Re-introduction of Governor Laffan's Fern (*Diplazium laffanianum*) to the wild

Report on plantings for calendar year 2020

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Summary for 2020

As of December 31st 2020, the total number of Governor Laffan's Ferns (*Diplazium laffanianum*) surviving in the wild was thirty; including fifteen at Sear's Cave, eleven at Paynter's Hill, three at Bee Pit Cave and one at Causeway Cave. The wild population includes ferns planted in 2015 (one), in 2019 (fourteen) and in 2020 (fifteen).

In 2020 twenty five *D. laffanianum* were planted out, and of these fifteen survived the year. Therefore survivorship amongst the 2020 plantings was 60%. This is up slightly from the 15/27 (or 56%) that were planted in 2019 and survived the year (Copeland, 2019). The results of the 2020 plantings are as follows:

- Sear's Cave - 3 planted in 2020, 3 surviving as of Dec. 31st 2020
- Paynter's Hill – 19 planted in 2020, 11 surviving as of Dec. 31st 2020
- Causeway Cave – 3 planted in 2020, 1 surviving as of Dec. 31st 2020

An accounting of the planting material used in 2020 and its fate is given in Table 1 and a running total for all *D. laffanianum* plantings carried out since 2014 are given in Table 2.

Table 1: Status table for *Diplazium laffanianum* planted in 2020

Planting Site	Pot Batch	Date Planted	Surviving Dec. 2020	Origin
Causeway Cave	Danone container no letter	10th February 2020	no	Danone pot from QQ Oct14, (14-34, 14-9, or 14-5 all were 4 yrs. old when received in Bda.)
Causeway Cave	PP Oct 14 Chobani potted 8.3.19	10th February 2020	no	oct14-9 or oct14-34 (4yrs old)
Causeway Cave	SS Oct 14 potted black pot 26.1.16	10th February 2020	yes	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont.
Paynter's Hill breathing cave	QQ Oct 14 potted 23.1.19 Chobani pot	14th January 2020	no	14-34, 14-9, or 14-5 all were 4 yrs. old when received in Bda.
Paynter's Hill breathing cave	SS Oct 14 potted 28.1.19 black pot	14th January 2020	no	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont.
Paynter's Hill breathing cave	QQ Oct 14 pudding cup planted 23.1.19	14th January 2020	no	14-34, 14-9, or 14-5 all were 4 yrs. old when received in Bda.
Paynter's Hill breathing cave	SS Oct 14 potted 28.1.19 square pot	14th January 2020	no	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont.
Paynter's Hill breathing cave	PP Oct 14 pudding cup potted 8.3.19	26th February 2020	no	oct14-9 or oct14-34 (4yrs old)
Paynter's Hill breathing cave	QQ Oct 14 small black pot, 23.1.19	26th February 2020	no	14-34, 14-9, or 14-5 all were 4 yrs. old when received in Bda.

Planting Site	Pot Batch	Date Planted	Surviving Dec. 2020	Origin
Paynter's Hill breathing cave	12-12BC round pudding cup deep blue soil (1/2)	26th February 2020	no	12-12
Paynter's Hill breathing cave	12-12BC round pudding cup deep blue soil (2/2)	26th February 2020	no	12-12
Paynter's Hill breathing cave	TT Oct 14 pudding cup potted 23.1.19	14th January 2020	yes	Oct14-12 (4yrs) or Oct14-31 (2.5yrs)
Paynter's Hill breathing cave	Chobani pot no letter	14th January 2020	yes	Probably one of the QQ Oct14.
Paynter's Hill breathing cave	small black pot, potted 7.11.18 no letter	14th January 2020	yes	Possibly is one of the small ones from 12-11/6.
Paynter's Hill breathing cave	14Q black pot, potted 25.1.16 (1 of 2)	14th January 2020	yes	May 2014 shipment, 14-37 callus + 14-13 sporos
Paynter's Hill breathing cave	14Q black pot, potted 25.1.16 (2 of 2)	14th January 2020	yes	May 2014 shipment, 14-37 callus + 14-13 sporos
Paynter's Hill breathing cave	PP Oct 14 pudding cup potted 8.3.19	14th January 2020	yes	oct14-9 or oct14-34 (4yrs old)
Paynter's Hill breathing cave	SS Oct 14 small black pot 28.1.14	26th February 2020	yes	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont. or oct14-9 or oct14-34 (4yrs old)
Paynter's Hill breathing cave	SS+PP Oct 14 small black pot 8.3.19	26th February 2020	yes	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont. or oct14-9 or oct14-34 (4yrs old)
Paynter's Hill breathing cave	TT Oct 14 pudding cup potted 23.1.19	26th February 2020	yes	Oct14-12 (4yrs) or Oct14-31 (2.5yrs)
Paynter's Hill breathing cave	small black pot labelled '?2014	26th February 2020	yes	
Paynter's Hill breathing cave	SS+PP Oct 14 small black pot 8.3.19	26th February 2020	yes	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont. or oct14-9 or oct14-34 (4yrs old)
Sear's Cave	QQ Oct 14 small black pot, 25.1.16	11th February 2020	yes	14-34, 14-9, or 14-5 all were 4 yrs. old when received in Bda.
Sear's Cave	SS Oct14 small black pot 28.1.19	11th February 2020	yes	14-5 or 14-12 (4yrs old when received) or 14-31 (2.5yrs old) middles cont.
Sear's Cave	PP Oct 14 pudding cup 8.3.19	11th February 2020	yes	oct14-9 or oct14-34 (4yrs old)

Table 2: Running total of *Diplazium laffanianum* planted since the beginning of the programme

Planting Site	Date Planted	Number Planted	Number Presently Surviving
Paynter's Hill breathing cave	26 February 2020	9	5
Sear's Cave	11 February 2020	3	3
Causeway Cave, Blue Hole Park	10 February 2020	3	1
Paynter's Hill breathing cave	14 January 2020	10	6
WWS and Bee Pit Cave	4 March 2019	9	3
Deep Blue Cave, Walsingham Trust	18 February 2019	6	0
Sear's Cave	18 January 2019	12	11
West Walsingham Sink Cave	3 February 2016	10	0
Cow Cave, Walsingham Trust	4 March 2015	6	0
Sear's Cave	29 January 2015	8	1
Zuill's Cave site, Walsingham Trust	21 January 2015	6	0
Tom rockface, Walsingham Trust	25 November 2014	6	0
Zuill's Cave site, Walsingham Trust	24 November 2014	23	0
Totals		**111**	**30**

Site Notes

Sear's Cave

To date the Bermuda Audubon Society's Sear's Cave Nature Reserve has been the most successful re-introduction site for *Diplazium laffanianum*, with fifteen specimens currently living there, representing age cohorts from 2012, May 2014 and October 2014. In 2020 it also became significant as the only place in the world where reproductively active *Diplazium laffanianum* can be found in the wild.

Spores on PP Oct14 on the lower slope of Sear's Cave in July 2020

On a visit to Sear's Cave on July 17th 2020 we discovered that four of the *D. laffanianum* planted in 2019 were producing spores. I don't know when the sporing started, as I was unable to visit the cave

in the spring. By July, one very large fern (14L on the upper slope) had fully developed, open sporangia on several fronds (cover photo) and newly forming sporangia on others. This fern continued to produce spores for the rest of the year. On Dec. 31st it had sporangia at all stages of development on almost all of its fronds. Three of the ferns on the lower slope showed signs of spores developing in July, which was a surprise as they were relatively small. 14J had open sporangia shedding spores on July 17th, while QQ Oct14 in the centre of the lower row, and PP Oct14 on the ledge above both had immature sporangia. These three ferns were affected by heat stress in the summer which appeared to stall spore development. By December, PP still had undeveloped sporangia visible on its fronds, while the other two had no visible sporangia on old or new fronds by December. 14L on the upper slope was shaded throughout the summer, and produced spores continuously.

It will likely be several years before any *D. laffanianum* prothalli or small sporophytes resulting from the 2020 spores are visible. The chances of *D. laffanianum* spores landing where juveniles can develop is probably low, as the habitat is choked with other vegetation. In the future, space should be cleared around sporing ferns, and spores should be transferred to open spaces within the cave and even to other sites. Collecting spores to try propagation in containers is also recommended.

The spores produced on these four ferns at Sear's Cave in 2020 represent the only recorded reproduction by *D. laffanianum* in the wild in over 100 years. It is a significant first step towards re-establishing this species in wild, but there is no guarantee that juveniles or a self-sustaining population will result. Nothing is recorded in the literature on the reproductive biology of this species, so much will be learned at Sear's Cave in the coming years.

The habitat in the sinkhole at Sear's Cave is critical for the rare native Bermuda Cave Fern (*Ctenitis sloanei*). I was conscious of not over-planting *D. laffanianum* near the *C. sloanei*, so as not to crowd the latter, and because *C. sloanei* get very big and will block the light. More space needs to be cleared of less desirable vegetation to make planting space for rare ferns. For this reason, we only planted three *D. laffanianum* at Sear's Cave in February. During Bermuda's COVID-19 shelter-in-place in March and April 2020 it was not possible to work in Sear's Cave, and by May the weather was too hot for planting, so no further introductions were done this year.

The February 2020 planting material was all from the October 2014 shipment, and were about ten years old. They were planted, by myself and Lawrence Doughty, in a rough triangle in a cleared patch on the south-eastern side of the sinkhole slope, where we had removed some invasive plants to make space. Throughout the year they have all increased in size and put out new fronds, however they are all leaning downhill on the steep slope. Although the planting was small this year, it was successful, with 100% surviving until the end of the year.

Keeping this spot clear will be a challenge, as large *C. sloanei* and dense Larger Marsh Shield Fern (*Thelypteris kunthii*) overhang the much smaller *D. laffanianum*. An important lesson learned from this planting is that space needs to be left to step between the plantings to weed them. In Sear's Cave extra space should be left, as the slope is steep and unstable. Weeds that need removing here include *Oxalis sp.,* Creeping Day Flower, Allspice seedlings, Mariana Maiden Fern and Tuberous Sword Fern.

The three *D. laffanianum* planted at Sear's Cave on February 2nd 2020 (left) and January 11th 2021 (right).

On April 22nd I discovered that the large limestone outcrop on the western side of the sinkhole had broken free and a roughly 2m x 2m boulder had rolled down the slope. Thankfully it missed the *D. laffanianum* planted in 2019, and most of the large *C. sloanei*. The scar where the rock fractured quickly filled with weeds over the summer. Clearing this as future fern planting site will be a priority in 2021.

July 17th 2020 photo showing the rock fall from April. The lower arrow is the boulder, the top arrow is the gap it left. Note the prevalence of sword fern, mostly invasive *Nephrolepis cordifolia*.

In May we extensively weeded the lower slope of the sinkhole where *D. laffanianum* had been planted in 2015 and 2019. We removed large, sporing Marina Maiden Ferns (*Macrothelypteris torresiana*), Rouge Berry (*Rivina humilis*) and something that I think is Gale of the Wind (*Phyllanthus niruri*). This zealous weeding turned out to be a mistake, as the lower slope of the sinkhole is in direct sun for much of the day in the summer. On visits in July and August, it was incredibly hot on the lower slope, and most of the large *C. sloanei* and all of the *D. laffanianum* were showing signs of heat stress. Fortunately, all of the *D. laffanianum* recovered again by November, but the spores that were developing at the start of the summer never progressed, likely due to stress.

In the future, weeding should be done in November and December to make space for planting, and in March and April around newly planted ferns. Selective weeding should be done carefully over the summer, while leaving large plants that may offer some shade in place. An artificial source of shade is needed on the lower slope, and a solution should be installed before May 2021. Several Pawpaw (*Carica papaya*) trees have sprouted near the plantings on the lower slope and I have left these in place, but once they get taller, they will no longer offer much shade.

Weeding at Sear's Cave needs to be undertaken with extreme caution. I accidentally uprooted NNOct14 in July whilst pulling out a large *M. torresiana*. I replanted the *D. laffanianum* and it did not seem to suffer from the experience. Tuberous Sword Fern (*Nephrolepis cordifolia*) has taken over large areas of Sear's Cave over the last two years. The roots and creeping rhizomes of this species spread out in all directions for great distances, so pulling up one part of it dislodges the substrate all around. Care should be taken on rock faces not to dislodge the numerous juvenile *C. sloanei* while pulling out sword fern roots.

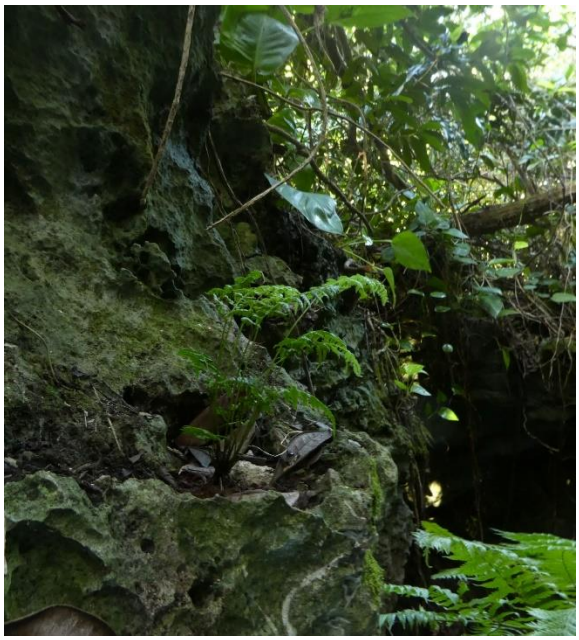
Paynter's Hill

Paynter's Hill was a new re-introduction location for *Diplazium laffanianum* in 2020. The breathing cave within the government-owned nature reserve was the planting site for two batches of ferns. I planted ten specimens from the May 2014 and October 2014 cohorts, with the assistance of Lawrence Doughty and Mark Outerbridge, on January 14th 2020. I added an additional nine *D. laffanianum* on February 26th, after determining that all the planting sites at Walsingham Trust were not useable this year. The planting material added in February included two individuals from the 2012 cohort, with the rest being from the two 2014 shipments (Table 1). Paynter's Hill now forms the second largest wild sub-population of *Diplazium laffanianum*, with eleven of the nineteen planted ferns (58%) surviving until the end of the year.

On January 14th we planted three specimens on the steep slope down into the large, deep mouth of the breathing cave, on the northern side (closest to the hotel). Here, air flows roughly north-south via two cave mouths with noticeable variation in temperature and humidity compared to the surrounding area. One fern, 14Q ½ is under the drip line of the southern cave mouth and I was concerned that it would be damaged by dripping water, but it has done well; as has PPOct14 a few feet away. I had thought the third fern, 14Q $^{2}/_{2}$ had fallen down the slope into the cave, but I found it with a tiny frond showing on December 31st. This area of the sink is incredibly treacherous as it is wet, steep and unstable. No further plantings are planned here.

We planted three large *D. laffanianum* in the big holes on the vertical rock walls of the sinkhole near the breathing mouth, and two more on the northern rim of the sinkhole by the pathway in. The

holes were filled with extra soil, which needed to be carried to the site, as there is very little soil in the rubbly bottom of the sink or in the surrounding woodland. All five of these ferns planted in the walls had died by September 17th. On February 26th, I planted one fern in a hole in the mossy wall at the western end of the sinkhole, where the Toothed Spleenworts grow. This area felt drier than the rest of the sinkhole, despite the moss and spleenworts, so I only tried one *D. laffanianum* here. I found it dead on March 11th. Therefore none of the *D. laffanianum* planted in soil pockets on vertical rock faces survived. This is consistent with what was observed at Walsingham with the earliest out-planting experiments (Table 2). It is likely these pockets drain water too quickly and loose soil too easily. Pockets in rock faces should not be used as planting sites in the future, and the presence of other ferns and mosses on a surface should not be used as a proxy for good *D. laffanianum* habitat.



QQ Oct14 on the north wall at the breathing cave in January 2020.
It had died by September.

The *Diplazium laffanianum* specimens that we planting on the floor of the sinkhole fared much better. Three of the five planted in the ground survived the year. The two that did not survive were small ferns from the same pot (12-12BC). The 2012 cohort in general has not survived well.

In January I left one fern (labelled 7 Nov 18) in its pot, as I could not dig a good enough hole for it. I was concerned that it might fall over, which is exactly what happened. In February I found it had rolled downslope and was lying under the overhang of the cave mouth. I dug it into the ground and it has thrived. I've tried leaving ferns in pots where there isn't enough soil to plant them properly at Walsingham Trust, and it has never been successful there either.

In February Mark Outerbridge gave me a Bermuda Cedar stump, which we transported to Paynter's Hill and placed into the sinkhole at the breathing cave. I had good success at Walsingham in 2014 with *D. laffanianum* planted into a cedar log. They grew well and survived multiple hurricanes before the cedar was finally stolen. Our plan was to attempt a similar planting here, with a stump that could be moved out of the way if necessary during future work. I planted three *D. laffanianum* into the cedar stump on February 26th. On March 11th I found one had dried out, but it rebounded and survived. On close examination in December 2020, it appears the *D. laffanianum* on the east side of

the stump is tiny and what is now filling the rest of the planting hole is another fern, possibly *Thelypteris kunthii*. The Larger Marsh Shield Fern (*T. kunthii*) is now growing as a contaminant in many of the *D. laffanianum* pots at Shorelands, and we may have accidentally brought them to Paynter's Hill. Once the ferns are big enough to confirm their identity, they can be removed.

The cedar stump planted with 3 *D. laffanianum* in February 2020

There is not much space for additional plantings on the floor of the sinkhole around the breathing cave, and our experience in 2020 shows that *D. laffanianum* did not survive on the walls of the sink. Therefore, in 2021 I would like to search for additional locations on Paynter's Hill where *D. laffanianum* can be introduced in 2022.

We began clearing pothos vine from the breathing cave in December 2019, and completed this task in January 2020 to enable fern planting. Keeping the space clear of pothos vine will be an ongoing management challenge, and it should be checked at least twice a year. After Hurricane Paulette passed Bermuda in September, a huge amount of Allspice leaf litter from the surrounding trees fell into the sinkhole and buried the ferns. A large number of spice berries also fell into the sink, resulting in hundreds of seedlings that need to be managed. In places where we brushed away the accumulated Allspice litter, juvenile *Ctenitis sloanei* have appeared, suggesting the litter might be limiting their numbers within the cave.

Causeway Cave

On February 10th 2020 I planted three *Diplazium laffanianum* at Causeway Cave in the government park at Blue Hole. The planting location was a ledge above the cave, which was rocky with little soil and covered in Allspice leaf litter. I put two of the ferns into the ground, away from the overhanging rock face so that they would receive light and rainwater. The third was planted into a gap in a large root, which I filled with soil.

The central one on the ledge died sometime before July 22nd. The other two were surviving in July but the one in the root died sometime before September 23rd. As of the end of the year, only one of the three has survived and it is smaller now than when it was planted, having lost its fronds in September.

This planting site was marginal, and I don't intend to put any more here. The microclimate created by the cave mouth at Causeway Cave is ideal for ferns, but the site is too heavily visited to be useful as a planting location. I would like to explore Blue Hole Park for additional planting locations, since *Diplazium laffanianum* should be distributed with the government parks system.

West Walsingham Sink and Bee Pit Cave

I did not plant any additional *Diplazium laffanianum* in the west sink at the Walsingham Trust property in 2020. After hurricane Humberto in 2019 the leaf loss from the invasive-dominated tree canopy made much of Walsingham too open, sunny and hot for ferns.

On January 9th 2020 I determined that four *D. laffanianum* planted in 2019 continued to survive in the vicinity of Bee Pit Cave, but all were very small after losing fronds following hurricane Humberto. When I re-visited the site on July 22nd 2020, one of them (BBBOct14) had doubled in size, while the other three were still small. On visiting again on September 23rd (following hurricane Paulette on Sept. 14th) I noted that BBB and PP had died, while the two other only had a few small fronds. BBB miraculously recovered, and was once again the largest at this site by December 2020. PP never recovered, so at years end there were three surviving ferns from the nine planted in 2019. Yet again this site showed that even when presumed dead, planted *D. laffanianum* should never be removed.

BBB Oct14 appearing dead in September 2020 (left) and showing a newly unrolled frond in December 2020 (right)

General Observations and Other Activities

Category 2 Hurricane Paulette passed over Bermuda on September 14th 2020. The eye was over the island for about 3 hours. It seems like Paulette did not have the associated salt spray that others recent storms have had; and there was rain in the back part of the storm. Therefore, there was not

as much salt burn on the vegetation after Paulette as there had been after Humberto in 2019. All of the *D. laffanianum* plantings that were alive in September survived this storm.

The main cause of death among the 2020 plantings was likely the lack of rainfall. By March 11th we were already an inch down on rain for the year. By August 17th the year-to-date rainfall was 732mm, with a normal year being 879mm. The rain we did receive this year fell in a few intense rain events interspersed with long dry periods.

It became apparent to me this year that sun-mapping prospective planting sites would be incredibly beneficial. At Sear's Cave from December to February, the sun does not illuminate the slope of the sinkhole in the afternoon. In the summer however, the lower part of the slope is in direct sun. If I'd known this, I would not have planted *D. laffanianum* on the lower slope. Therefore, researching methods for sun mapping a site, creating sun maps for existing plantings, and sun mapping potential new sites at various times of the year, is a goal for 2021.

In 2020 I was fortunate to collaborate with two photographers on projects to better document the wild *Diplazium laffanianum*. On March 11th Michael Wang, a photographer from New York, photographed the ferns on Paynter's Hill and the habitat at Church Cave as part of his project documenting extinct-in-the-wild species. On August 25th I asked Chris Burville to accompany me to Sear's Cave to photograph the sporing ferns. His photos document this historic first sporing event in wonderful detail.

References

Copeland, Alison. 2019. Re-introduction of Governor Laffan's Fern (*Diplazium laffanianum*) to the wild: Report on plantings for calendar year 2019. Biodiversity Section, Department of Environment and Natural Resources, Government of Bermuda. Pp. 6. https://environment.bm/s/BAMZ-3378-BBP-281-Copeland-2019.pdf