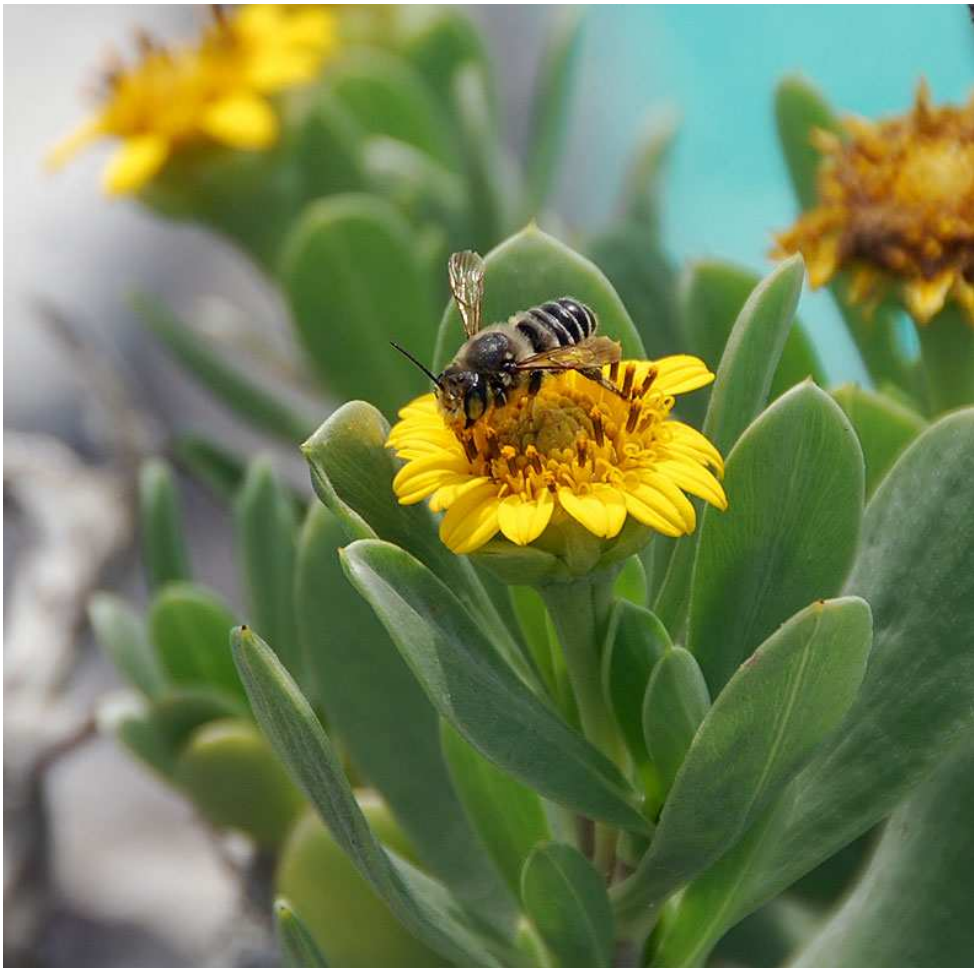
Recovery Plan for the Leafcutter Bee, *Megachile pruina pruina*, on Bermuda



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

Recovery Plan for the Leafcutter Bee, *Megachile pruina pruina*, on Bermuda

Prepared in Accordance with the Bermuda Protected Species Act 2003

Authors

This recovery plan was prepared by:
Mark Outerbridge (mouterbridge@gov.bm) and
Tommy Sinclair (tjsinclair@gov.bm)

Cover photo: Solitary bee collecting pollen from sea-ox eye
Photo credit: Drew Pettit

Published by

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

"To conserve and restore Bermuda's natural heritage"

CONTENTS

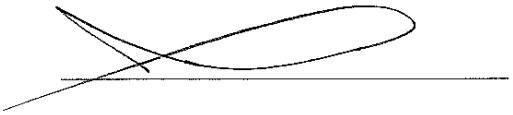
LIST OF FIGURES & TABLES

DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the Department of Environment and Natural Resources, publish recovery 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 recovery plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved. Recovery plans may not represent the views nor the official positions or approval of any individuals or agencies involved in the recovery 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 recovery plans are subject to modifications as dictated by new findings, changes in species status, and the completion of recovery actions.

Literature citation of this document should read as follows: Outerbridge, M.E. and Sinclair, T.J. 2017. Recovery Plan for the Leafcutter Bee, *Megachile pruina pruina*, on Bermuda. Department of Environment and Natural Resources, Government of Bermuda. 22 pages.

An electronic version of this recovery plan will also be made available at www.environment.bm



27th Feb 2018

Andrew Pettit
Director
Department of Environment and Natural Resources
Bermuda Government

Date

EXECUTIVE SUMMARY

Current Species Status:
Legal protection for leafcutter bees on Bermuda is provided by the Protected Species Act (2003). Leafcutter bees are classified as Vulnerable (VU) under the Protected Species Amendment Order (2016).

Habitat Requirements and Threats:
Bermuda's leafcutter bees are only known from a few coastal locations within the Castle Islands Nature Reserve, which makes them very vulnerable to the effects of climate change (i.e. inundation due to sea level rise and increased coastal erosion caused by hurricanes). At this point in time, other local threats to the species are unknown.

Recovery Objective and Actions Needed:
Favorable conservation status will be achieved when there is a better understanding of the status of Bermuda's leafcutter bees as well as baseline data which can be compared with future changes observed within the local population. Improved conservation status for this species on Bermuda will occur when the following has been accomplished:

1. Genetic analysis to confirm the taxonomic status of Bermuda's leafcutter bees (i.e. are they native or non-native; could they possible be an endemic sub-species?)
2. Conduct surveys to determine current distribution and estimate relative abundance of leafcutter bees on Bermuda.
3. Identify the scope and severity of the threats to Bermuda's leafcutter bees.
4. Initiate research on the biology and ecology of leafcutter bees on Bermuda (e.g. foraging and nesting material preferences, annual reproductive output).
5. Trial using artificial nest blocks as a means of providing suitable nesting habitat outside of the known coastal range.
6. Develop public awareness about the importance of bees to Bermuda.

Recovery Costs:
The total cost of recovery 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

A. Brief Overview

Bees are flying insects that play a critical role in plant pollination. Some species are colonial (e.g. honey bees and bumble bees) while others are solitary (e.g. leafcutter, mason, and carpenter bees). Nectar and pollen collected from flowering plants is used as sources of energy and protein by bees at different life stages. During the process of gathering nectar and pollen, bees fertilize the flower they forage from. Solitary bees are considered to be excellent pollinators but because they are not a colonial bee species, like the European honeybee, they are not traditionally used for commercial crop pollination (a notable exception is the alfalfa leafcutter bee *Megachile rotundata*). However, interest in leafcutter bees is increasing due to widespread global declines in honeybee populations (see Young et al. 2016).

Hilburn et al. (1990) listed three species of bee from Bermuda; the ground nesting bee *Halictus semiviridis* (once very common but not seen or collected since the nineteenth century), the leafcutter bee *Megachile pruina pruina* (a cavity nesting, solitary species), and the European honeybee *Apis mellifera* (introduced from England circa 1616 and presently the most abundant bee on Bermuda).

This recovery plan outlines threats and conservation efforts for leafcutter bees on Bermuda, summarizing known distribution, habitat requirements and reproductive cycle. Very little is known about the biology and ecology of Bermuda's leafcutter bees, or the threats they face. They presently have a limited distribution and are found within coastal environments on South Shore, particularly in St. George's Parish.

B. Taxonomy and Description of Species

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hymenoptera
Family: Megachilidae
Genus: *Megachile*
Subgenus: *Pseudocentron*
Species: *pruina*
Sub-species: *pruina* (formerly *bermudensis*)
Common name: Leafcutter bee

The genus *Megachile* contains 50 subgenera with nearly 1500 recognized species (Wedmann et al. 2009), of which 395 species from 26 subgenera are Neotropical (i.e. tropical terrestrial regions of the Americas and the entire South American temperate zone) (Raw 2004). According to Young et al (2016) the identification to species-level of most leafcutter bees is challenging because the morphological differences between species are subtle.

Mitchell (1929) considered the leafcutter bees on Bermuda a new variety of *M. pruina* and described their physical characteristics, using a single female specimen, below (note that male and female leafcutter bees are known to differ considerably in their morphology).

"*Size: Length 13 mm; breadth of abdomen 5 mm; anterior wing 9 mm.*

Structure: Head broad; eyes slightly converging below; clypeus entire apically, the margin slightly thickened and shining medially; mandibles 4-dentate, cheeks as broad as eyes; vertex flat, hind margin slightly concave; lateral ocelli slightly nearer edge of vertex than to nearest eye; basal joint of flagellum longer than the second joint; hind metatarsi almost as long and as broad as the tibiae; abdomen cordate, the apical margins of the segments rather strongly depressed laterally, but not medially; segment six straight in profile, slightly concave at sides in dorsal aspect, with only suberect black hairs visible in profile, the ventral plate bare except for a marginal fringe of black hairs, the apical margin extending as a bare lip beyond the apical fringe.

Puncturation: Close on cheeks and pleura, and on clypeus except in center; on the vertex close on either side of the median line, more sparse laterally; distinctly separated on mesonotum medially, but close laterally and anteriorly, and quite widely separated on scutellum; fine and close on basal abdominal segment, becoming relatively coarse and sparse on segment five, close and fine on segment six.

Color: Black; the tegulae and antennae below more fuscous; the wings quite uniformly infuscated, with fuscous nervures; spurs pale yellow.

Pubescence: White at sides of face, between antennas, on cheeks, pleura, propodeum, coxae, femora, tibiae, and basal abdominal segment; black on vertex, mesonotum, scutellum, and discs of abdominal segments 2-5, with intermixed black hairs between antennae; more fuscous on clypeus, front tibiae and tarsi anteriorly, and on outer face of mid tarsi; segments 2-5 with narrow entire white apical fasciae; segment six whitish tomentose, with erect black hairs laterally, these subappressed medially; scopa white, black on segment six and at extreme sides of segment five."

For a full description of male *M. pruina pruina* within the North American range see www.discoverlife.org/20/q?search=Megachile+pruina

Mark Outerbridge

Figure 1. Leafcutter bee on Southampton Island

Leafcutter bees look similar to honeybees, but they have broader heads and larger mandibles (for cutting leaves). They carry pollen within stiff hairs on the underside of their abdomens (the scopa), rather than in pollen baskets on their legs; this often gives them a yellow-orange appearance.

C. Current Status

Global Distribution

The genus *Megachile* is found virtually everywhere there are flowering plants (note New Zealand is an exception); however most species are tropical in origin. On the American continent *Megachile* ranges from Alaska to southern Chile and Argentina, as well as on islands throughout the Caribbean (Raw 2004). The sub-species *Megachile pruina pruina* occurs in the southeastern U.S.A. and ranges from North Carolina to Florida (Hilburn et al. 1990) through to Texas (Mitchell 1962).

Local Distribution

Information describing the historical distribution of this species is very limited. The first confirmed record of a leafcutter bee on Bermuda occurred in May 1913; however the collection location was not described (Mitchell 1929). Anecdotal information suggested their presence on Delta Island in the Great Sound during the 1970s and 1980s (Faries pers. comm.). Hilburn et al (1990) reported that leafcutter bees were no longer present on the main islands of Bermuda and only survived on Nonsuch Island. More recent observations have revealed that Cooper's Island and Southampton Island also serve as foraging and nesting areas (J. Madeiros, *pers. comm*.; M. Outerbridge, *pers. obs.*) (Fig. 2).

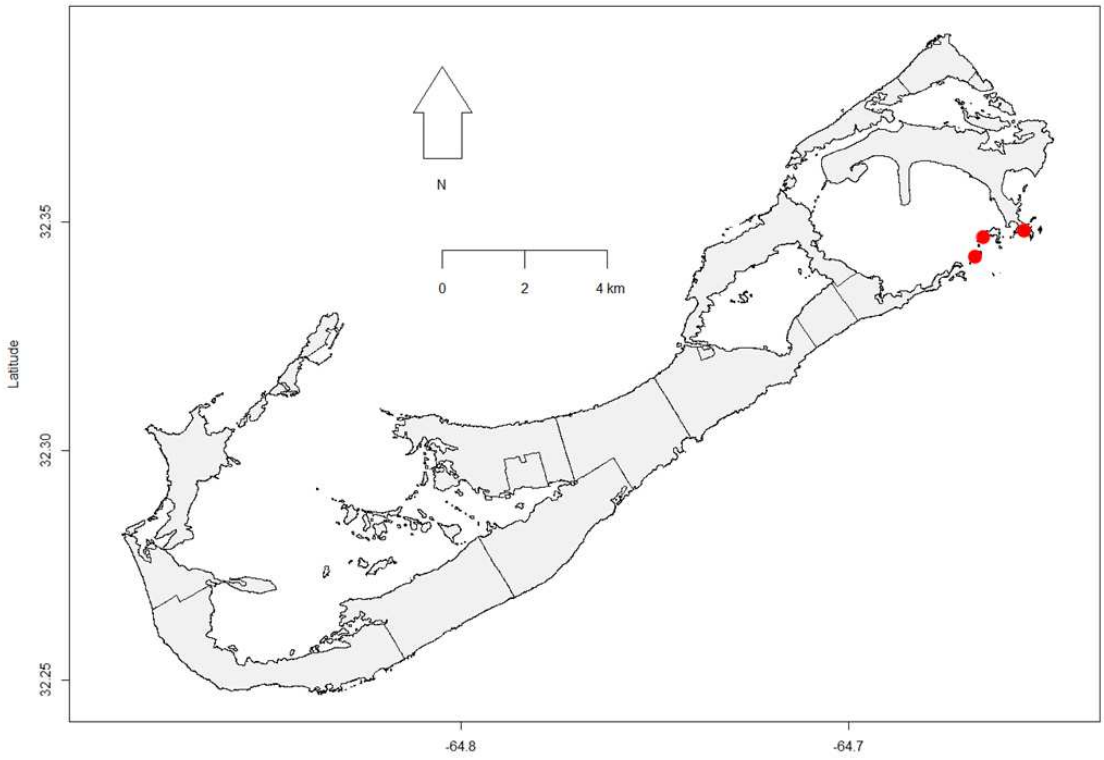


Figure 2. Known leafcutter bee distribution on Bermuda in 2017

At the time of writing, 12 leafcutter bees were accessioned in the specimen collection of the Bermuda Natural History Museum, and one was in the insect reference collection at the Plant Protection Laboratory at the Botanical Gardens. The collection dates and locations are summarized in Table 1 in the Appendix.

Species Protection

Legal protection for the leafcutter bee is provided by the Protected Species Act (2003) and is classified as Vulnerable (VU) under the Protected Species Amendment Order (2016).

Habitat Protection

Some of the localities where leafcutter bees have been observed foraging and nesting are within park lands and nature reserves (i.e. Cooper's, Nonsuch and Southampton Islands), and are therefore protected under the National Parks Act (1986). The National Parks Regulations (1988) provide additional protection by prohibiting the destruction and collection of any plants and animals found within protected areas under the Act.

D. Ecology

Habitat Requirements

Foraging

Female leafcutter bees generally prefer to harvest soft flexible leaves for nest construction. On Bermuda these plants include roses (*Rosa spp*.) (Ogilvie 1928), Jamaica dogwood *Dodonaea viscosa* (Hilburn et al. 1990), Virginia creeper *Parthenocissus quinquefolia,* peach *Prunus persica,* burr bush *Triumfetta semitriloba* and wax myrtle *Myrica cerifera* (Pettit 2016; T. Sinclair, pers. obs.). These plants are found in a variety of habitats; upland coastal, upland hillside, garden, arable land and peat marsh. Adult bees have been observed foraging for food on sea ox-eye *Borrichia frutescens* (see cover photo), a succulent plant that is very common in the rocky coastal environment. Pimentel (2010) reported that leafcutter bees were important pollinators of native plants on coastal sand dunes in California, U.S.A.

Nesting

Leafcutter bees historically nested in walls on the main islands of Bermuda (Ogilvie 1928); however nesting is now only known to occur within the rocky limestone coastal environment, a habitat generally characterized by rough, jagged ridges with small, sharply pointed peaks and many cavities of varying size (Fig. 3a). This environment is frequently affected by salt spray, high winds and inundation during stormy weather (i.e. winter gales, summer tropical storms, autumn hurricanes). It is unclear how this affects the survival rate of bees, especially those in the pre-pupal stage of development (i.e. overwintering fully developed larva in diapause).

The rocky coastal habitat (defined as lands which extend from the high water tide mark inland up to 15 m above sea level) is approximately 368 acres in area (Anderson et al. 2001) and encompasses most of Bermuda's shoreline, a linear distance of 296 km (Meyer et al. 2015). An additional 855 acres of land comprises the upland coastal habitat (Anderson et al. 2001). Present range size for leafcutter bees on Bermuda is unknown; however anecdotal reports within the North American range suggest that individuals have a small home range which makes them vulnerable to localized threats.

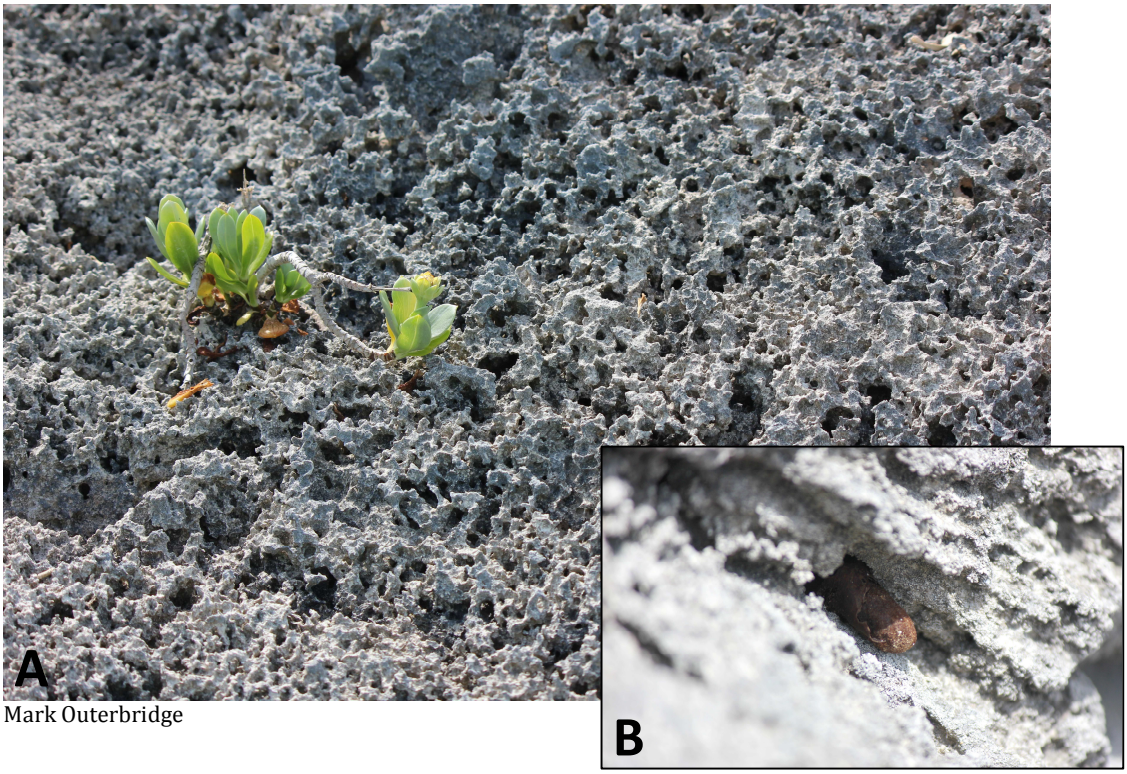
Life Cycle

Leafcutter bees are solitary; there is no queen and individuals do not live together in a social unit. This species exhibits complete metamorphism (i.e. egg, larva, pupa, adult). Nesting on Bermuda has been observed in June and involves the selection of a suitably sized cavity which is then lined with pieces of leaves harvested from specific plants. Once a favoured leaf has been found, the female will use her mandibles to cut a semicircular section (Fig. 4), roll it up and fly back to the nest holding it between her legs. This will be repeated several times until the cell has been constructed, at which point the female will lay a single egg, add food and cap off the opening with additional leaf material (Fig. 3b). Fertilized eggs produce female offspring; unfertilized eggs produce males (Mader et al. 2010). A larva subsequently hatches and feeds upon the provisions while progressing through the various larval stages of development. After pupating, the adult chews through the end cap and emerges. The duration of the nesting

season on Bermuda is unknown and it is presently unclear if leafcutter bees have one brood or multiple broods each year.

Diet

Adult leafcutter bees feed on flower nectar and pollen; larvae feed upon a mixture of both while transitioning through the instar growth stages within their cells. It is unclear if the Bermuda bee diet is highly specialized or whether their limited distribution is restricting their ability to forage on more diverse plants.



Mark Outerbridge

Figure 3. (A) An example of the rocky coastal limestone environment used by nesting leafcutter bees on Bermuda. (B) End cap of a bee nest on Southampton Island.

Tommy Sinclair

Figure 4. Circular leafcutter bee incisions on Virginia creeper leaves (left) and peach leaves (right).

E. Current Threats

Leafcutter bees comprise the largest percentage of potentially at-risk species of any insect group that has been comprehensively assessed for conservation status by NatureServe. Of the native species known to be extant in North America, 47% are considered to be at risk for extinction. The species *Megachile pruina* has been given a conservation rank of 'vulnerable' (see Young et al. 2016). Habitat loss and/or degradation, pathogens and pesticide use have been cited as contributing to leafcutter bee declines.

On Bermuda, the loss and/or replacement of traditional drystone walls with solid concrete walls may have led to diminished nesting across the main islands, thereby possibly restricting nesting activity to rocky and upland coastal environments. Unfortunately these habitats are highly susceptible to the impacts of climate change, which include inundation due to sea level rise and increased coastal erosion caused by storm activity. The rate of coastal erosion will also increase with increasing storm intensity. Glasspool (2008) calculated that 32% of the Island's rocky coastal habitat would be lost with a 0.59 m rise in sea level and a loss of 52.7% with a 2 m rise. Horn Rock, Charles Island and Southampton Island, three islands within the Castle Islands Nature Reserve, have all experienced cliff collapse which was attributed to wave action and heavy rainfall associated with major storms during the past 15 years (Glasspool 2008; Madeiros pers. comm.).

Honey bees on Bermuda are affected by some viruses (e.g. sacbrood, deformed wing virus and black queen cell virus), fungal pathogens (e.g. American foulbrood, European foulbrood, chalkbrood, nosema), parasites (e.g. Varroa mites) and pests (e.g. wax moth); however it is unlikely that many of the above threaten the leafcutter bees. An exception

may be chalkbrood, which has been identified as a serious problem in managed populations of leafcutter bees (i.e. alfalfa) throughout the USA and Canada (see Mader et al. 2010 and Young et al. 2016). The full effects that bacteria, viruses and fungi have on Bermuda's leafcutter bees warrant particular study.

In North America, insect pests and predators known to kill the developmental stages of solitary bees include dermestid and tenebrionid beetles (which consume the stored food and incidentally kill bee larva), bee flies, and parasitoid wasps from the genera *Leucospis*, *Melittobia*, *Monodontomerus* and *Tetrastichus* (which kill and consume developing bee larva, pupa and adults before the host can leave the cell (see Mader et al. 2010)). Nine species of dermestid beetles, 15 species of tenebrionid beetles and at least three species of parasitoid wasps from the genus *Tetrastichus* have been recorded from Bermuda (Hilburn and Gordon 1989; Hilburn et al. 1990) but it is unknown if any negatively impact leafcutter bees. Bee flies and parasitoid wasps from the genera *Leucospis*, *Melittobia* and *Monodontomerus* were not present on Bermuda at the time of writing (Smith, pers. comm.).

Bees are negatively affected by pesticides (i.e. insecticides, herbicides, fungicides) world-wide either through drinking contaminated nectar, consuming contaminated pollen, absorption through the exoskeleton and, in the case of leafcutter bees, harvesting contaminated leaf pieces for nest construction. Poisoning can result in death or, if sub-lethal, damage to the nervous system which impairs movement, navigation and behaviour. Studies have shown that some species of leafcutter bees are more sensitive to certain pesticides than honey bees (see Young et al. 2016). In Bermuda, some of the most commonly used groups of pesticides indirectly involved in poisoning (sub-lethal levels and rare mass die-off event) of insect pollinators (including the accidental poisoning of bees) are the organophosphates (e.g. malathion), neonicotinoids (e.g. imidicloprid), carbamates (e.g. carbaryl) and pyrethroids (e.g. cypermethrin). Other groups of pesticides are used in Bermuda on a regular basis and may also occasionally be to blame for negatively impacting pollinators. The application of these chemicals occurs on lands used for commercial farming as well as in private garden settings.

F. Current Conservation Actions

Leafcutter bees are not currently being researched, or are the focus of any direct conservation actions, on Bermuda. Indirectly, the strict policies regarding the importation of any live bees (regardless of species) or used apiary equipment to Bermuda offers some protection against the introduction of non-native pathogens.

PART II: RECOVERY

A. Recovery Goals

The aim of this Recovery Plan is to determine if leafcutter bees are a native, or an endemic sub-species to Bermuda, and to improve local knowledge about its life history. If proven to be a native/endemic element of Bermuda's fauna, steps that will lead to population and range expansion should be undertaken.

B. Recovery Objective and Criteria

Favorable conservation status will be achieved when there is a better understanding of the status of Bermuda's leafcutter bees as well as baseline ecological data which can be compared with future changes observed within the local population. The short-term (five year) recovery objectives are to undertake comparative genetic analysis of specimens collected from Bermuda with specimens collected across the native range in the SE U.S.A. as well as initiate research on the biology and ecology of leafcutter bees on Bermuda. The longer-term (30 year) objectives involve protecting and managing favored habitats, including nesting sites and floral resources, so as to maximize recovery efforts for this species.

C. Recovery Strategy

There is a dearth of information about Bermuda's leafcutter bees which is challenging for conservationists to make management decisions. Leafcutter bee presence can be determined during vegetation surveys, which should be undertaken in May and June, to find evidence of circular incisions on the leaves of favoured plants. Additionally, the effective use of nest blocks will help determine reproductive biology, aid in the study of nest pathogens and pests and, if placed in suitable environments, may lead to population and range expansion across Bermuda. Given the fact that Bermuda's leafcutter bees appear to nest within the rocky coastal environment, it would be prudent to trial cut limestone blocks in addition to other materials.

D. Tools Available for Strategy

Research and monitoring plans for this group of bees are available from other regions, and should be used to guide the appropriate research undertaken on Bermuda. Methodologies for survey techniques have already been developed in other countries (e.g. Larsson and Franzen 2008) and should be used or modified as required. Nest blocks are commonly used overseas (e.g. Mader et al. 2010, MacIvor 2016) and should serve as a starting point for any local experimentation.

E. Step-down Narrative of Work Plan

Abbreviations used in Section E and Part III:

DENR – Department of Environment and Natural Resources
BBA – Bermuda Beekeepers Association

The actions needed to achieve recovery are as follows:

1. Genetic analysis to confirm the taxonomic status of Bermuda's leafcutter bees (i.e. are they native or non-native; could they possible be an endemic sub-species?)
2. Conduct surveys to determine current distribution and estimate relative abundance of leafcutter bees on Bermuda.
3. Identify the scope and severity of the threats to Bermuda's leafcutter bees.
4. Initiate research on the biology and ecology of leafcutter bees on Bermuda (e.g. foraging and nesting material preferences, annual reproductive output).
5. Trial using artificial nest blocks as a means of providing suitable nesting habitat outside of the known coastal range.
6. Develop public awareness about the importance of bees to Bermuda.

1. Genetic analysis to confirm the taxonomic status of Bermuda's leafcutter bees.

Actions proposed:

- Collection and appropriate preservation of male and female bees (see Raw 2004),
- Analysis of genetic materials (potentially as a collaborative cross-regional project),
- Publish results.

Work Team: Leafcutter bee specialist, DENR
Outputs: Confirmation of native/endemic status of extant population on Bermuda.

2. Conduct surveys to determine current distribution and estimate relative abundance of leafcutter bees on Bermuda.

Actions proposed:

- Undertake presence/absence surveys, beginning within coastal environments along South Shore,
- Develop and undertake appropriate survey methodology for population assessment.

Work Team: DENR, graduate student
Outputs: Range map for Bermuda identifying areas that have the largest populations of leafcutter bees.

3. Identify the scope and severity of the threats to Bermuda's leafcutter bees.

Actions proposed:

- Determine if leafcutter bee nests are parasitized by other insects,
- Determine if leafcutter bees are negatively affected by any pathogens,
- Initiate research into the impact that pesticides might have on leafcutter bees on Bermuda.

Work Team: DENR
Assistance: Members of the BBA and general public.
Outputs: Report on the various threats negatively affecting Bermuda's leafcutter bees.

4. Initiate research into the biology and ecology of leafcutter bees on Bermuda.

Actions proposed:

- Determine the various foraging and nesting plant preferences,
- Study reproductive cycle.

Work Team: DENR, graduate student
Outputs: Report which includes the favored forage plants, preferred nesting substrates, and a description of their reproductive biology.

5. Trial using artificial nest blocks as a means of providing suitable nesting habitat outside of the known coastal range.

Actions proposed:

- Experiment with nest block design (e.g. tunnel diameter, tunnel depth, block material) and nest block placement,
- Investigate the effectiveness of using manmade nest blocks in comparison with cavities in the natural environment.

Work Team: DENR
Assistance: Members of the BBA and general public.
Outputs: nest blocks that are used by leafcutter bees on Bermuda.

6. Increase public awareness about the importance of bees to Bermuda.

Actions proposed:

- Develop materials which explain why bees are critical to Bermuda's plants and the agricultural industry,
- Develop a campaign which promotes friendly gardening practices for all bee species on Bermuda.

Work Team: DENR, local media, BBA

Outputs: Awareness raising documents and engagement of the community.

F. Estimated Date of Down Listing

It is anticipated that the natural history research may take up to three years to complete and that it will take three to five years to confirm the genetic status of Bermuda's leafcutter bees. Should the species prove to be a subspecies endemic to Bermuda; its classification will be re-assessed immediately.

PART III: IMPLEMENTATION

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
1		**Clarify taxonomic status**		
	1	Collect bees	1 month	DENR
	2	Analyze materials	6 months	Bee specialist
	3	Publish results	6 months	Principle investigator
2		**Assess population and distribution**		
	4	Undertake population assessment	1 year	DENR, graduate student
	5	Undertake presence/absence surveys	1 year	DENR, graduate student
2		**Research biology & ecology**		
	6	Undertake floral surveys	3 months (May-July)	DENR, graduate student
	7	Undertake nesting surveys	3 months (May-July)	DENR, graduate student
2		**Identify threats**		
	8	Study degree of parasitism	1 year	DENR, graduate student
	9	Study incidence of disease	1 year	DENR, graduate student
	10	Study impact of pesticides	1 year	DENR, graduate student
2		**Trial artificial nest blocks**		
	11	Experiment with design	1 year	DENR
	12	Determine effectiveness	3 years	DENR
3		**Public awareness**		
	13	Develop awareness campaign	1 month	DENR
	14	Promote bee-friendly practices island wide	ongoing	DENR

APPENDIX

Table 1. Summary of the leafcutter bees in the specimen collections at the Bermuda Natural History Museum and the Plant Protection Laboratory.

Collection site	**Date of collection**	**Comments**
'St. George's Parish'	June 30, 1988	1 specimen *
Nonsuch Island	June 30, 1988	1 specimen ″
Nonsuch Island	July 5, 2012	4 specimens *
Nonsuch Island	June 2013	3 specimens *
Nonsuch Island	July 2015	4 specimens *

* Natural History Museum
″ Plant Protection Lab.

REFERENCES

Anderson, C., DeSilva, H., Furbert, J., Glasspool, A. F., Rodrigues, L., Sterrer, W. E. and Ward, J. (2001). Bermuda biodiversity country study. The Bermuda Zoological Society and The Bermuda Aquarium Museum and Zoo. Flatt's Village. 124 pp.

Faries, C. Personal Communication. Member of the general public. Bermuda.

Glasspool, A. F., 2008. The Impact of Climate Change on Bermuda. Report Prepared for the Bermuda National Trust. 190 pp.

Hilburn, D.J. and Gordon, R.D. 1989. Coleoptera of Bermuda. Florida Entomologist 72(4):673–692.

Hilburn, D.J., Marsh, P.M., Schauff, M.E. 1990. Hymenoptera of Bermuda. Florida Entomologist 73:161–176.

Larsson, M. and Franzen, M. 2008. Estimating the population size of specialised solitary bees. Ecological Entomology 33(2):232–238.

Meyer, E.L., Matzke, N.J., Williams, S.J. 2015. Remote sensing of intertidal habitats predicts West Indian topsnail population expansion but reveals scale-dependent bias. Journal of Coastal Conservation. DOI 10.1007/s11852-014-0371-7.

MacIvor, J.S. 2016. Cavity-nest boxes for solitary bees: a century of design and research. Apidologie. 17 pp.

Madeiros, J. Personal Communication. Senior Terrestrial Conservation Officer. Department of Environment and Natural Resources. Bermuda Government.

Mader, E., Spivak, M., Evans, E. 2010. Managing alternative pollinators: a handbook for beekeepers, growers and conservationists. SARE Handbook 11, NRAES-186. Co-published by SARE and NARES. 170 pp.

Mitchell, T.B. 1929. A species of *Megachile* from Bermuda. Psyche 36:93–94.

Mitchell, T.B. 1962. Bees of the Eastern United States. North Carolina Agricultural Experiment Station Technical Bulletin No. 152.

Ogilvie, L. 1928. The insects of Bermuda; a preliminary check list. Department of Agriculture. Government of Bermuda. 52 pp.

Pettit, D. 2016. Leafcutter bee fact sheet *in* Flora and Fauna of the Bermuda Protected Species Act. Department of Environment and Natural Resources. Government of Bermuda. 143 pp.

Pimentel. E.T. 2010. Removing exotic annual grasses from coastal dunes: effects on native ground-nesting solitary bees. MSc thesis. Humboldt state University, California. 46 pp.

Raw, A. 2004. Leafcutter and mason bees; a biological catalogue of the genus *Megachile* of the neotropics. 97 pp.

Raw, A. 2007. An Annotated Catalogue of the Leafcutter and Mason Bees (Genus *Megachile*) of the Neotropics. Zootaxa 1601:1–127.

Smith, S.R. Personal Communication. Curator of the Natural History Museum, Bermuda Aquarium Museum and Zoo.

Wedmann, S., Wappler, T., Engel, M.S. 2009. Direct and indirect fossil records of megachilid bees from the Paleogene of Central Europe (Hymenoptera: Megachilidae) Naturwissenschaften 96(6):703–712.

Young, B.E., Schweitzer, D.F., Hammerson, G.A., Sears, N.A., Ormes, M.F., Tomaino, A.O. 2016. Conservation and management of North American leafcutter bees. NatureServe, Arlington, Virginia. 20 pp.