

Recovery Plan for Six Fern Species From Bermuda

(*Diplazium laffanianum* (Baker) C. Chr, *Goniopteris bermudiana* (Baker) comb.,
Ctenitis Sloanei (Poepp. Ex Spreng.), *Asplenium heterochroum* Kunze,
Asplenium dentatum L., *Rumohra adiantiformis* (G. Forst.) J.)



Government of Bermuda
Ministry of The Environment and Sports
Department of Conservation Services

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Prepared in accordance with the Bermuda Protected Species Act 2003

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Primary Author

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The underside of a Governor Laffan's fern leaf showing linear sori (collection of spores),
by L. Greene, BAMZ Image Collection

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Department of Conservation Services

“To conserve and restore Bermuda’s natural heritage”

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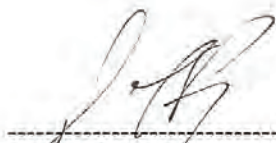
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DISCLAIMER


Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. We, the Department of Conservation Services, publish recovery plans, 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 for additional peer review before they are adopted by us, and formulated with the approval of interested parties mentioned in Parts II and III of the plan. 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 do not represent the official positions 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 Conservation Services as approved. Approved recovery plans are subject to modifications as dictated by new findings, changes in species status, and the completion of recovery actions.

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



Acting Director
Department of Conservation Services
Government of Bermuda



Date

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EXECUTIVE SUMMARY

Current Species Status:

This recovery plan addresses the need to actively intervene in the conservation of two endemic and four native fern species in Bermuda. The endemic ferns are Governor Laffan's fern (*Diplazium laffanianum* (Baker) C. Chr.) and Bermuda Shield fern (*Goniopteris bermudiana* (Baker) comb.). The native ferns are Bermuda Cave fern (*Ctenitis sloanei* (Poepp. ex Spreng.)), Long spleenwort (*Asplenium heterochroum* Kunze), Toothed spleenwort (*Asplenium dentatum* L.), and Ten-day or Leatherleaf fern (*Rumohra adiantiformis* (G. Forst.) J.). All six fern species are listed under Bermuda legislation as either Critically Endangered, or Endangered as per IUCN criteria under the Protected Species Act 2003. Population levels for all species in Bermuda are extremely low and distribution is very fragmented. The most threatened species is Governor Laffan's fern, of which only one mature plant remains maintained at the Government nursery, leading to its classification as "Extinct in the Wild" in the IUCN Red List.

Habitat Requirement and Threats:

All fern species occur in cave entrances. Their habitats are under threat due to increasing human development. Moreover, overshading and crowding by alien invasive species contributes to habitat loss. Habitat management is vital, and has been shown to be an important factor in maintaining successful fern population levels.

Recovery Objective:

The primary goal of this recovery plan is to propagate, protect and maintain the existing populations of the six fern species listed. Actions towards legal protection of critical habitats, management of invasive species, and active propagation of ferns by spore germination are recommended. Overseas collaboration is required, to investigate propagation techniques and train a Bermudian skilled force. The establishment of a dedicated greenhouse and nursery will allow for long-term sustainability of the fern populations.

Recovery Criteria:

Down listing for all fern populations will be considered when:

- Critical habitat legislation is passed
- Management programme is in place for invasive species control specific to fern habitats
- Accurate assessment of current taxonomic and population status completed
- Successful translocation of all species to a minimum of 10 sites around the island
- Stable reproductive populations of each fern species at each site
- Successful spore germination and subsequent transfer to the natural environment, especially for the Bermuda Shield fern and Governor Laffan's fern
- A greenhouse population of a minimum of 20 mature plants for all fern species
- Educational and research documentation completed

Actions Needed:

1. Develop habitat management programme
2. Protect critical habitats under existing legislation
3. Sample collection for genetic analysis
4. DNA analyses to assist population management strategy development
5. Population mapping
6. Investigate suitable habitats for translocation efforts
7. Investigate translocation techniques
8. Monitoring programme for assessment of growth and survival in the natural environment
9. Propagation programme with overseas collaboration
10. Training of local staff in spore germination
11. Develop techniques for culture of prothalli stage
12. Techniques for sporophyte transfer to natural environment
13. Develop management plan for re-introductions
14. Investigate growth of sporophytes to mature plants in greenhouse
15. Maintenance of reproductive plant stock in greenhouse
16. Botanical illustrations and publication of educational material

Recovery Costs: The total cost of recovery actions cannot be defined at this point. Funding needs to be secured, through the dedication of funds by government departments mentioned as responsible parties in this document and/or through external funding raised by NGOs and other interested parties, for implementing the necessary research and monitoring studies on the biology of the fern species. Developing budgets for each action are the responsibility of the leading party as outlined in the workplan.

Date of Recovery: No recovery date can be projected at this time. This plan aims towards the establishment of mature plants in the natural environment and of a reproductive stock in a dedicated greenhouse. Since growth rate to maturation is uncertain at this time, and time for achievement of a mature population of sporophytes in a greenhouse cannot be projected, date of recovery cannot be provided. However, the project progress will be evaluated every five years, following the timeline provided in the implementation section of the plan. A total re-evaluation will be made following 12 years of implementation and based on the recovery criteria, the threatened status of each species will be re-assessed. This may lead to down listing for some of the fern species.

PART I: INTRODUCTION

A. BRIEF OVERVIEW

The six fern species, (*Diplazium laffanianum* (Baker) C. Chr, *Goniopteris bermudiana* (Baker) comb., *Ctenitis sloanei* (Poepp. Ex Spreng.), *Asplenium heterochroum* Kunze *Asplenium dentatum* L., *Rumohra adiantiformis* (G. Forst.) J.), endemic or native to Bermuda, are listed under the Protected Species Act 2003, as Critically Endangered, or Endangered as per IUCN criteria. Population levels are extremely low for the majority of these plants, especially concerning for *D. laffanianum*, of which only one adult plant is surviving at the Government nursery (Department of Parks) at the time of publication of this document. For others, populations are fragmented making them vulnerable to a rapid decline. In addition, the availability of suitable habitats is decreasing, due in great part to increasing human development and uncontrolled growth of invasive species.

This recovery plan discusses threats and conservation efforts for the six fern species individually, summarizing current knowledge of the taxonomy, distribution, habitat requirements, biology and threats for each species. The plan recommends habitat protection through legislation and control of invasive species, as well as active intervention in increasing the current area of occupancy. In order to achieve this, translocation of fern species by division will be attempted, as well as investigations in propagation by spore germination. Collaboration with overseas institutions will be necessary and should lead to the production and maintenance of reproductively mature plants under controlled conditions as a preventative measure against natural disasters. If these measures are successfully carried out, it may be possible to down list the fern species to a less threatened category.

Historical Distribution

Britton (1918) recorded all fern species in Bermuda as favouring shady moist areas surrounding cave entrances. Many of them were found in crevices between Harrington Sound and Castle Harbour. The Ten-day fern was also found in Devonshire Marsh. The Long spleenwort used to be common on cliffs, walls and shaded rocks in most parts of the island, and the Toothed spleenwort was also reported on Abbott's Cliff. Populations have slowly declined due to decreasing habitat availability. Governor Laffan's fern used to be between Harrington Sound and Paynters' Vale. However, there has been no record of Governor Laffan's fern in the wild since 1905. Five plants were kept for several years in the Botanical Gardens collection. These were later moved to the Government nursery at Tulo valley; two of which were lost following a hurricane. At the time of writing this plan, there were three mature sporophyte plants maintained at the government nursery; by the time of publication (two years later), only one mature plant remains.

B. CURRENT PROTECTION STATUS

The only current protection for the six fern species is that provided for by the Protected Species Act 2003. Table I lists the status of each species classified according to IUCN criteria. Two of the fern species are endemic, Governor Laffan’s fern, and Bermuda Shield fern. Although Governor Laffan’s fern is strictly speaking “Extinct in the Wild”, for the purpose of legislation and its incorporation in this recovery plan, it has been classified as “Critically Endangered”. The Long and Toothed spleenwort, as well as the Cave fern and the Ten-day fern are native to Bermuda.

Table 1. List of threatened fern species under Bermuda legislation, based on IUCN criteria. (E) refers to endemic, (N) to native.

Classification	Species	Threatened Category in Bermuda
Ferns		
	Governor Laffan’s fern (<i>Diplazium Laffanianum</i>) (E)	*Critically Endangered (CR, D)
	Bermuda Shield fern (<i>Goniopteris bermudiana</i>) (E)	Critically Endangered (CR, B2)
	Bermuda Cave fern (<i>Ctenitis sloanei</i>) (N)	Critically Endangered (CR, B1)
	Long spleenwort (<i>Asplenium heterochroum</i>) (N)	Endangered (EN, C2a)
	Toothed spleenwort (<i>Asplenium dentatum</i>) (N)	Endangered (EN, B1a,b)
	Ten-day or Leatherleaf fern (<i>Rumohra adiantiformis</i>) (N)	Critically Endangered (CR,D)

**Please note: There is a discrepancy in the classification of Governor Laffan’s fern (*Diplazium laffanianum*) between that reported in the Bermuda legislation and that in the IUCN Red List; this is to enable listing under the Protected Species Act 2003.*

Local Protection

Legal Protection

The Protected Species Act 2003 considers as an offence the willful destruction, damage, removal or obstruction of a habitat, and the taking, importing, exporting, selling, purchasing, transporting or having in possession a protected species. Offenders are liable to a fine of \$5,000 and up to \$10,000 for continuing offences.

Habitat Protection

For those individuals inhabiting areas protected under the Department of Parks, as parks, nature reserves or woodland reserves, protection by the Parks Authority is provided under the overarching objective to “safeguard and maintain plants, animals and fragile ecosystems”. This applies to the Toothed spleenwort found in the nature reserve of the Walsingham Trust and to the Shield fern found at Sears Cave. These areas are protected under the Bermuda National parks Act 1986, which prohibits the taking of any flora or fauna within the park.

Global Protection

Ctenitis sloanei and *Asplenium dentatum* are listed as Endangered by the State of Florida. (Source: Plants in the Preservation of Native Flora of Florida Act. Chapter 5B-40, Florida Administrative Code. 1998, amended). The handling of these species is regulated under this Act.

C. TAXONOMY AND DESCRIPTION OF THE SPECIES

Governor Laffan's fern, *Diplazium laffanianum* (Baker) C.Chr. (Ind. 234. 1905. 1905)

Family: Woodsiaceae

Genus: *Diplazium*

Species: *laffanianum*

This was first described by Mr. J. G. Baker in the Gardener's Chronicle, 51:673, 1882, from a living plant sent by Governor Laffan to the RBG KEW in 1880 and by a dried specimen from Governor Lefroy in 1874. The genus *Diplazium* consists of mostly large ferns with simple or compound leaves, the venation free. Sori linear, borne at the sides of veinlets, the indusium mostly of a double membrane (Britton, 1918).

Figure 1. Governor Laffan's fern, *D. laffanium*. (Photo: D. Lubin)



The following description is taken from Britton (1918): Rootstock short, erect or oblique, bearing several leaves, somewhat scaly. Petioles 4"–8" long, blackish and scaly toward the base, green and naked above, the brown lanceolate acuminate scales 0.16"–0.25" long; blades bipinnate, ovate-deltoid in outline, 8"–12" long, about half as wide as long, bright green, rather firm in texture, smooth on both sides; pinnae lanceolate in outline, nearly sessile, 3½"–5" long, close together; pinnules oblong to lanceolate, obtuse, or the larger acute, serrate, or the large incised; sori 0.08"–0.16" long, simple, or mostly so, slightly curved, the persistent indusium glabrous, membranous.

Bermuda Shield fern, *Goniopteris bermudiana* (Baker) combined.

Family: Thelypteridaceae

Genus: *Goniopteris*

Species: *bermudiana*

Syn.: *Dryopteris bermudiana*

Figure 2. Bermuda Shield fern (Photo: D. Lubin)



The following description was taken from Britton (1918):

The species was illustrated in Botany of the Voyage of the Challenger (plate 13), where Mr. J. G. Baker first described it in 1885 as *Dryopteris bermudiana*. The species was determined as *Goniopteris bermudiana* by C. Fraser-Jenkins (1979). The taxonomy is currently disputed, and the species is being referred to at times as *Goniopteris (Nephrodium) bermudiana*; it has

been recommended more recently to refer to it as *Goniopteris bermudiana* (M. Hamilton, *pers.comm.*).

Rootstock thick, creeping, chaffy at the crown with lanceolate acuminate scales. Leaves 2" long or less, 3"-6" wide, pinnate, the rachis pilose; pinnae 1 ½"-3" long, ½"-1" wide, very short-stalked, blunt, cut about half-way to the mid-vein, dark green and canescent above, paler beneath, their lobes blunt, entire, the basal ones on one or both sides enlarged; veinlets of the lobes 5-7 pairs, unforked, pilose beneath, the lowest veinletes uniting into a vein running to the sinus; sori small; involucre small, reniform, fugacious.

Bermuda Cave fern, *Ctenitis sloanei* (Poepp. ex Spreng.) C.V. Morton (American Fern Journal 59: 66. 1969)

Family: Dryopteridaceae

Genus: *Ctenitis*

Species: *sloanei*

Syn: *Dryopteris speluncae* (Underwood), *Polypodium sloanei* (Poeppig ex Sprengel, 1827)

Common names: Bermuda Cave fern, Red-hair Comb fern, Florida Tree fern

This species was for the longest time considered to be an endemic under the name *Dryopteris speluncae* as it was recorded in the Flora of Bermuda by Britton (1918). More recently, it has been re-identified as *Ctenitis sloanei*, a species which is found throughout the Caribbean and as a result is now listed as a native (M. Hamilton, *pers.comm.*).

Figure 3. Bermuda Cave fern (Photo: D. Lubin)



The following description is taken from Britton (1918):

Rootstocks, leaves 2"–3 ½" long, bipinnate or tripinnate, broadly ovate, nearly or quite as wide as long, the stipes and rachis paleaceous and pubescent with crisped hairs; pinnae ovate to ovate-lanceolate, the lower somewhat stalked, the upper sessile; pinnules oblong to oblong-lanceolate, obtuse or acutish, crenate-serrate or the larger ones lobed, pubescent on the veins beneath, the veins simple; sori borne about halfway from the mid-vein to the margin of the pinnules.

Toothed spleenwort, *Asplenium dentatum* L. (Species Plantarum 2: 1080-1081. 1753)

Family: Aspleniaceae

Genus: *Asplenium*

Species: *dentatum*

Syn: *Asplenium (Trich.) dentatum* L., *Asplenium trichomarnes-dentatum* L.

Common names: Toothed spleenwort, slender spleenwort

Figure 4. Toothed spleenwort, *A. dentatum*, from Bermuda collection. (Photo: L. Greene)



The following description is taken from Britton (1918):

Petioles tufted, 2"–6" long, naked, weak, blackish below. Fertile leaf-blades 2"–3" long, with 6–8 pairs of stalked oblong or rhombic pinnae, the lower side truncate with a curve, the outer edge irregularly crenate; sterile leaves similar but with shorter petioles; rachis naked; sori copious, in parallel rows.

Figure 5. Long spleenwort in Bermuda (Photo: D. Lubin)



Long spleenwort, *Asplenium heterochroum* Kunze, (Linnaea, 1834)

Family: Aspleniaceae

Genus: *Asplenium*

Species: *heterochroum*

Syn: *Asplenium muticum* Gilbert

Common name: Long spleenwort, varicoloured spleenwort, bicoloured spleenwort

The following description is taken from Britton (1918):

Rootstock short; petioles tufted, black ½"–4" long, stiff, erect or somewhat spreading; leaf blades linear in outline, 6"–16" long, 1" wide or less, once pinnate with mostly 20–4- pairs

of pinnae; pinnae close together or the lower distant, mostly opposite, very nearly sessile, oblong, obtuse, few-toothed, or the lower nearly orbicular and much smaller than the middle ones, all subtruncate at the base; veins, except the lowest on the upper side of the pinna, simple; sori oblique, about 0.2" long, borne close to the mid-vein, the indusium membranous.

Ten-day or Leatherleaf fern *Rumohra adiantiformis* (G. Forst.) Ching (Sinensia 5: 70. 1934)

Family: *Davalliaceae*

Genus: *Rumohra*

Species: *adiantiformis*

Syn: *Aspidium capense*, *Dryopteris adiantiformis*, *Polystichum adiantiforme*

Common names: Iron fern, Ten-day fern, Leatherleaf fern

Figure 6. Ten-day or Leatherleaf fern, Bermuda (Photo: D. Lubin)



This fern has a varied taxonomic history, and has been assigned previously to the genera *Polystichum* and *Polypodium*, and placed into the plant families Polypodiaceae, Aspidiaceae, and Davalliaceae. (Little and Barrington, 2003).

The following description is taken from Britton (1918): Rootstock stout, creeping; leaves several, 1'–4' high, subcoriaceous, 2–3 pinnate. Lower pinnae the largest, sometimes 1' long, 3"–4" wide; pinnules ovate-lanceolate in outline, acuminate; ultimate segments or

lobes oblong or oblong-lanceolate, acutish serrate; rachis smooth and somewhat shining; stipes scaly at the base; sori nearly .08" broad, mostly in 2 rows between the margin and the mid-vein of the segments.

D. ECOLOGY

Habitat Requirements

Ferns of Bermuda are generally found in two main types of locations, the marshes and in and around cave entrances. They prefer shady, moist rocks and crevices. The specific sites where ferns have been recorded in Bermuda occur mainly in the eastern end of the island in the Walsingham Trust area, and Paynter's Hill (Britton, 1918). More recently some seedlings have been transplanted to managed nature reserves surrounding other cave areas, more specifically at Sears Cave in Smith's parish.

Reproduction and Life Cycle

Little information is available pertaining to the life cycle characteristics of Bermuda's endemic fern species. As for other ferns, these species produce spores, which develop in specialized structures called sori. Sori occur on the underside or around the margins of fronds. In *Diplazium laffanianum*, sori are located on the underside of fronds and are linear in pattern.

Figure 7. Fertile frond of Governor Laffan's fern (Photo: D. Lubin)



The life cycle has two distinct stages; a sporophyte asexual stage (the spore producing plant) – such as the typical relatively long-lived perennial fern plant – and a sexual gametophyte stage referred to as prothallus. The sporophyte produces large numbers of spores, that are dispersed by the wind, and germinate under favourable conditions to produce the gametophyte. It is uncertain whether spores can remain dormant and viable.

The gametophytes are small, inconspicuous simple short-lived plants (1–2 years), which develop into heart-shaped prothalli. The gametophytes produce

the male antheridia and the female archegonia. Fertilization occurs in the presence of moisture as the sperm are released from the antheridia and swim to the eggs in the archegonia. Ferns may either be homosporous, where spores produce both male and female parts, or heterosporous, where spores germinate into either microgametophyte (male) or megagametophyte (female). For fertilization to occur with heterosporous ferns, both types of spores must be present for successful germination.

Figure 8. In vitro prothalli cultures of Governor Laffan's fern grown at the Government nursery (Department of Parks, Bermuda). (Photo: S. Northcott)



E. CURRENT THREATS

The native vegetation of Bermuda has been dramatically altered due to man's influence. Land cleared for development and agriculture, accidental and intentional animal and plant introductions have had a major effect on the decline of the natural environment. The major threats to the endangered ferns listed here are habitat loss due to development and competition with invasive species.

Loss of Habitat and Habitat Disturbance

With a land mass of 55 km² and a resident population of 60,000, Bermuda is one of the most densely populated countries in the world. Land development is continuous, encroaching on the few remaining natural habitats. Thus far, the nature of fern habitats may have helped the species to survive, as many of the sites are in rocky, inaccessible areas. Nonetheless, such areas are also being put under increasing pressure from human development and in danger of being destroyed in the near future. Some of the habitats identified as critical for survival of ferns, occur on private land, and are hence not protected by law. Conservation efforts in these cases rely on the owner's good will. Two development cases illustrate the current situation and status of some of these sites.

- Paynter's Hill. This area is privately owned. Development of the hill has been twice attempted and successfully rejected by the Bermuda National Trust and Department of Parks. Nonetheless, development plans may proceed in the future.
- Walsingham Trust. This woodland area, also privately owned, was cleared for the creation of an eight-foot wide pathway for reopening of the Wonderland Cave to the public. This unauthorized action proved detrimental to not only the ferns, but to other endemic and native species of threatened status. Coincidentally, the Shield fern population declined by 40% in the last three years in this region.

Impact of human development also results in quarrying of cave areas, filling, dumping and littering, water pollution and vandalism. As mentioned previously, cave entrances or sinkholes are prime habitats for ferns in Bermuda. At least eight major caves have been destroyed by filling or quarrying; the worst case being one of the largest caves, Bassett's Cave, formerly used by the U.S. Navy for dumping fuel oil and raw sewage, is at present incapable of supporting any life form. Sears Cave was also used as a dumping site, negatively impacting Bermuda Cave fern populations; however, recent management of the area as a nature reserve has resulted in increasing numbers of healthy fern seedlings.

The examples above demonstrate the impact of human activity on critical habitats and hence on plant populations. Full protection of areas identified as critical to the species survival is warranted through legislation, as a means to control human activity.

Competition from invasive species

Prior to man's arrival on the islands the number of plants found growing in Bermuda was estimated at 167 native species. Today the number of introduced plants is over 1,000

species (Sterrer, 1998). Many of these plant introductions have caused major problems for the natural flora. Around 500 species of introduced plants have become naturalized (i.e., self-propagating in the wild without further intervention from man), and about 15 of these are considered major invasive species, seriously competing with the native flora, often completely replacing it. Introduced species outnumber native species by 4:1 and in most habitats consist of 90% of the flora biomass. The Shield fern has shown a severe decline in the last three years, due in part to the overshadowing caused by introduced species, such as the Brazil pepper (*Schinus teribinthifolius*), Surinam cherry (*Eugenia uniflora*), and fiddlewood (*Citharexylum spinosum*).

F. CURRENT STATUS

Global Distribution

Ctenitis sloanei, referred to as Bermuda Cave fern in Bermuda occurs throughout the Caribbean and South Florida; it is considered threatened in Florida (McCoy, 1981).

The Toothed spleenwort, *Asplenium dentatum*, is only found in Florida and Puerto Rico within the U.S., but also occurs throughout the Caribbean Region, namely Barbados, Belize, Cuba, Guadeloupe, Haiti, Jamaica. It also occurs in Mexico and Venezuela, bordering the Caribbean Sea, but it has also been reported in Guam and Spain (GBIF, 2007)

The Long spleenwort, *Asplenium heterochroum*, has been recorded in North America, namely in the southern states of Alabama, Florida, Georgia, Puerto Rico and South Carolina. It also occurs throughout the Caribbean, namely Costa Rica, Cuba and the Dominican Republic, and Central and South America in Ecuador, Mexico and Bolivia (GBIF, 2007).

The Ten-day or Leatherleaf fern, *Rumohra adiantiformis*, occurs in North America and in the Caribbean (ITIS, 2008). It is however, not native to North America but naturalized and used in mass planting for borders and edging in the southern states of the U.S., namely Florida. (Gilman, 1999). Leatherleaf ferns are circum-austral, native to the tropics around the Southern Hemisphere. The species occurs in Africa, South America, New Zealand and Australia (Jones, 1987).

Local Distribution

The current population size for each one of these endemic and native fern species in Bermuda is low, as seen in Table 2 below. In the case of Governor Laffan's fern, the population is now reduced to one mature plant, maintained by the Department of Parks Government Nursery at Tulo Valley. For other species, namely for the Shield fern and the Cave fern, populations in the wild are restricted to mainly one site, with <300 specimens at most per site. Last recorded locations are given in Table 2. The populations of the Long spleenwort, are distributed across the island, but there is little data on their size and exact location. This also proves true for the Toothed spleenwort, for which an adequate assessment of the population status is not available; populations of this species are

confined to cave entrances. Finally, the Ten-day fern is only found at one site, with an extremely low number of mature plants (<5).

Overall the survival of endemic and native fern species listed in this document is a serious cause for concern in Bermuda, as a single human-caused or natural event may be permanently destructive.

Table 2. Current population status and distribution of six species of ferns in Bermuda (S. Northcott, and J. Madeiros, *Pers. comm.*).

Common Name	Scientific Name	Current Population Status	Location
Governor Laffan's fern	<i>Diplazium laffanianum</i>	Extinct in the wild. 1 mature plant at Government nursery.	Last record 1905 in caves between Harrington Sound and Castle Harbour
Bermuda Shield fern	<i>Goniopteris bermudiana</i>	Fragmented population and localised to 3 sites. Total: 150 specimens. 3 or 4 in Grotto Bay; 9–12 Paynter's Hill; 100 Walsingham Trust population decline by 40% in last three years	Walsingham Trust; Grotto Bay Hotel; Paynter's Hill
Bermuda Cave fern	<i>Ctenitis sloanei</i>	Rare, confined to 4 fragmented sites. Total: 300 specimens 24 Walsingham Trust; 9 Paynter's Hill; 250 Sears Cave. Stable population	Walsingham Trust Paynter's Hill Sears Cave
Toothed spleenwort	<i>Asplenium dentatum</i>	Localised to Cave entrances. Total: 500	Walsingham cave
Long spleenwort	<i>Asplenium heterochroum</i>	Fragmented population, found islandwide.Total:200–500 Declining	Walsingham Cave, Paynter's Hill
Ten-day or Leatherleaf fern	<i>Rumohra adiantiformis</i>	3–4 specimens	Edge of Devonshire Marsh

G. CURRENT CONSERVATION ACTION

The facts point to the need for active intervention to ensure the conservation of listed fern (see Table 1). Up to date, the actions taken have been: 1) the general management of protected areas, including the removal of invasive species and 2) the successful in-vitro propagation of *Diplazium laffanium* with the collaboration of overseas expertise (The Omaha Zoo). These conservation efforts provide the basis for a successful recovery strategy. It is apparent that the management of important habitats through removal of invasive species has resulted in the preservation of the existing ferns. In addition, translocation efforts have shown the adaptability of some of the fern species to new habitats with suitable conditions, seen recently for the Cave fern. The success obtained in preliminary propagation efforts, namely for Governor Laffan's fern, demonstrates the potential for culturing prothalli, and warrants further research aiming towards the transfer of cultures to suitable natural environments.

Figure 9. *D. laffanium* cultured in Bermuda (Tulo Valley), once received from Omaha Zoo. (Photo: S. Northcott)

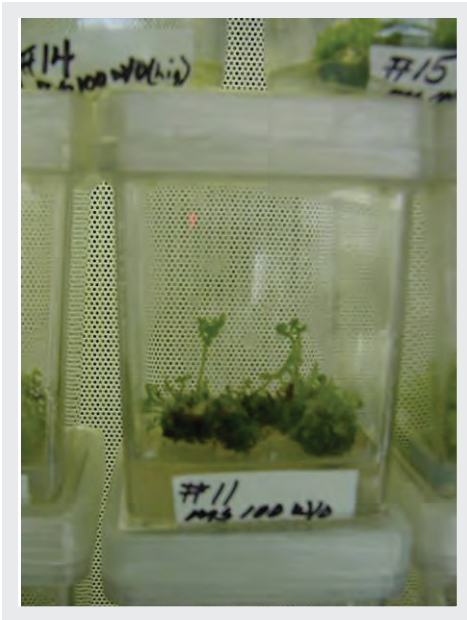
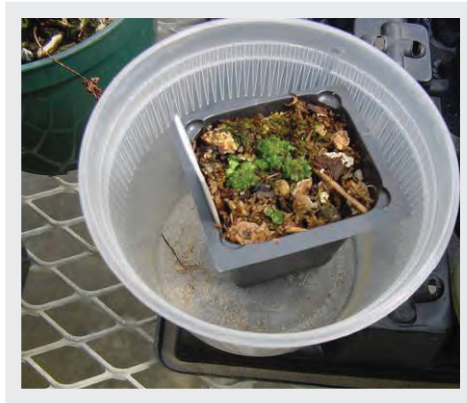


Figure 10. Governor Laffan's fern grown for transfer in the wild (Photo: S. Northcott)



PART II: RECOVERY

A. RECOVERY GOAL

The primary objective of the Fern Recovery Plan is to reverse the decline in the numbers of ferns of *Diplazium laffanianum*, *Goniopteris bermudiana*, *Ctenitis sloaeni*, *Asplenium dentatum*, *Asplenium heterochroum* and *Rumohra adiantiformis* by protecting their habitats in Bermuda, maintaining the existing populations and establishing *ex situ* populations.

The short-term goal (two years) is to first ensure legal protection of the habitats identified as critical under the Protected Species Act 2003, and manage invasive species in these habitats. Within this time period, verification of the taxonomy, population genetics and population status for all fern species will be ascertained.

The long-term goal (10 years) is to actively propagate fern species through translocation and/or artificial propagation. This includes the re-introduction of *Diplazium laffanianum* into the wild. Successful artificial propagation will require research and collaboration with overseas institutions. Although a period of 10 years has been assigned here, it is difficult to provide a precise time-frame until additional information is obtained on spore germination techniques for endemic species and on their growth rate to a mature sporophyte stage. Self-sustainability of all species at suitable sites is strived for.

B. RECOVERY OBJECTIVE AND CRITERIA

Favourable conservation status will be achieved when:

- Critical habitat protection is legislated
- Management programme for invasive species control specific to fern habitats implemented
- Verification of taxonomy for all fern species
- Population level variation of fern species ascertained through DNA analysis to aid management planning
- Accurate assessment of current population status made
- Successful translocation of all species to a minimum of 10 sites around the island
- Establishment of a thriving, reproducing population of each species at each site
- Successful spore germination, and subsequent transfer to the natural environment for the Shield fern and Governor Laffan's fern
- A greenhouse population of a minimum of 20 mature plants for all fern species
- Increased public awareness of threatened status of fern species

These overall objectives translate into specific targets outlined below:

Short-term target (two years): Critical habitats have been identified for some of these fern species. These need to be listed with a well-defined boundary and conditions for access under the Protected Species Act 2003, to allow enforcement of protection. A management programme for invasive species needs to be specifically developed and implemented for listed fern species. Finally, a programme for sample collection and DNA analyses needs to be developed with the collaboration of an overseas institution. This will also include a comprehensive survey on the current populations of the fern species island-wide, especially needed for the Long and Toothed spleenwort.

Long-term target (10 years): The development of a propagation and translocation programme for all species listed, focusing on the establishment of populations at a minimum of 10 sites per species. More specifically, propagation techniques for Governor Laffan's fern need to be investigated further, as well as research into the growth of prothalli cultures to the sporophyte stage, and their acclimation to natural conditions is necessary in order to re-establish a natural population of this species. Collaboration with overseas institutions is required for this.

C. RECOVERY STRATEGY

It is probable that continued control of invasive plant growth leading to the management of habitat through control of invasive species growth, coupled with active propagation, will enhance the fern populations and yield self-sustainability in the long term. This has been demonstrated following efforts by the Department of Conservation Services to date. However, as for other plant species in Bermuda, the status of the endemic and native species needs to be confirmed through taxonomy and genetic analyses, as a first step towards prioritizing recovery actions. Most of the fern species populations have declined due to reduction in habitat; conservation efforts have shown the potential for growth in suitable habitats clear of invasive species. It follows that protection of habitat, and continued efforts in habitat management will prove beneficial. As for the poor status of Governor Laffan's fern, a comprehensive programme involving overseas expertise is necessary for the re-establishment of this species in the wild. Preliminary results in propagation have been promising, however, a dedicated staff is necessary to ensure the continued care necessary to achieve the sporophyte stage, and to investigate and monitor transfer into the natural environment. Similar efforts would also be applied to the other endemic species, the Bermuda Shield fern, to ensure the recovery of its population. In addition, the general public has limited awareness of Bermudian fern species and their threatened status; raising such awareness through wide distribution of educational material should result in the engagement of the community in protecting critical habitats.

D. TOOLS AVAILABLE FOR STRATEGY

Techniques have been tested for translocating various fern species to different suitable sites. A structured programme will allow for translocation on a larger scale expanding the extent of occupancy of these fern species.

Recent efforts on spore germination have been promising. Spores of Governor Laffan's fern, *Diplazium laffanianum*, have been sent by the Department of Parks nursery to Omaha Zoo for investigations in germination. A first shipment was sent in January 2002, and one year later (Feb 2003), a back-up supply of spores was sent from Omaha Zoo to Northcross Wildlife Sanctuary in Massachusetts. Germination was achieved in Feb 2003, and sporophyte stage achieved in July 2003, with approximately 40 sporophytes in good health recorded in August 2003. One year later (August 2004), 20 prothalli cultures were reported at Omaha Zoo. Fifteen of these in-vitro cultures were shipped back to Bermuda in August 2004, for acclimation and development to the sporophyte stage. Additional efforts in 2008 and 2009 for strengthening collaboration led to the shipment of gametophytes from Omaha Zoo to the Plant Protection Lab (Department of Environmental Protection), where preliminary investigations are currently undertaken for optimal culture conditions of Governor Laffan's fern and Ten-day Leatherleaf gametophytes. In addition, spores were also sent to RBG Kew, U.K. (Martin Hamilton), in March 2007 to investigate germination potential.

E. STEP-DOWN NARRATIVE OF WORKPLAN

The following abbreviations are used throughout the next two sections:

DCS – Department of Conservation Services

Government nursery – Tulo Valley site (Department of Parks)

Parks – Department of Parks

BSAP – Bermuda Biodiversity Strategy Action Plan

KEW – Royal Botanic Gardens Kew, U.K.

The actions needed to achieve recovery are as follows:

1. Protect existing populations

Actions proposed:

- Develop current removal programme for control of invasive species into more extensive management program for all sites
- Identify and list critical habitats under legislation

Work Team: DCS/Parks

Team Leader: Terrestrial Conservation Officer (DCS)

Assistance: Protected Species Coordinator (DCS)

Outputs: The sustainability of existing fern populations will be ensured. Critical habitats will be listed under the Protected Species Act 2003, with conditions for access specified.

List of Equipment: already provided for by Department of Conservation Services

2. Verification of taxonomy, genetic analyses and population mapping

Actions proposed:

- Programme for sample collection from 5–10 ‘parent’ populations across the island.
- Taxonomy and genetic analyses (DNA) by overseas institutions.
- Mapping of populations especially required for the two species of spleenwort.

Work Team: DCS

Team Leader: Protected Species Coordinator (DCS)

Assistance: members of the community, volunteer field botanists listed as the ‘Plant Action Team’. Kew for DNA analyses.

Outputs: Confirmation of endemic and native species of ferns listed under the Protected Species Act 2003. Knowledge of population status and distribution for all species.

List of Equipment: Funds for DNA analyses and chemicals required. Handheld GPS required for recording collections and populations in the field as detailed in the “Plant Workshop Report: March 2007”.

3. Increase area of occupancy

Actions proposed:

- Investigate suitable habitats, namely surrounding caves
- Translocation programme by division for fern species to a minimum of 10 sites per species
- Develop monitoring programme for assessment of growth and survival following transfer

Work Team: DCS/Parks

Team Leader: Terrestrial Conservation Officer (DCS)

Assistance: Members of the community

Outputs: Increasing population distribution range of fern species island-wide.

List of Equipment: Translocation material.

4. Re-introduction of fern species from in-vitro cultures into the wild, especially for Governor Laffan’s fern and Bermuda Shield fern

Actions proposed:

- Expand collaboration with overseas institution for propagation programme of fern species
- Training of Bermuda staff in spore germination
- Determine viability of spores during storage
- Investigations in optimal growth of prothalli cultures (growth media, soil pH, photoperiod, temperature, pests, etc) in Bermuda
- Acclimation of sporophytes and transfer to natural environment
- Develop research programme testing ability of greenhouse-raised plants to adapt to natural conditions

Work Team: DCS/Parks

Team Leader: Government Nursery

Assistance: Omaha Zoo/RBG Kew (for propagation). Dedicated greenhouse staff in Bermuda

Outputs: Training of dedicated staff in germination/propagation techniques and in nursery requirements for fern species. Establishment of dedicated greenhouse and nursery for threatened fern species. Re-establishment of Governor Laffan's fern into the wild. Supplementing natural reproduction for other fern species through active spore germination. Database on growth rate of fern species at all stages of in-vitro cultures, and following transfer into the natural environment.

List of Equipment: Funds for propagation materials. A dedicated greenhouse for reception of prothalli cultures from overseas institutions, and rearing to sporophyte stage. Need for dedicated staff in Bermuda for monitoring of prothalli cultures, and acclimation of sporophytes to natural environment.

5. Ensure preservation of mature fern specimens

Actions proposed:

- Investigate growth of sporophyte stage to mature plants
- Maintain a minimum population of 20 mature plants in captivity

Work Team: Government Nursery

Team Leader: Dedicated greenhouse staff

Assistance: DCS

Outputs: Healthy population of mature fern plants ensuring long-term conservation of species in case of dramatic decline in the wild.

List of Equipment: Dedicated greenhouse and nursery. Funds for dedicated staff. Nursery and mature plants materials.

6. Promote public awareness

Actions proposed:

- Create illustrations of fern species as collector's prints

- Design and publish bookmarks or other form of information for distribution in community

Work Team: DCS, Botanical illustrator

Team Leader: BSAP Coordinator

Assistance: Community members

Outputs: Raise public awareness of threatened fern species. Engage community in supporting recovery plans and help obtain funds.

List of Equipment: Funds for publication of prints and bookmarks

F. ESTIMATED DATE OF DOWN-LISTING

It is anticipated that it will take two years to identify and legally protect critical habitats of fern species, as well as develop a management programme for the control of invasive species within these habitats. Within these two years, the endemic and native status of the listed fern species will be confirmed and DNA analyses completed to help inform management options. A further 10 years is dedicated to increasing the area of occupancy of the fern species across the island, through division of mature plants and propagation. The monitoring programme will evaluate the success of fern growth and survival in new sites. Down listing will only be considered once long-term sustainability is ensured; more specifically that growth, survival and reproduction of all fern species at a minimum of 10 sites is determined, and that a greenhouse stock of reproductively mature plants is established. As there is currently a lack of information on growth rate for most of these fern species, it is not possible to provide a date for recovery. Evaluation of the progress made is planned five years from start of implementation. A complete assessment of the recovery objectives will be undertaken following 12 years of implementation of the recommended actions, and objectives re-defined if need be.

G. RECOVERY COSTS

The total cost of recovery actions cannot be defined at this point. Funding needs to be secured, additional to the core funding obtained through government funds, for implementing the necessary research studies on the natural population status, habitat requirements, and propagation techniques for these fern species. Developing budgets for each action are the responsibility of the leading party as outlined in the workplan.

PART III: IMPLEMENTATION

The table that follows is a summary of scheduled actions and costs for this recovery program. It is a guide to meet the objectives of the Fern Recovery Plan, as detailed in the Step-Down Narrative Plan (Section E). This table indicates the priority in scheduling tasks to meet the objectives, which agencies are responsible to perform these tasks, a time-table for accomplishing these tasks.

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		Protect existing population	1 year	
	1	Develop habitat management programme	1 month	DCS
	2	Legislate critical habitats	1 year	DCS
2		Species taxonomy and and population mapping	2 years	
	3	Sample collection (herbarium and DNA)	12 months	DCS
	4	Genetic analysis	12 months	Kew
	5	Population mapping	12 months	DCS
1		Increase area of occupancy	5 years	
	6	Investigate suitable habitats	6 months	DCS/Parks
	7	Translocation of fern species	2 years	DCS/Parks
	8	Monitoring programme	5 years	DCS
2		Re-introduction from in-vitro cultures into the wild	5 years	
	9	Collaborative propagation programme	4 years	Government Nursery Omaha Zoo/RBG Kew
	10	Training in spore germination	3 years	Government Nursery/ Omaha Zoo/ RBG Kew
	11	Determine viability of spores during storage	5 years	Parks (Nursery)/ RBG Kew
	12	Prothalli culture	4 years	Parks (Nursery)
	13	Sporophyte transfer to natural environment	4 years	Government Nursery/DCS
	14	Research in adaptability of sporophytes	2 years	DCS
2		Preservation of mature ferns	indefinite	
	15	Investigate growth of sporophytes to mature plants	4 years	Government Nursery
	16	Maintain mature plants in greenhouse	indefinite	Government Nursery
3		Promote Public Awareness	2 years	
	17	Botanical Illustrations	2 years	Botanical Illustrator
	18	Publish material for distribution and information	1 year	DCS

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