Darwin Plus:
Overseas Territories Environment and Climate Fund
Annual Report

To be completed with reference to the "Writing a Darwin Report" guidance: (http://www.darwininitiative.org.uk/resources-for-projects/reporting-forms). It is expected that this report will be a **maximum** of 20 pages in length, excluding annexes)

Submission Deadline: 30th April 2020

Darwin Plus Project Information

Project reference	DPLUS080
Project title	Securing South Georgia's native habitats following invasive species control
Territory(ies)	South Georgia
Lead organisation	Royal Botanic Gardens, Kew (Kew)
Partner institutions	Indigena Biosecurity International (Indigena) and Durham University
Grant value	£256,544 (Y2 = £89,123)
Start/end dates of project	01 April 2018 – 31 March 2021
Reporting period (e.g. Apr 2019-Mar 2020) and number (e.g. Annual Report 1, 2)	April 2019 – March 2020 AR 2
Project Leader name	Rosemary Newton
Project website/blog/social media	Kew project website: https://www.kew.org/science/our-science/projects/south-georgias-native-habitats Twitter: Follow @KewUKOTs; Search #KewSouthGeorgia
Report author(s) and date	Rosemary Newton & Colin Clubbe 21 September 2020

1. Project summary

The project is focussed on securing native habitats and their constituent native species on South Georgia following non-native species control. South Georgia is an isolated UK Overseas Territory in the Southern Atlantic Ocean. The island is 165 km long and 35 km wide and located around 1300 km south-east of the Falkland Islands (Figure 1).

Invasive non-native species are one of the most important drivers of biodiversity loss, and this impact is particularly severe on islands. South Georgia is a wildlife haven which has, until recently, been significantly impacted by introduced reindeer and rodents. Reindeer have been successfully removed and the island was declared rodent free in May 2018 (DPLUS031; http://www.sght.org/news/south-georgia-declared-rodent-free/).

In response to the predicted grazing pressure release following mammal eradication, a Non-Native Plant Management Strategy was developed by the Government of South Georgia & the South Sandwich Islands (GSGSSI; DPLUS015) and is now being implemented, to manage to zero density 33 of the 41 non-native plant species on the island and to control the more widespread invasive plant species (Annex 3). Eradication of non-native plant species is exceedingly difficult because of the formation of a soil seed bank from which plants can regenerate, often for many years.

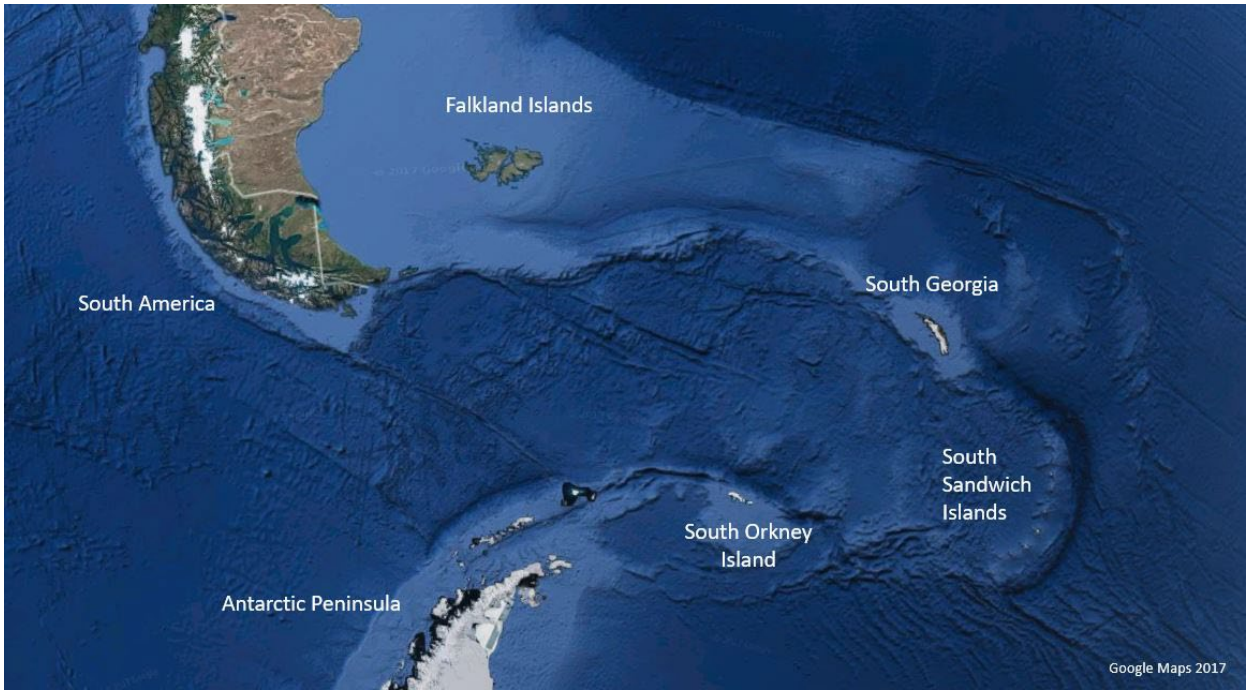

Figure 1: Location of the UK Overseas Territory of South Georgia and the South Sandwich Islands.

This project aims to safeguard South Georgia's native habitats by monitoring and assessing vegetation changes following invasive non-native species control; estimating from soil seed bank and seed viability studies the risk of non-native plant species persisting beyond 2020 (the end date for the current Non-Native Plant Management Strategy) to inform future management strategy; quantifying the potential for non-native plant species to disperse into new areas following glacial retreat due to climate change; and, securing seed and fern spore collections of native plant species for long-term conservation at Kew's Millennium Seed Bank (MSB).

The outcomes of the project will inform future management strategies by GSGSSI of non-native plant control and of terrestrial communities in the face of predicted climate change (Needs Assessment: South Georgia and South Sandwich Islands, DFID, July 2012).

2. Project stakeholders/partners

Regular email and phone conversations have been held between Kew (Rosemary Newton, Colin Clubbe, Marcella Corcoran) and project partners, Indigena (Bradley Myer, Kelvin Floyd) and Durham University (Wayne Dawson) to discuss and review project activities. In addition, Six-monthly Steering Group meetings have been held to monitor project progress (Annex 4 - 7). This is a strong partnership of people who know each other well, and have worked together for some time. The partnership is functioning well.

Kaitalin White and Calum Sweeney (Queen Mary and Kew joint MSc students) joined the project in March 2019 and March 2020, respectively. Kaitalin set up and monitored seed germination tests on South Georgia species from MSB collections and analysed South Georgia soil samples for viable seed as part of her MSc thesis (Available from the Kew Research Repository: K White Thesis). She achieved a distinction in both her project and overall for her Master of Science degree and her results have been fully integrated into the project. Calum's project will be using the thermal gradient plate experiments to assess climate change impacts on native and non-native flora. [September update: Due to the inability of lab work to be done during the coronavirus pandemic, Calum's project changed to a desk-based one, analysing MSB germination data of native and non-native plant species found on South Georgia, predicting temperature changes on the island due to climate change, and constructing a DNA "library" to enable species to be identified from vegetative material originating from South Georgia.]

The main stakeholder is the Government of South Georgia & the South Sandwich Islands (GSGSSI) who are kept informed of project progress and outputs. The main period of active contact is during the actual field season on South Georgia. A face to face meeting with the Environment Officer, Jennifer Lee and Chief Executive, Helen Havercroft of GSGSSI (at the GSGSSI Science and Stakeholder Event, hosted at Kew in September 2019) enabled useful discussions between Kew and GSGSSI on how the findings from the current Darwin Plus project would inform the development of future plans for non-native plant management and control when the period covered current Management Plan ends in 2021.

3. Project progress

3.1 Progress in carrying out project Activities

Output 1 activities

A Regulated Activity Permit (RAP) is required for any field work on South Georgia; these ensure that GSGSSI is aware of and granted approval for all planned activities and that any possible environmental impacts are minimized. Following the first field season, the required RAP feedback form was returned to GSGSSI (Annex 8). In the lead up to the second field season, the RAP renewal application was submitted (Annex 9) and the permit for the second field season approved and issued (Annex 10), enabling the field activities to commence.

The field team spent a total of 12 weeks on South Georgia completing activities for the DPLUS080 project (e.g. monitoring non-native plant abundance and distribution; collecting seeds, soil samples and dispersing seeds) and the related Non-Native Plant Management Strategy project (e.g. treating non-native plants with herbicide; surveying new areas for non-native plant occurrence). The field team leader, Kelvin Floyd, kept in email contact with Kew throughout the field season ensuring a dialogue on progress was maintained. Weekly accounts of field activities were kept, including details on the occurrence of non-native plant species at field sites for the second field season (Annex 11). Regular photographs documenting activities were emailed by the field team to Kew, which were posted on Twitter (Annex 12).

Wayne Dawson completed a preliminary analysis on the vegetation monitoring plots to determine vegetation changes following reindeer removal (Annex 13) which he presented at the July 2019 steering group meeting (Annex 5). It appears as if convergence is occurring in fellfield/scree and dry grassland with vegetation in plots becoming more similar. Beach tussac and tussac quadrats are becoming more tussac dominated and the Maiviken wet grassland is more dominated by *Deschampsia antarctica*. Clear reductions of non-native target species can be seen from herbicide treatment plots monitored on Thatcher Peninsula. Uploading summary reports onto websites and Research Gate were agreed to be premature at this stage as these data are still being worked on with the aim to publish these at the end of the project.

Output 2 activities

Funds were available from Kew to support a student to work on the South Georgia project in the second year. Kaitalin White, a Kew MSc student, started at the MSB in late March. Following training in seed processing techniques and researching different seed extraction methods, she tested the feasibility of these methods on UK soil.

Seeds are typically concentrated by washing soil through a series of sieves using water, removing large and small soil particle fractions not containing seed. This method was not, however, possible to use, due to stringent Quarantine requirements of the Defra soil licence issued to legally import the soil.

Seed was therefore dry-extracted from twenty South Georgia soil samples of 20 ml each (five replicates from four sites) using sieves. Over 600 seeds or seed fragments were found, including 122 full seeds, with 51 viable. Viable seeds comprised four native species, four non-native species (three Class 3 and one Class 1 species) and some unknown species. Although this was a very precise and accurate method for obtaining seeds from the soil, it was exceptionally time intensive.

Another method, consisting of spreading a thin layer of a subsample of South Georgia soil on top of sterilized potting soil and then moistening and incubating at temperatures most likely to stimulate seed germination (25°C, 12 h day / 10°C, 12 h night, with a corresponding 12 h / 12 h photoperiod), was tried for one replicate of soil samples collected from all 26 sites in 2018-2019. These were kept in sealed plastic bags in growth chambers (according to agreed quarantine conditions) and monitored for germination for a minimum of 66 days: 482 seedlings germinated and were identified, where it was possible to do so. This method proved to be the more efficient method and will therefore be used for the remainder of soil sample processing. Kaitalin achieved a distinction in both her project and overall for her Master of Science degree (Available from the Kew Research Repository: K White Thesis).

Identification of species, both from seed and seedlings, has been challenging. Seeds of 56 native and non-native species that occur on South Georgia from collections held at the MSB were photographed; some seeds were straightforward to distinguish; however, seeds, particularly of the Poaceae (grass family), were very similar and difficult to identify to species level with reasonable certainty. Seedlings of 55 species from germination tests have been photographed, but again, particularly in the Poaceae, seedlings were very similar and difficult to identify to species level. Young plants are being grown on and photographed to determine whether distinguishing between different species at a later stage is possible. We are also seeking additional funding from other sources to try DNA barcoding as an alternative way to identify unknown seeds and seedlings.

In preparation for the upcoming 2019-2020 field season, the licence to import, move and keep soil was renewed by Defra with an added minor amendment to enable the harvesting of leaf material for DNA analysis from seedlings germinated in South Georgia soil (Annex 14). The letter of Authority for soil import (Annex 15) was also obtained while the second field season was underway. The second field season had to be cut short to ensure the safe return of field team members to their respective countries following the coronavirus outbreak. These last minute changes in field work plans did not have a major impact on the project as soil samples had already been collected (Annex 16).

Output 3 activities

Unlike soil, which had already been sampled as scheduled, seed traps had to be removed sooner than planned because of the early departure of the field team from the island. The coronavirus outbreak also affected international flights, including the military flight from the Falklands to Brize Norton in the UK. The boxes of seed and soil samples are being safely stored in cool, dry conditions in the Falkland Islands; until it is possible for these to be transported to the United Kingdom. [September update: samples have been safely transported and are now at the MSB.]

In the 2018-2019 field season, the 30 seed traps collected 748 seeds, of which 218 were empty seed husks. The remaining 530 seeds appeared full. Seeds were identified where possible from seed morphology: 5% were native, 62% non-native and 33% could not be identified (so unknown). Seeds of Poaceae species, *Taraxacum officinale* and *Cerastium fontanum*, the latter two both Class 3 non-native plant species, were most abundant in the traps.

Thirty seed traps were installed during December 2019 and early January 2020, in the same six localities (five per site) as the 2018-2019 field season (Annex 17). Earlier removal of seed traps due to the sudden departure of the field team from the island as a result of the coronavirus pandemic may have influenced the diversity of seed collected, as the latter part of the seed dispersal season may have been missed. However, as other methods of monitoring non-native plant species are being used (soil samples, monitoring of plants establishing in areas of glacial retreat), the overall understanding of non-native plant species threat to South Georgia should still be able to be adequately determined from the combination of these different monitoring approaches. [September update: Seed trap contents have been received at the MSB and processing of the contents will commence as soon as full access to the laboratories is permitted.]

Output 4 activities

Suitable pairs of congeneric native and non-native plant species were selected to determine the impact of climate change on seed germination experimentally using a thermal gradient plate, which enables the germination characteristics of a species to be precisely determined over a wide range of constant and alternating temperatures. It was decided that native *Poa flabellata* would be paired with either non-native *P. annua* or *P. pratensis*; native *Festuca contracta* with non-native *F. rubra*; and native *Deschampsia antactica* with non-native *D. parvula* or *D. cespitosa*.

Seed collections with initial tests yielding >85% germination should ideally be used for thermal gradient plate experiments, to ensure maximum germination at optimum temperatures. The first thermal gradient plate germination experiment to characterise germination response to different constant and alternating temperatures and under simulated climate change scenarios has been completed for the native grass, *Poa flabellata*, yielding interesting results and validating the methodology.

Germination testing of species pairs could only proceed once 2018-2019 seed collections had been processed (accessioned, counted and x-rayed) and initial germination tests to assess seed viability were complete. Only non-native *P. annua* and native *P. flabellata* initial seed germination tests achieved >85% germination. Although germination in native *F. contracta* and non-native *D. parvula* seed was >75%, and could likely be used, the non-native *F. rubra* seed collection was immature and therefore unusable. Seeds of the native *D. antarctica* achieved <20% seed germination; physiological dormancy is suspected to be the reason why this is so low, as seeds appear full and viable in x-ray tests. From the literature, a period of cold treatment (termed cold stratification) is known to result in greater seed germination when moved to warmer temperatures in this species, and so the optimal duration of this for these collections is being experimentally investigated.

Preparations for setting up the *Poa* species pair on the thermal gradient plate included x-raying seeds of non-native *P. annua* to enable any empty or partially-filled seeds to be removed prior to starting the experiment. This was completed, and the seeds were ready for sowing in March; however, this could not be done due to the closure of the MSB building because of the coronavirus pandemic. Thermal gradient plate tests on this *Poa* species pair will commence as soon as the MSB reopens. [September update: limited MSB laboratory access is now possible; this experiment was started in early September 2020 with much germination taking place]

Additional seeds of non-native *F. rubra*, *D. parvula* and *D. cespitosa* have been collected in the 2019-2020 field season to complete the remaining species pairs for this work (Annex 18). Thermal gradient plate tests on *Festuca* and *Deschampsia* species pairs will commence as soon as the 2019-2020 seed collections have been accessioned and processed by the Seed Collections Teams. [September update: this will likely be in November 2020.]

Output 5 activities

In the first field season from December 2018 - March 2019, 29 collections of 18 species in total were collected, consisting of 11 seed collections from six native plant species; seven seed collections of five non-native plant species and 11 spore collections of seven native fern species (Annex 19).

Collections with good germination (≥ 65%) were obtained for four collections of three fern species and five collections of four grass species. Germination tests are ongoing for seven collections to ensure good viability. Five collections are unable to be tested because the collections (one plant and two fern species) are too small (<250 seeds or spores) for germination testing (according to MSB Germination Testing Procedures) or germination requirements are known to be difficult and require extensive research (two fern species). Two fern collections had poor germination/viability (<20%) and six collections (four grasses and two rushes) possessed no or immature seeds and had to be discarded. This information was communicated to the field team, enabling them to modify the field collection protocol. These species were incorporated into the target list of species for collecting during the 2019-2020 field season.

Using seeds already banked at the MSB, seed germination tests at different conditions (e.g. constant and alternating temperatures), and with pre-treatments (such as chipping or cold stratification) on South Georgia seed collections, and also seed collections from other regions for species that occur on South Georgia, have been used to produce seed germination protocols. From these results an understanding of seed dormancy characteristics, and consequently the conditions required to break dormancy, have been determined for most of the native and non-native angiosperm species on South Georgia. Good germination (>75% germination of viable seed) has been achieved in banked collections of all plant species native to South Georgia except six (three achieved ≥50% and the remaining three had 19-40% germination). These six species are still being worked on.

Germinated seeds were grown on to produce seedlings for imaging. At least two, and in many cases three, stages of seedlings from these germinated seeds have been photographed in preparation for the production of a seedling field guide.

All the required paperwork for importing seeds from the 2019-2020 field season (Annex 20) was in place prior to their transport to the MSB. The boxes of samples were unable to depart the Falkland Islands due to the coronavirus pandemic. They are being safely stored in cool, dry conditions in the Falkland Islands; until it is possible for them to be transported to the United Kingdom. [September update: samples have been safely transported and are now at the MSB.]

3.2 Progress towards project Outputs

Output 1: All data required to analyse changes in numbers and frequency of native and non-native plants from established vegetation monitoring plots and invaded sites have been collected, and preliminary analysis of the first year's data has been completed. Analysis of these data will reveal any changes in native and non-native species on South Georgia.

Output 2: Soil samples collected from the island (n = 230) have exceeded the target (n = 100). Planned seed extraction methodology by master's student Kaitalin White was tested for 20 soil samples, and although successful, proved too time consuming for the quantities of soil requiring processing. A second method of assessing seed viability, by watering soil samples to encourage germination, was then successfully trialled. This methodology is suitable for processing larger quantities of soil. However, identification of some species, especially in the Poaceae (grass family), is difficult because of the lack of characteristic morphological features of seedlings, and soil quarantine restrictions have prevented plants being grown on to a reproductive stage at which identification could be confirmed. Vegetative material of all seedlings has been collected to enable positive identification from extracted DNA.

Output 3: Double the target of seed traps (5 replicates from 6 sites) have been collected over both field seasons. Seed trap contents (n = 30) from the first field season have been extracted from traps and identified where possible. Germination tests are still required to determine viability and confirm species identification for unidentified seeds.

Output 4: Germination characteristics of native *Poa flabellata* have been determined from a banked MSB seed collection, and the methodology for the species pairs experimentation finalised. Final germination percentages of all other banked South Georgia MSB collections chosen for the thermal gradient plate experiment were too low for thermal gradient plate tests and so fresh seed collections were required for this work. Processing of South Georgia seeds collected in 2018-2019 took longer than anticipated and so initial germination tests of seeds were completed in early 2020. Collections of *Poa annua*, *Festuca contracta* and *Deschampsia parvula* are suitable for the work, but the only *Festuca rubra* seed collection was immature and so unusable. *Festuca rubra* was put on the target list for further seed collection; two collections of this species were collected in the 2019-2020 field season and these will be processed as soon as the laboratory reopens. Low germination obtained for *Deschampsia antarctica* seeds requires further work as a period of cold stratification is likely required before thermal gradient plate testing can begin. The first species pair (*Poa flabellata / Poa annua*) was about to be set up in March by MSc student, Callum Sweeney, when the MSB labs were shut due to the coronavirus outbreak. [September update: The MSB laboratories are gradually opening again, and the thermal gradient plate experiment for the first species has been set up.]

Output 5: In total, 52 collections of seeds and spores from 22 species (comprising eight ferns, seven native and seven non-native angiosperm species) have been collected in both field seasons, the majority of seed dormancy syndromes have been identified and seed germination protocols determined, for both native and non-native species. Seedling images have also been captured for most species. This output target has largely already been met and is expected to be exceeded.

3.3 Progress towards the project Outcome

There have been some challenges in Outputs 2-4 which have slightly delayed progress towards the project outcome; however, these have largely been resolved, and under normal circumstances would remain on track to be delivered by the end of the project. Recently, the shutdown of the laboratory at the MSB due to the coronavirus pandemic, and consequent inability to proceed with laboratory work, poses a threat to achieving the project outcomes without a time extension to the project. [September update: The MSB is gradually opening to staff; however, 6 months have been lost due to the inability to do laboratory work. The full impacts of this are being assessed and a formal change request will be made if necessary.]

3.4 Monitoring of assumptions

- Weather conditions and transport problems did not significantly hamper project activities in either field season. The field team received full support from the British Antarctic Survey (BAS) and the Government of South Georgia & the South Sandwich Islands on-island support teams, enabling them to get to all field sites for both year one and year two activities. The second field season was cut short due to having to leave the island early because of the coronavirus pandemic; however, all planned samples were still collected (Assumptions 0.1, 1.1, 1.2).
- Seeds or spores from all target species were collected in the first field season (Annex 19). Seven of these collections, following processing, had to be discarded as they did not contain fully developed seeds or few spores, indicating that they had been collected too early in their development (or too late, in the case of fern spores). Missing species were included in the 2019-2020 target list for collection, and have been recollected. These are still to be processed, however, and so there remains a risk that collection numbers, quality and viability are insufficient to count towards the target as safely stored for conservation at the MSB. There is also a risk that insufficient quantities of high-viability seed have been collected for thermal gradient plate germination experiments (Activity 4.1). This risk continues to be monitored (Assumptions 0.2; 4.1, 4.2, 5.1).
- The success of the non-native plant control programme remains at risk from new non-native species being discovered or introduced to South Georgia. The field team have identified four species requiring further research (*Gaultheria pumila*, *Gunnera magellanica*, a likely hybrid between *Poa annua* and *P. flabellata*, and *Rumex acetosa*). Additionally, *Lobelia pratiana* has been reclassified as a Class 2 species from Class 1, and *Poa trivialis* as a Class 1 species from a Historic species). Herbarium specimens and DNA material have been collected for investigation at Kew. The biosecurity measures implemented on South Georgia are amongst the most rigorous in the world and are regularly reviewed and strongly enforced (add in link to GSGSSI website: http://www.gov.gs/biosecurity/). Consequently these occasional new discoveries are more likely to represent over-looked species rather than genuine new recent introductions to South Georgia. However, appearance of new non-native plant species remains a threat to native South Georgia plant species, and this is being carefully monitored during each field season.
- Soil samples from 26 sites in the first field season and from 20 sites in the second field season (5 replicates at each site, resulting in 230 soil samples in total) were collected. Initial investigations of suitable methodology enabled the extraction of over 600 seed fragments from 400 ml of soil (20 ml x 5 replicates of 4 sites), 122 of which were full seeds, with 51 of these viable. Samples of 80 ml of soil from the first replicate of all 26 sites in the first season were then watered, and 482 seedlings germinated. Having insufficient seeds in samples is therefore no longer a risk (Assumption 2.1).

- Seed and seedling imaging of native and non-native plant species that occur on South Georgia has shown that identification of some species with a reasonable level of certainty is impossible. Therefore Assumptions 2.2 and 3.3 remain a risk. However, DNA barcoding is being investigated as a new solution to this problem.
- Dispersal traps were robust and were not disturbed whilst they were *in-situ* in either field season. Assumption 3.1 is therefore no longer a risk.
- The number of full seeds extracted from seed dispersal traps from the 2018-2019 field season was 530. Seed traps from the 2019-2020 field season have not yet been analysed; however, it is likely that a similar number of seeds would have been collected this field season. The field teams observed that dispersal traps had to be removed from the field before seed dispersal from some plant species had finished in the 2018-2019 field season. To ensure that later dispersing species would also be collected, the plan was to stay on the island for a few weeks longer in the 2019-2020 field season. Frustratingly, the coronavirus outbreak necessitated an early departure from the island, so the risk remains that a representative sample of seed dispersing over the late summer months on South Georgia was not collected (Assumption 3.2). However, other monitoring methods (e.g. surveys of plants establishing in recently exposed areas due to glacial retreat) should gather similar information about plant establishment; thus answering the question on which plant species are likely to establish on new ground exposed to retreating glaciers should still be possible.

4. Project support to environmental and/or climate outcomes in the UKOTs

The main stakeholder is GSGSSI, with responsibility for managing terrestrial and marine biodiversity. GSGSSI have strong policies and principles around stewardship, environmental protection, biosecurity, and evidence-based decision making. An example of this is the Non-Native Plant Management Strategy (Annex 3).

One of GSGSSI's key environmental objectives is to effectively manage invasive alien species, and in particular better understand the distribution and abundance of non-native plants to control their spread. This project will identify non-native plants (from soil and seed traps) that pose a risk to persisting on South Georgia post-2020, which directly supports the long-term objectives of GSGSSI of controlling and eradicating invasive alien species and restoring native biodiversity and habitats (Target 9, Biodiversity Action Plan for South Georgia & the South Sandwich Islands 2016-2020; Annex 21). The outputs of this project will also provide GSGSSI with direct evidence for the development of the next Non-Native Plant Management Strategy which is currently in the planning phase for a planned publication date in 2021.

The project is also contributing to the establishment of scientific baselines from which to assess environmental change (Objective 5) and informing on non-native plant species threats to ensure best practice biosecurity protocols (Objective 6) in the current Biodiversity Action Plan for South Georgia & the South Sandwich Islands (2016-2020).

5. OPTIONAL: Consideration of gender equality issues

South Georgia is uninhabited apart from the research scientists that are based there seasonally, at either King Edward Point or Bird Island. The research teams are recruited via their institutional recruitment schemes which incorporate processes to promote diversity. The collaborating partners for this project have processes in place to promote diversity and inclusion. These partners came together to implement this project, but individuals were already on staff and not recruited specifically for this project. The Kew Team consists of three staff members (1 male, 2 female) with 1 female and 1 male Masters student helping in 2019 and 2020, respectively. The gender-balance of our partners is skewed (6 male : 2 female), but in 2019 a locally-based Chilean female was included in the 2018-2019 field team.

6. Monitoring and evaluation

The steering group, led by Colin Clubbe, was formed. Half-yearly Skype meetings with Brad Myer of Indigena (based in New Zealand) and half yearly face-to-face meetings with Wayne Dawson (Durham University) have been held on 22 July 2019 and 7 January 2020 as planned

(Annex 4 - 7). The Darwin annual and half-year reports were submitted as agreed and feedback on these welcomed, and acted upon. Regular discussions (every month, and often more frequently) between Rosemary Newton and Colin Clubbe about project progress and between Rosemary Newton and the project partners have taken place. These provide an active forum for discussing the project, its progress and enable the identification of any potential shortcomings. To date this has formed an efficient and effective way to monitor progress.

The lead up to the field work season required good communication and co-ordination between partners to ensure that all equipment was ready and required information available prior to travel. Field work progress was monitored by means of weekly reports (Annex 11) from the team leader, and an end of field season report produced (Annex 22).

The period in between field seasons is relatively straightforward as it comprises the laboratory-based research at the MSB where we have all the facilities needed to complete this work, This element of the project is progressing well, if a little delayed in some aspects due to the usual challenges of fundamental research, none of which we see as having significant impacts on the project delivery. The quarantine requirements and conditions placed on us by Defra added extra challenges as to how we deal with materials from South Georgia, particularly soil, but we have established a dedicated quarantine area in one of the labs where this work can be undertaken within the requirements of the Defra license. It impacts on the speed of processes, but again these are all manageable within the timeline of the project.

7. Lessons learnt

South Georgia is a harsh environment in which to undertake field work. Having a team that is experienced working in these conditions is key. Despite the challenging environment, both field seasons proceeded well. With the support of BAS and GSGSSI, the field team were able to access all areas necessary to deploy and later retrieve seed traps, collect samples, and monitor non-native plant populations in areas of concern. Seeds and spores from all targeted species were collected, often from more than one population. Soil samples collected and seed traps set and collected also exceeded target numbers.

Arranging sample shipment was very time consuming last year, and care had to be taken to ensure no documentation or permissions were missing. Keeping detailed records of the process and contacts during the first year made the shipment of second year South Georgia samples much easier, despite coronavirus pandemic difficulties. The samples were flown directly from Mount Pleasant Airport in the Falkland Islands to Brize Norton in the UK. Mount Pleasant and Brize Norton staff provided helpful advice to ensure smooth passage of the samples and Kuehne and Nagel, the handling agents, cleared the samples through customs.

Unfamiliarity with permit regulations related to soil importation resulted in more time than anticipated ensuring the correct permits were in place to move soil from South Georgia into the UK via the Falkland Islands. This, accompanied by stringent procedures required in dealing with soil under quarantine conditions in the UK, led to slower progress than anticipated, and consequently some delays in starting the laboratory work. Alternative processing methods were trialled for extracting and germinating seeds and they had to be grown on in sealed polyethylene bags in designated Quarantine growth chambers for identification, instead of being placed in glasshouse facilities as was originally planned. This highlights the need for flexibility when undertaking this sort of experimental work.

8. Actions taken in response to previous reviews (if applicable)

The report and feedback was shared and discussed with all project partners; positive and constructive feedback and comments were welcomed. The feedback was considered useful and helped us clarify our reporting of activities.

Comment 1: The Report indicates that seed was collected from six native plant species and seven native fern species (Activity 5.2); the Report also states that germination tests have commenced for all native plant species on South Georgia. It is not clear whether seed of other native species are already in the MSB, or that these species will be collected in the second field season.

Answer: Tests to determine germination requirements and dormancy characteristics of seeds of both native and non-native South Georgia plant species have been possible using seed collections of species already held in the MSB. Some were seed collections from South Georgia from a Kew-led trip to the island in 2009-2010. Other seed collections of native and non-native plant species that occur on South Georgia but were collected in other countries are also held in the MSB and these seeds and data are available for use. Germination of seeds collected in the 2018-2019 and 2019-2020 field seasons will also be checked to ensure that these behave in a similar manner to the seed collections already tested.

Comment 2: There is some concern over the timing of the collection of the seed dispersal traps. These were removed from the field before the seed dispersal of some plant species had finished. The traps may therefore not contain a representative sample. Is there any way of mitigating this problem during the second year?

Answer: The plan was to stay on the island for a few weeks longer during the 2019-2020 field season to ensure that later dispersing species would also be collected. Frustratingly, the coronavirus pandemic necessitated an early departure from the island for the field team, so the risk remains that a few species that disperse seed late in the summer season may have been missed. However, other monitoring methods (e.g. surveys of plants establishing in recently exposed areas due to glacial retreat) should gather similar information about plant establishment, and thus enable the question on what plant species are likely to establish on new ground exposed to retreating glaciers to be answered.

Comment 3: The Report states that the M&E remains as written in the Application, but there is no mention of the formation of a Steering Group, or quarterly meetings of this group. Will this be put in place for the second year?

Answer: The Steering Group, led by Colin Clubbe, was formed, and regular meetings took place (as in the previous year). Project PI, Rosemary Newton, took minutes, which are circulated and agreed by the Steering Group. These Minutes form a formal record of the Monitoring and Evaluation of the project (Annex 5, 7).

Comment 4: Some clarification of the exit strategy would be useful.

Answer: A major long-term commitment of the Government of South Georgia and South Sandwich Islands is “To conserve the Territory’s environment, minimise human impacts and, where practicable, restore the native biodiversity and habitats” (2019 Annual Report http://www.gov.gs/2019-annual-report/) and to “Ensuring South Georgia’s biodiversity is protected from invasive species” (2019-2020 Biosecurity handbook http://www.gov.gs/biosecurity/). For invasive plants the Non-Native Plant Management Strategy (http://www.gov.gs/environment/eradication-projects/eradication-projectsweeds/) remains GSGSSI’s main implementation strategy. The current Darwin project provides data specifically to inform the current strategy and helps inform the development of the follow-up strategy which is currently in development. So, the impacts of this project will be incorporated into Government strategy ensuring a long-term legacy for the project.

9. Other comments on progress not covered elsewhere

Soil processing methods have been refined (details in Section 3.1 and Section 3.2).

Difficulties of identification of species from seed and seedling morphology (details in Section 3.1 and Section 3.2) are being managed by exploring identification from extracted DNA.

The coronavirus pandemic and uncertainty of how long the MSB laboratory will remain closed poses a significant risk of delivering the project on time. We are considering the option of requesting a no-cost extension to the project to ensure that the work can be completed. [September update: The MSB laboratory has been opened to select few staff; however, processes and restrictions that have been put in place to ensure staff safety will affect the speed at which laboratory work can proceed. Furthermore, project staff are still part-furloughed and this will continue until the end of September and possibly longer, following a carefully

planned phased return to work for Kew staff. A no-cost extension to the project will be requested because of the six months of laboratory time lost to the pandemic.]

10. Sustainability and legacy

South Georgia is uninhabited apart from research scientists and visiting tourists, so there are relatively few opportunities to promote the work in South Georgia. Hence most of the promotion has been done in and from the UK:

- Colin Clubbe gave a KABaM Science Seminar at Kew Gardens on the South Georgia project in July 2020.
- Kaitalin White gave a talk at Kew and the Linnean Society on her project in June and September 2020, respectively.
- The high profile of the project within the Government of South Georgia & South Sandwich Islands resulted in them asking us whether we could host their annual South Georgia Stakeholder meetings at Kew, which we were happy to do. The meeting, held in September 2019, was a great success, attracting more than 100 participants. This provided us with opportunities to promote our current project and the Darwin Initiative. The meeting was co-facilitated by the Chief Executive of GSGSSI, Helen Havercroft, and Colin Clubbe. Rosemary Newton presented latest findings at the meeting.
- A blog on the field season and progress on laboratory work was published on the Kew website in January: https://www.kew.org/read-and-watch/invasive-species-south-georgia
- Progress on the project has been regularly updated on the Twitter feed (#KewSouthGeorgia)

As the project progresses, we will be reviewing the appropriateness of this regularly.

11. Darwin identity

The Darwin Initiative has been identified as the funder of the project in all communications, including in all the presentations mentioned in the answer to Q10 above, on the Kew website (https://www.kew.org/science/our-science/projects/south-georgias-native-habitats) and frequently on our Twitter feed (by using the @Darwin_Defra tag; search: #KewSouthGeorgia).

The Darwin Initiative funding has always been recognised as a distinct project with a clear identity. The Darwin Initiative is well known by researchers on South Georgia and has received exposure in the Falkland Islands, the closest inhabited territory to South Georgia. Local radio interviews and the article in the Penguin News (detailed in the First Annual Report) clearly identified the project as a Darwin project and the Darwin Initiative as the project funder.

Twitter is an effective way of promoting the project, @Darwin_Defra is always tagged along with @GovSGSSI, @KewScience and @KewUKOTs, who have a large number of followers, and usually retweet tweets about the project. The blogs at Kew also have a large readership. [September update: The January blog on the field season and progress on laboratory work (see answer to Q10 above) has been viewed 601 times since it was published (26/08/2020).]

12. Safeguarding

Kew, the lead organisation for this project, has two policy documents pertinent to this matter: a staff Code of Conduct, which forms part of staff contract of employment at Kew, and a safeguarding policy. The main focus of Kew's safeguarding policy is safeguarding children and vulnerable adults visiting Kew and Wakehurst. Kew's safeguarding policy is publicly available on Kew's website: https://www.kew.org/about-us/reports-and-policies/safeguarding. Kew staff are required to undergo mandatory training regarding safeguarding of vulnerable people.

Furthermore, Kew's Code of Conduct outlines staff roles and responsibilities (professional, legal, ethical), and protocols for reporting improper conduct, with further guidance on Kew's stance on bullying and harassment.

Project partner, Durham University, also has a safeguarding policy, details of which are publicly available here: https://www.dur.ac.uk/safeguarding/.

Project partner, Indigena, do not have a specific policy about safeguarding, as this is covered by laws in New Zealand. However, they do have stated Values, which are used to assess performance and as a standard (Annex 23).

South Georgia is not permanently inhabited. The project work on the island does not include any interaction with vulnerable people.

13. Project expenditure

Table 1: Project expenditure during the reporting period (1 April 2019 – 31 March 2020)

Project spend (indicative) in this financial year	**2019/20 D+ Grant (£)**	**2019/20 Total actual D+ Costs (£)**	**Variance %**	**Comments (please explain significant variances)**
Staff costs				
Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items				
Others (Please specify)				
TOTAL				

A change request was submitted and approved in February 2020 to move £ from the category "Other" to "Operating Costs". Operating costs therefore increased from the budgeted amount of £ to £ and Other decreased from the budgeted amount of £ to £.

A change request was submitted and approved in March 2020 for £ to be moved from this financial year to next financial year, as sample shipping could not be completed this year due to the coronavirus pandemic. The category "Other" was therefore decreased by £ from £ to £.

A change request was submitted and approved in March 2020 for the amount of £, which was budgeted for Indigena fieldwork travel and subsistence for additional time on South Georgia for Kelvin Floyd to complete field work (specifically to ensure later collection of seed dispersal traps) during the current financial year, to instead be made available for ensuring his safe return home to New Zealand, as it was anticipated that changing flights and potential unanticipated accommodation costs (if stranded due to rerouting of flights) would be costly. However, Kelvin was able to travel back to New Zealand without any additional costs, so this money remained unspent.

Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2019-2020 – if applicable

Project summary	Measurable Indicators	Progress and Achievements April 2019 - March 2020	Actions required/planned for next period
Impact South Georgia's native habitats and plant species diversity are protected through the eradication of non-native species, conservation of native species, rehabilitation and maintenance of native habitats and improved biosecurity		Eradication efforts on South Georgia proceeded well during the 2019-2020 South Georgia field season. Signs of reduction in non-native plant species are supported by the preliminary analysis of 2018-2019 field data (Annex 13) and observations by the field team (Annex 11).	
Outcome South Georgia's native habitats protected by identifying non-native species most likely to persist, determining potential climate change effects on native and non-native species survival and banking seeds of native species	0.1 The number of non-native species predicted to persist post-2020 determined 0.2 Native and non-native species likely to colonise new habitats identified 0.3 Spores of at least three fern species and all native seed plants of South Georgia securely banked at the MSB	0.1 Non-native species predicted to persist post-2020 determined from reductions in non-native plants requiring herbicide control in the 2019-2020 field season (Annex 22). 0.2 Native and non-native species likely to colonise new habitats identified from seed caught in traps in the 2018-2019 field season and plant surveys in deglaciated areas in the 2019-2020 field season. 0.3 Three fern species (*Polystichum mohrioides*, *Grammitis poeppogeana* and *Cystopteris fragilis*) with good spore germination (≥65%) and at least one collection of all native plant species from South Georgia securely banked at the MSB. Additionally, a further eleven spore collections of seven native fern species collected in the 2019-2020 field season, adding to collections from the previous field season. *Trisetum spicatum* (not present at MSB) and other species (with small seed collections), also collected (Annex 18).	Data and samples collected during the 2019-2020 field season will be analysed to enable progress towards indicators 0.1 and 0.2 in support of the project outcome. Spore and seed collections from the 2019-2020 field season will be processed and banked at the MSB.
Output 1. Vegetation changes following reindeer removal from established vegetation monitoring plots quantified and success of the control programme of non-native plants on South Georgia evaluated	1.1 Data from 2 established vegetation monitoring plots analysed in year 1 and year 2 and across the monitoring period to demonstrate change in numbers and frequency of native and non-native plant species 1.2 Data from at least 2 invaded sites (4 plots per site) analysed in year 1 and year 2 and across the monitoring period to demonstrate change in numbers and	1.1 Preliminary analysis of the 2018-2019 field data (Annex 13) suggests that the vegetation is converging (plots becoming more similar in fellfield.scree and dry grassland) and that Beach Tussac and Tussac is becoming more Tussac dominated. Maiviken wet grassland appears to be shifting towards a more *Deschampsia antarctica* dominated community. South Georgia vegetation monitoring plots database to be updated with the 2019-2020 field season data and the analysis rerun. 1.2 Non-native plant species are decreasing in areas where plant control is occurring (Annex 22). Data from invaded sites collected during the 2019-2020 field season to be added to the 2018-2019 field season data and reanalysed.	

Project summary	Measurable Indicators	Progress and Achievements April 2019 - March 2020	Actions required/planned for next period
	frequency of native and non-native plant species		
Activities 1. 1.1 Agree a Memorandum of Collaboration with GSGSSI, Indigena, Durham University and Kew 1.2 Review and finalise current methodology, including sites and plots for sampling, in light of planned South Georgia activities and data analyses 1.3 Project launch and workshop in the Falkland Islands 1.4 Discuss and finalise field data protocols at Falkland Islands workshop 1.5 Collect data on non-native species distribution at field sites visited in year 1 and year 2 1.6 Analyse data to quantify the success of control methods in year 1 and year 2 1.7 Update excel database and produce a summary report on non-native species distribution 1.8 Upload summary report onto GSGSSI and Kew websites and Research Gate 1.9 Prepare scientific paper for open access publication in an international peer-reviewed journal		1.1 Memorandum of Collaboration agreed and signed by all parties (see previous annual report). 1.2 Methodology, sites and plots agreed at Falkland Islands workshop. 1.3 Project launched and successful workshop held in the Falkland Islands in December 2018. 1.4 Field data protocols finalised (see previous annual report). 1.5 Data collected by field team during 2018-2019 field season. 1.6 Preliminary analysis completed. 1.7 Excel database updated. 1.8 - 1.9 N/A for this reporting year.	Data from the 2020 field season to be added to the database and analysed in relation to data from previous years; summary report to be written and a manuscript prepared for open access publication.
Output 2. The risk of non-native plant species persisting past 2020 estimated	2.1 Viability of seeds from at least 20 invaded sites with a minimum of 5 soil samples of 200 cm3 per site determined	2.1 Subsamples from all soil samples collected during the 2018-2019 field season have been processed and identified where possible. Soil samples from the 2019-2020 season to be processed.	
Activities 2. 2.1 Develop soil sampling protocols 2.2 Discuss and finalise field data protocols at Falkland Islands workshop 2.3 Collect soil samples from field sites in South Georgia 2.4 Transport samples to the MSB for analysis 2.5 Process samples in the laboratory by sieving soil and removing seeds		2.1 - 2.2 Soil sampling protocols finalised and agreed at the Falkland Islands workshop. Laboratory Standard Operating Procedure developed and agreed by Defra enabling a soil licence to be obtained for the work to be conducted at the MSB (see previous annual report). 2.3 Five reps from 26 sites (130 soil samples in total) collected from South Georgia field sites during 2018-2019 and five reps	Remaining unidentified viable seeds from 2018-2019 field season to be identified from seedling material. Additional soil samples (5 replicates from 20

Project summary	Measurable Indicators	Progress and Achievements April 2019 - March 2020	Actions required/planned for next period
2.6 Identify species where possible from seeds 2.7 Seed germination and tetrazolium tests to quantify seed viability 2.8 Grow on seedlings in a glasshouse at Kew for plant species identification 2.9 Analyse data to estimate the proportion of viable non-native seeds in soil samples 2.10 Update excel database and produce a summary report on soil sample analysis and the risk of non-native plant species persisting past 2020 2.11 Upload summary report onto GSGSSI and Kew websites and Research Gate		from 20 sites (100 soil samples in total) collected from South Georgia during 2019-2020. 2.4 - 2.8 Soil samples (5 replicates from 26 sites) collected on South Georgia during the 2018-2019 field season have been processed using two different methods: a) Seed extracted from subsamples of soil (5 reps x 4 sites = 20 samples); extracted seed checked for viability using germination and tetrazolium testing. b) Subsamples of soil moistened and seed germination monitored (5 reps x 26 sites = all 130 samples). Seeds identified where possible, and seedlings grown on in growth chamber for identification. DNA analysis investigated to assist with identification. 2.9 Preliminary analysis completed. 2.10 Excel database updated. Summary report to be completed following processing of 2019-2020 field samples. 2.11 N/A for this reporting year.	sites) collected on South Georgia during the 2019-2020 field season to be transported to the MSB for processing and viability testing of seeds in soil completed. Data from the 2019-2020 field season to be added to the excel database and a summary report produced and uploaded onto Research Gate, Kew and GSGSSI websites.
Output 3. The potential for non-native species to spread quantified	3.1 The number of species and number of seeds per species dispersed into at least 5 traps per site each placed in a minimum of 2 invaded sites, 2 native sites and 2 sites recently exposed by retreating glaciers identified 3.2 Likelihood of new areas recently exposed by retreating glaciers being colonised by non-native species, over native species, quantified	3.1 Seed trap contents (5 replicates from 6 sites) collected on South Georgia during the 2018-2019 field season have been processed and identified where possible. Seed trap contents (5 replicates from 6 sites) from the 2019-2020 field season to be processed. 3.2 Plant surveys in deglaciated areas in the 2019-2020 field season completed.	
Activities 3. 3.1 Develop and test seed trap design 3.2 Agree seed trap sites and set-up protocols at Falkland Islands workshop 3.3 Set seed traps at the beginning of the field season to catch dispersed seeds		3.1 - 3.2 Seed trap design researched and developed and seed trap sites agreed at the Falkland Islands workshop. 3.3 - 3.4 Thirty seed traps installed at six different locations on South Georgia at the beginning and retrieved at the end of the 2018-2019 field season. The same traps installed and retrieved	Remaining unidentified seeds from 2018-2019 field season to be identified from seedling material. Seed trap

Project summary	Measurable Indicators	Progress and Achievements April 2019 - March 2020	Actions required/planned for next period
3.4 Collect seed from seed traps before the end of the field season 3.5 Transport samples to the Millennium Seed Bank (MSB) for analysis 3.6 Identify species where possible from seeds 3.7 Seed germination and tetrazolium tests to quantify seed viability 3.8 Grow on seedlings in a glasshouse at Kew for plant species identification 3.9 Analyse data to quantify potential native and non-native species spread 3.10 Update excel database and produce a summary report on the potential for non-native species to spread 3.11 Upload summary report onto GSGSSI and Kew websites and Research Gate		at the end of the 2019-2020 field season. 3.5 Seed traps from 2018-2019 field season processed. 3.6 Seeds extracted and identified where possible from 2018-2019 field season. 3.7 - 3.9 Seed germination and tetrazolium tests to quantify seed viability and identify unknown seeds to be completed with seeds extracted from 2019-2020 field season traps. 3.10 Excel database updated. Summary report to be completed following processing of 2019-2020 field samples. 3.11 N/A for this reporting year.	contents for 2019-2020 field season to be documented, and seeds removed and identified. Seed viability to be determined by germination and tetrazolium tests, and seedlings grown on for identification if needed.
Output 4. Impact of climate change on selected native and non-native plant species in South Georgia estimated	4.1 Germination characteristics of 3 native and 3 non-native plant species at current and warmer temperatures of seeds determined (as a proxy of establishment success) 4.2 Likelihood of non-native success over native species under climate change quantified	4.1 Germination characteristics of native *Poa flabellata* seeds from a South Georgia collection banked at the MSB have been determined using the thermal gradient plate. Germination characteristics of non-native *Poa annua* will be determined using seeds collected in the 2018-2019 field season and non-native *Festuca rubra*, *Deschampsia parvula* / *Deschampsia cespitosa* and native *Festuca contracta* and *Deschampsia antactica* will be determined using seeds collected in the 2019-2020 field season. Likelihood of non-native success over native plant species will be determined when all thermal gradient plate results have been collected and analysed.	
Activities 4. 4.1 Identify non-native and closely-related native species to research the impact of climate change on seed germination and subsequent recruitment in South Georgia 4.2 Determine germination requirements for paired native and non-native plant species from SBD or the literature 4.3 Collect target non-native seed from populations in South Georgia or the Falklands if not available from MSB collections 4.4 Seed germination tests on a thermal gradient plate at the MSB on three closely related species pairs, where one species is native and the other is non-native 4.5 Analyse data to determine germination characteristics (e.g. temperature thresholds)		4.1 - 4.2 Suitable pairs of native and non-native congeneric plant species selected and germination requirements checked on SBD. 4.3 Seed from both native and non-native target species were collected in field season 2018-2019 (see previous annual report). 4.4 Thermal gradient plate germination completed for native *Poa flabellata.* Germination difficulties with collections from 2018-2019 collections delayed additional test setup. 4.5 Analysis is comparative so will be started when species pairs germination tests are complete. 4.6 N/A for this reporting year.	Thermal gradient plate germination tests to be completed on non-native *Poa annua*; native *Festuca contracta* and non-native *Festuca rubra*; native *Deschampsia antarctica* and non-native *Deschampsia parvula* or *Deschampsia cespitosa.* Results to

Project summary	Measurable Indicators	Progress and Achievements April 2019 - March 2020	Actions required/planned for next period
4.6 Prepare scientific paper for open access publication in an international peer-reviewed journal			be analysed and a manuscript prepared for open access publication.
Output 5. Seeds and fern spores of native plant species of South Georgia collected and stored at the Millennium Seed Bank for ex-situ conservation and seed germination protocols determined	5.1 Spores of at least three fern species and all native seed plants of South Georgia securely banked and at least two thirds (i.e. 17 species) with multiple collections for genetic diversity at the Millennium Seed Bank 5.2 Seed dispersal and dormancy syndromes identified and seed germination protocols determined for all native species 5.3 Seedling images captured for all native plant species	In the 2018-2019 field season, 29 collections of 18 species in total were collected, consisting of 11 seed collections from 6 native plant species; 7 seed collections of 5 non-native plant species and 11 spore collections of 7 native fern species. An additional 23 collections of 15 species in total were collected in the 2019-2020 field season, consisting of 11 spore collections of 7 native fern species, 1 seed collection of a native plant species and 11 seed collections of 7 non-native plant species. Germination tests for native and non-native plant species that occur on South Georgia have been conducted and data analysed to determine germination requirements. Dormancy syndromes are being determined from these analyses. Germinated seeds have been grown on to produce seedlings which have been imaged, with approximately 70% of images captured for both native and non-native species.	
Activities 5. 5.1 Identify suitable populations for seed and fern spore collection 5.2 Collect seeds and fern spores of native plant species of South Georgia for ex-situ conservation at the MSB 5.3 Transport collections to the MSB for processing and banking 5.4 Produce blog on South Georgia collecting trip for GSGSSI and Kew websites 5.5 Process seed and fern spore collections and produce germination protocols 5.6 Identify seed dispersal and dormancy syndromes 5.7 Photograph seedlings from germination tests and make images available online 5.8 Upload germination protocols onto the Seed Information Database (SID) 5.9 Publish a Guide to Seeds and Seedlings of the Plants of South Georgia		5.1 - 5.2 Suitable populations were identified, and seed and fern spores collected during the 2018-2019 field season (see previous annual report). 5.3 Seed and fern spore collections from 2018-2019 at the MSB. 5.4 Blog on Kew website: https://www.kew.org/read-and-watch/invasive-species-south-georgia 5.5 Seed and fern spore collections from 2018-2019 have been processed and banked. 5.6 Seed germination requirements for South Georgia native and non-native plant species collated; these data being analysed to determine dormancy syndromes. 5.7 Seedlings for most species produced and photographed. 5.8 - 5.9 N/A for this reporting year.	

Annex 2: Project's full current logframe as presented in the application form (unless changes have been agreed) - if applicable

N.B. if your application's logframe is presented in a different format in your application, please transpose into the below template. Please feel free to contact Darwin-Projects@ltsi.co.uk if you have any questions regarding this.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: South Georgia's native habitats and plant species diversity are protected through the eradication of non-native species, conservation of native species, rehabilitation and maintenance of native habitats and improved biosecurity			
Outcome: South Georgia's native habitats protected by identifying non-native species most likely to persist, determining potential climate change effects on native and non-native species survival and banking seeds of native species	0.1 The number of non-native species predicted to persist post-2020 determined 0.2 Native and non-native species likely to colonise new habitats identified 0.3 Spores of at least three fern species and all native seed plants of South Georgia securely banked at the Millennium Seed Bank	0.1 Summary report published on GSGSSI and Kew websites and Research Gate 0.2 Seed Bank Database (SBD) for seed collected and excel database of results	0.1 Weather conditions allow boats to access South Georgia and field work to be completed 0.2 All target species produce sufficient seeds or spores during the lifetime of the project to allow safe collection for storage and not impact the future of native populations
Output 1 Vegetation changes following reindeer removal from established vegetation monitoring plots quantified and success of the control programme of non-native plants on South Georgia evaluated	1.1 Data from 2 established vegetation monitoring plots analysed in year 1 and year 2 and across the monitoring period to demonstrate change in numbers and frequency of native and non-native plant species 1.2 Data from at least 2 invaded sites (4 plots per site) analysed in year 1 and year 2 and across the monitoring period to demonstrate change in numbers and frequency of native and non-native plant species	1.1 Excel database and report on vegetation changes in established monitoring plots and in non-native species distribution in invaded sites where control is taking place 1.2 Summary report published on GSGSSI and Kew websites and Research Gate 1.3 Scientific paper on vegetation changes following non-native species control submitted to open	1.1 Team able to visit all sites every year to collect data unhampered by weather conditions 1.2 GSGSSI boat operational and able to transport team from the Falkland Islands to South Georgia and to field sites 1.3 No new non-native species introduced to South Georgia

Project summary	Measurable Indicators	Means of verification	Important Assumptions
		access journal for publication end of year 3	
Output 2 The risk of non-native plant species persisting past 2020 estimated	2.1 Viability of seeds from at least 20 invaded sites with a minimum of 5 soil samples of 200 cm^3 per site determined	2.1 Excel database on seeds found in soil seed bank 2.2 Summary report on potential for non-native species to spread into new areas published on GSGSSI and Kew websites and Research Gate	2.1 Soil samples contain sufficient seeds 2.2 Reliable identification of species is possible from seeds or young plants
Output 3 The potential for non-native species to spread quantified	3.1 The number of species and number of seeds per species dispersed into at least 5 traps per site each placed in a minimum of 2 invaded sites, 2 native sites and 2 sites recently exposed by retreating glaciers identified 3.2 Likelihood of new areas recently exposed by retreating glaciers being colonised by non-native species, over native species, quantified	3.1 Excel database on seeds caught in dispersal traps 3.2 Summary report on potential for non-native species to spread into new areas published on GSGSSI and Kew websites and Research Gate	3.1 Dispersal traps are robust enough to survive the field season and are not disturbed 3.2 Dispersal traps collect sufficient seeds 3.3 Reliable identification of species is possible from seeds or young plants
Output 4 Impact of climate change on selected native and non-native plant species in South Georgia estimated	4.1 Germination characteristics of 3 native and 3 non-native plant species at current and warmer temperatures of seeds determined (as a proxy of establishment success) 4.2 Likelihood of non-native success over native species under climate	4.1 Scientific paper on the thermal germination niche of three closely related pairs of native and non-native species and associated predictions of a changing climate on seed germination behaviour submitted to open access journal for publication by the end of year 3	4.1 Adequate seed can be sourced for germination experiments 4.2 Seeds germinate under tested conditions

Project summary	Measurable Indicators	Means of verification	Important Assumptions
	change quantified		
Output 5 Seeds and fern spores of native plant species of South Georgia collected and stored at the Millennium Seed Bank for *ex-situ* conservation and seed germination protocols determined	5.1 Spores of at least three fern species and all native seed plants of South Georgia securely banked and at least two thirds (i.e. 17 species) with multiple collections for genetic diversity at the Millennium Seed Bank 5.2 Seed dispersal and dormancy syndromes identified and seed germination protocols determined for all native species 5.3 Seedling images captured for all native plant species	5.1 Kew's internal Seed Bank Database at the Millennium Seed Bank 5.2 Blog detailing seeds banked at end of year 3 on GSGSSI and Kew websites 5.3 Germination protocols on Kew's open access Seed Information Database: http://data.kew.org/sid/ 5.4 Seedling images for native plant species to South Georgia available online 5.5 Publish a Guide to Seeds and Seedlings of the Plants of South Georgia	5.1 Populations of target native plant species produce seeds which are mature and in sufficient quantities for collection (no more than 20% of available seed to be collected to ensure native populations are not harmed) at the time the sites are visited

Annex 3 Onwards – supplementary material (optional but encouraged as evidence of project achievement)