( $\geq 1$ ha) woodlands,
- Advocate that landowners attempt to do extensive tree removal outside the Bermuda vireo nesting season, to prevent breeding disruptions,
- Similarly, suggest to landowners interested in native forest restoration to do a gradual cull and replant approach, as opposed to total eradication of invasive trees and replanting young, native trees.

**Work Team:** DENR and MM

**Team Leader(s):** MM and DENR

**Assistance:** BAMZ, BZS, BAS, general public, landowners, hired groundskeepers of managed sites.

**Outputs:** Increased island-wide awareness of the reliance of Bermuda vireos on their wooded habitat, and how subtle changes to landscaping practices may benefit this subspecies.

**List of equipment required:** A vehicle to travel to different sites, landscaping equipment that is appropriate for targeted trees, and binoculars.

## F. Estimated Date of Down Listing

The Bermuda White-eyed Vireo is currently listed as ‘Vulnerable’ (D1 + 2) under the Protected Species Amendment Order (2016). Despite its present-day island-wide distribution in nearly all thickets and woodlands, an official estimate of their numbers is currently unknown. The suggested series of capture, ringing, and monitoring programs in this Management Plan is essential in obtaining a more accurate estimate of their abundance, so that strategic decisions can be made with respect to down listing. Their island-wide distribution, high mist nest catchability, and tameness, are all traits that favour feasible assessment of their survival and abundance in the wild. A population assessment study of at least 5 years should be sufficient to determine a reliable estimate of population size and health necessary to consider the Bermuda vireo as a suitable candidate for down listing.

## PART III: IMPLEMENTATION

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*Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.*

*Priority 2: An action that must be taken to prevent a significant decline in the species population/habitat quality, or some other significant negative impact short of extinction.*

*Priority 3: All other action necessary to provide for full recovery of the species.*

Priority #	Task #	Task description	Task Duration	Responsible Party
		<b>Population Size and Survival</b>		
2	1	mist netting vireos	ongoing	MM
2	2	revisiting field sites	ongoing	MM
2	3	mapping general study sites	1-2 months	MM
3	17	encourage public bird sightings	ongoing	MM, DENR, BAS
		<b>Territory Mapping</b>		
2	4	collect GPS points	ongoing	MM
2	5	map GPS points	1 year	MM
2	6	monitor breeding of ringed vireos	ongoing	MM
		<b>Nest predator control</b>		
2	7	lecture to public	ongoing	MM, BAS
2	8	presence and abundance surveys	1-4 days	MM, DENR, BAS
2	9	promote nest predator control	ongoing	MM, DENR, BAS
2	10	work plan with BVC	1-2 days	MM, DENR, BAS
2	11	post-predation control follow-up	1-2 days	MM
2	12	monitor fledglings heard	4-5 months	MM, DENR, BAS
		<b>Silk Spider Surveys</b>		
3	18	encourage public to report sightings	1-2 years	MM, DENR, BAMZ
3	19	field surveys on spiders	1-2 years	MM, DENR, BAMZ
3	20	assess field observations and cameras	2 years	MM, DENR, BAMZ
		<b>Public Awareness and Management</b>		
2	13	public lectures	ongoing	MM, BAS, DENR
2	14	promote alternate tree culling strategies	ongoing	MM, BAS, DENR
2	15	create vireo management pamphlet	2-3 weeks	MM, DENR
2	16	make pamphlet available to public	4-5 months	MM, DENR



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