Department for Environment Food & Rural Affairs

DARWIN PLUS

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Darwin Plus: Final Report

To be completed with reference to the "Project Reporting Information Note": (https://darwinplus.org.uk/resources/information-notes/).

It is expected that this report will be a **maximum of 20 pages** in length, excluding annexes.

Submission Deadline: no later than 3 months after agreed end date.

Submit to: BCF-Reports@niras.com including your project ref in the subject line.

Darwin Plus Project Information

Project reference	DPLUS109
Project title	Initiating monitoring support for the SGSSI-MPA Research and Monitoring Plan
Territory(ies)	South Georgia
Lead Partner	The British Antarctic Survey
Project partner(s)	Government of South Georgia and the South Sandwich Islands
Darwin Plus Grant value	£283,417
Start/end date of project	03 August 2020 / 22 December 2023
Project Leader name	Dr Phil [redacted] (Originally Prof. Phil [redacted]
Project website/Twitter/blog etc.	https://www.bas.ac.uk/project/fixed-wing-wildlife-surveys-at-south-georgia/
Report author(s) and date	Phil [redacted], Phil [redacted], Nathan [redacted], Susan [redacted] (GSGSSI), Martin [redacted], Adrian [redacted], Jamie [redacted]. 27/03/2024

1 Project Summary

The ecosystem at South Georgia is experiencing ecological change in response to a changing climate, coupled with recovery of historically depleted species of seal, whale and finfish. Large changes are anticipated in the marine ecosystem as species populations (and diets) alter. Similarly, eradication of introduced non-native mammals from South Georgia is likely to lead to changes in terrestrial habitats, with consequent changes in species diversity. As ecosystem change proceeds consequent on the changes identified above, it is highly likely that changes in species, both for animal populations and vegetation, will occur. Understanding how these take place will enable GSGSSI to evaluate, and potentially mitigate, impacts on South Georgia. Establishing baseline datasets from which change over time can be determined is key for understanding these shifts. However, monitoring represents a significant funding challenge. Baseline estimates have been missed, due to a lack of resources before the eradication of non-native mammals. However, it is still feasible to establish recovery patterns if monitoring starts as soon as possible. The last comprehensive surveys of all seabirds and marine mammals were completed using yachts; these are expensive and logistically challenging platforms. This project aimed to initiate monitoring for a range of species in order to document change using unmanned aerial vehicles.

The methods used in this project can be divided into four parts. 1: selection of field sites, 2: field survey photography, 3: image analysis, and 4: documentation and handover to GSGSSI.

1: Field sites were chosen by the project team in consultation with GSGSSI and relevant experts at BAS and the wider South Georgia science community. Using variables such as geographic location, population size, and accessibility a priority list of sites was developed. An initial list of 26 sites was developed (covering 7 species on interest, Figure 1) with 17 of these sites eventually visited. A total of 35 surveys were conducted over two fieldwork campaigns in 2021 and 2022.

2: A fixed-wing drone (Sensefly eBee X) was used for the photographic survey. The capabilities of this platform are what enabled the surveying of large, sprawling colonies, coupled with permission for Beyond Visual Line Of Sight (BVLOS) operations (a first at South Georgia). The eBee X is stable in windy conditions (rated to 46kph), with flight times up to 90 minutes, flying at speeds up to 110kph. This stability and speed coupled with permission to operate up to 8 km away from the pilot allowed inaccessible sites and colonies to imaged from convenient launching locations distant from the target. The platform capabilities allow the surveying of up to 5 km^2 in a single flight, which is far superior to multi-copter systems that are now routinely used. The fixed-wing UAV used here was flown autonomously (limited human input), using pre-programmed flight plans. This is key as surveys can be repeated on a regular basis in the future, and surveys conducted using the same flight plan will be directly comparable. This will enhance the value of long-term comparisons.

3: Processing of the GNSS (global navigation satellite system) data was undertaken using a combination of the CSRS-PPP (Canadian Spatial Reference System – Precise Point Positioning) online tool and the Sensefly eMotion software. Processing of survey imagery was undertaken using either Agisoft Metashape or Pix4D software with subsequent analysis in ArcGIS Pro and QGIS. All population counts were generated either by manual (for smaller colonies and seals) or novel automated counting methods developed in ArcGIS Pro. This novel counting approach (described in detail in sections 3 and 13) allows automated and semi-automated counts of penguin colonies using a repeatable workflow and easily accessible software (annex 5.4). This approach has a wide applicability to a range of other species and locations and is a major and unexpected output from this project.

4: Two main reports have been completed on behalf of GSGSSI. One covering the two field campaigns and another a final summary report containing all project results and recommendations for future monitoring. Copies of all collected images and data have also been handed to GSGSSI. Key to the impact of this project is GSGSSI's ability to continue the monitoring programme after the project has ended.

This project successfully introduced new-generation fixed-wing survey drones, coupled with sophisticated analyses for monitoring of key higher predator species. This provides a step-change in ability for multi-species baseline reference surveys, while providing an established workflow into the SGSSI MPA Research and Monitoring Plan, facilitating updates for management policies. The resulting sample data has provided direct counts for a range of important higher predator species on the island. They have also helped to ground-truth satellite remote-sensing data that cover a wider perspective than is feasible from drone surveys. Future use of ground-truthed remote-sensing will ensure a lifetime beyond the scope of the current project. Such future-proofing, and legacy outputs will be vital for the SGSSI MPA Research and Monitoring Plan.

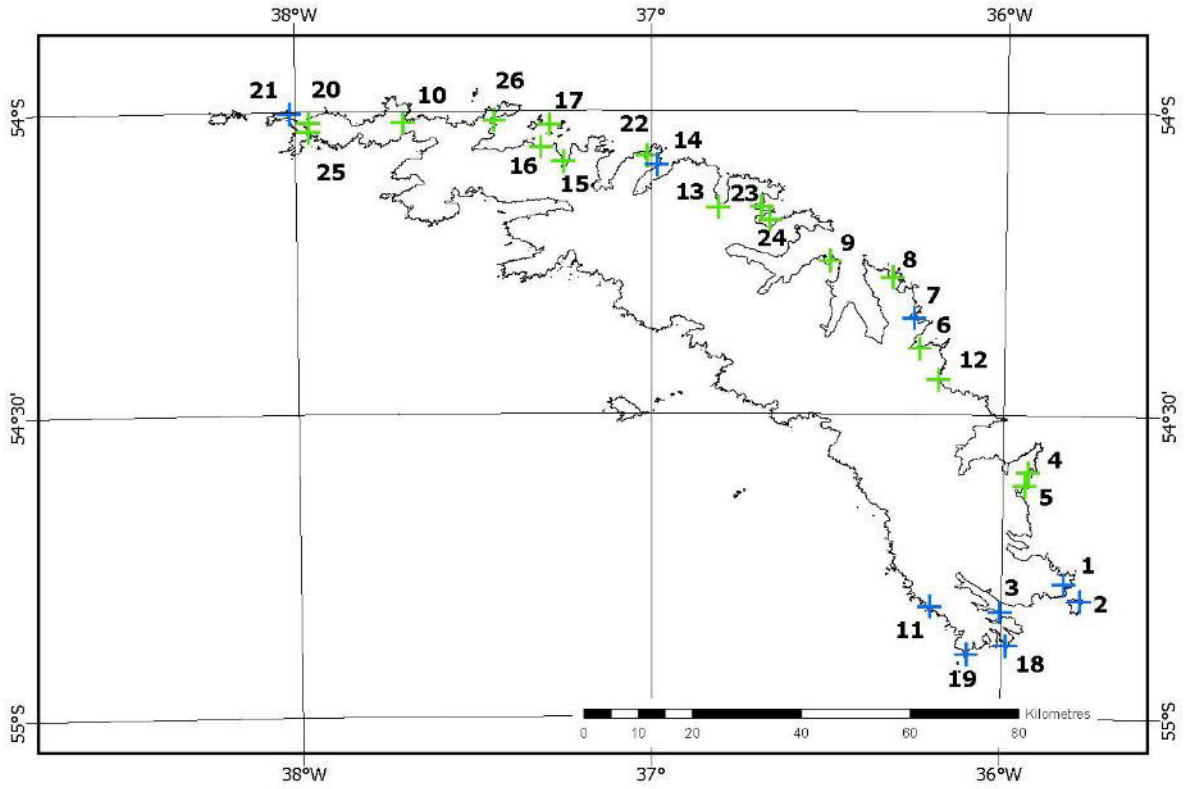

Figure 1. A map of the 26 original priority sites identified for UAV surveys during the project, denoting sites with (green) and without (blue) surveys completed.

2 Project Partnerships

There were two partners for this project, the British Antarctic Survey (lead partner) and the Government of South Georgia and the South Sandwich Islands (GSGSSI). Good collaboration existed between the two partners throughout each stage of the project, from inception to final delivery (including this final report). The majority of the roles within this project were undertaken by BAS (e.g., liaison with King Edward Point (KEP) project staff, financial management, fieldwork, image processing, image analysis), with key certain key roles undertaken by GSGSSI (e.g. access to field sites) and collaboratively between both partners (e.g. identification of baseline sites at South Georgia, development of fieldwork protocol).

Both partners worked together closely to develop the list of priority sites which covered as many accessible sites containing one or more colonies of the seven target species (king penguin, gentoo penguin, macaroni penguin, chinstrap penguin, Antarctic fur seal, elephant seal & wandering albatross) (annex 5.1). The project team then worked together to develop a testing structure for undertaking field surveys (annex 5.2). This structure splits drone flight complexity into stages, ranging from test flights (stage 1) to < 8 km BVLOS operations. The rationale for this was to ensure minimal disturbance to wildlife and ensure confidence in the safety of more complex operations. The identified sites were then graded based on which stage of the testing structure would need to be utilized to complete surveys in this location.

During the fieldwork planning, and during the fieldwork, both partners worked together to endeavour to facilitate access to as many sites as possible. This was done via a combination of support from the Pharos SG (the GSGSSI fishery patrol vessel), the use of KEP small boat facilities and travel on foot from KEP and neighbouring peninsulas.

Overall, the working relationship between the two partners has been productive and enjoyable. There were certain instances of tension at points throughout the project related to the availability of ship support from Pharos SG for access to field sites. This miscommunication seemingly stemmed from a lack of written agreements and detailed in-kind contributions at the planning stages of the project. When the fieldwork was eventually organised the initial expected amount of ship support was not available due to operational and budget constraints. This led to several sites on the priority list not being visited. There was also a plan to train a member of GSGSSI staff to undertake drone pilot training to ensure the continuation of surveys after the end of the project. Due to several changes in the recruitment and staffing structure within GSGSSI, a suitable person to do this training was regrettably not identified within the life of the project, even after extensive discussion. None of these issues caused lasting challenges for the working relationships within this project. Many of the issues could have been averted with clear and detailed in-kind contributions and costings at the planning stages.

We have no doubt that the partnership between BAS and GSGSSI will continue long into the future. BAS are one of the main providers of science and science advice for GSGSSI.

3 Project Achievements

3.1 Outputs

Output 1: *Creation of a list of high priority, long-term monitoring sites at South Georgia for species targeted as ecosystem indicators (king, macaroni and gentoo penguins, elephant and fur seals, and albatross species).*

This output was completed on time with the compiled site list shared with GSGSSI (annex 5.1), along with comprehensive maps for each species to be surveyed (e.g., Figure 1). Sites were discussed with GSGSSI in relation to site access and other environmental considerations. A detailed hierarchy of site 'difficulty' was developed with GSGSSI along with a testing structure that was to be completed before each flight to ensure safe flight operations (annex 5.2). Long discussions were undertaken with GSGSSI and Air Safety Support International (ASSI) to obtain permissions for beyond visual line of sight (BVLOS) operations. This was the first time this had been approved for flights at South Georgia, and the first time for UAV operations at BAS. The approval of BVLOS operations resulted in several sites with difficult boat landings now being accessible via remote, easier landings (e.g., Figure 2). This resulted in another layer of consideration for each site in the site list, denoting where each flight would be flown from.

Output 2: *High resolution, georeferenced, fixed-wing UAV aerial survey of each of the monitoring sites identified in Output 1 for the purpose of creating baseline reference datasets.*

The project had an initial covid-19 related delay, a Change Request was submitted and accepted to change the schedule for the field work.

Successful field seasons were completed over December 2021 and January 2022 and a final season (focussed on southern elephant seals) in October 2022. Seventeen sites were visited representing all of the main species we were aiming to target over this time period (gentoo penguins, Antarctic fur seals, king penguins, southern elephant seals and wandering albatross). Several of these sites were flown multiple times during different seasons in order to survey different species, resulting in a total of 35 drone flights. Unfortunately, due to logistical constraints no sites with macaroni penguins or chinstrap penguins were visited during either of the fieldwork seasons. The number of identified sites was always likely to be more than achievable in three shore field seasons when accounting for logistics and weather, the change in the availability of

Pharos SG support (discussed in Section 2) meant that several sites were no longer accessible (especially sites around the southeast of the island where chinstrap penguin colonies are found (Figure 1)).

BVLOS was used for all of the survey flights throughout the project. The BVLOS permissions allowed sites with restricted access to be flown remotely. Two examples of this are Fortuna Bay where king penguins were surveyed (Figure 2) and the Bay of Isles where wandering albatross were surveyed (Figure 3). For the second season of fieldwork, we also negotiated an increased maximum flying height of 600 feet from ASSI. Throughout the fieldwork, the maximum flight duration was 56 minutes and during that time we flew a distance of 42.8 km (at St Andrews Bay). The combination of BVLOS and the capability of the eBee X to survey large areas quickly made the ability to survey large colonies achievable within short weather windows that allowed for work.

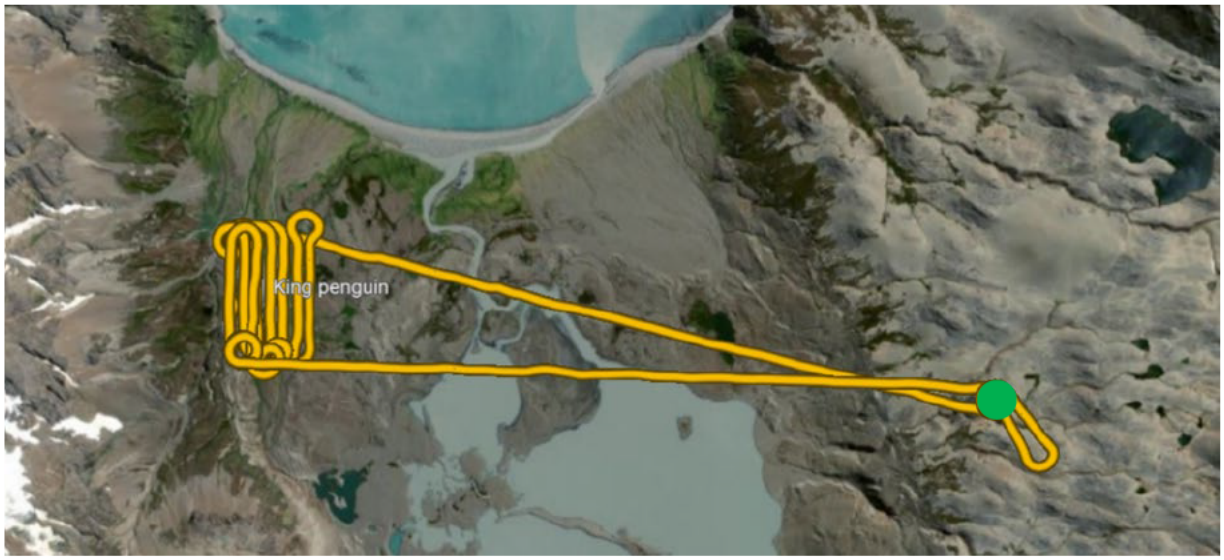

Figure 2. The flight path of the king penguin colony survey at Fortuna Bay. The take-off area (green dot) is located within the KEP field operational area, whereas the penguin colony is not. BVLOS made the survey of this site possible.

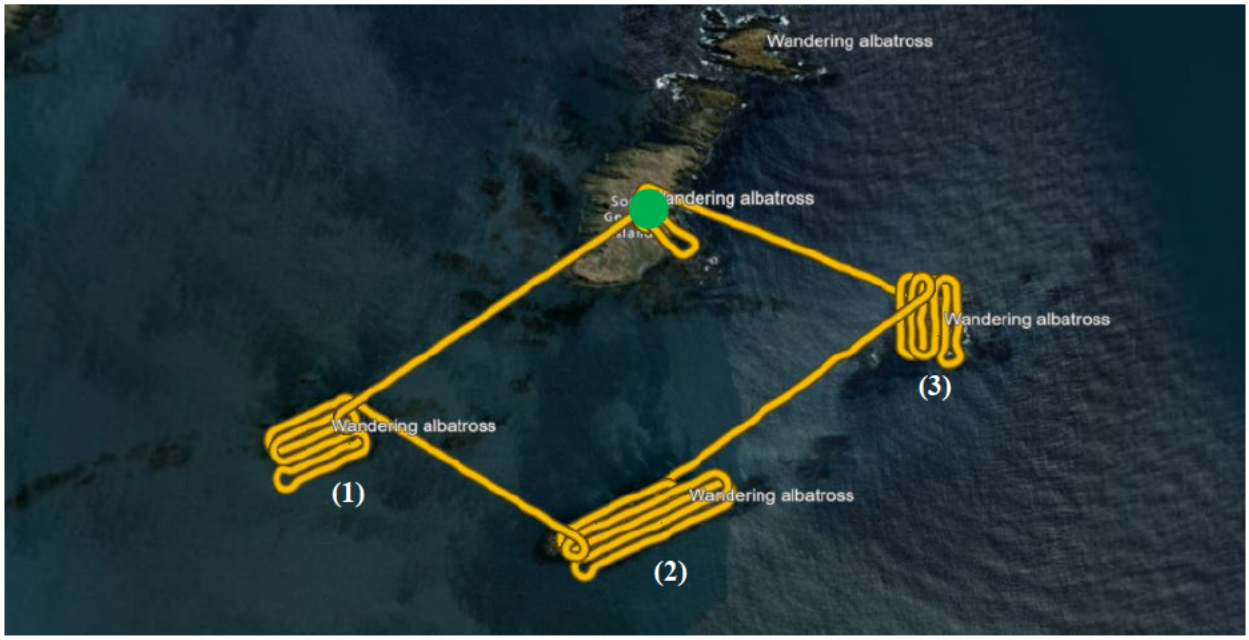

Figure 3. The flight path of the wandering albatross colony surveys on Petrel (1), Inner Lee (2) and Outer Lee (3) islands. The take-off area (green dot) was located on Prion Island where boat landings were possible, landings were not possible on the three other islands. Again, BVLOS enables these surveys.

Processing of imagery from both field seasons has been completed, resulting in the production of high-resolution, georeferenced, orthorectified (geometrically corrected), aerial imagery mosaics for each monitoring site. We are currently in the process of archiving all imagery with the Polar Data Centre.

Output 3: *Population counts for each of the monitoring sites identified in Output 1 using the aerial survey datasets and input into the relevant national and international governing bodies (such as GSGSSI and CCAMLR).*

The imagery created during Output 2 has been used to develop colony counts for all surveyed sites and species (Annex 5.3). Based on these results, three peer reviewed papers focussed on the population of king penguins, a methodological overview of all surveys and a pilot study using thermal imagery counts for fur seals are currently in submission. A paper on temporal trends in southern elephant seals is currently being written for submission, with further papers planned on the results of the wandering albatross and fur seal surveys. These papers look at change over time of key colonies and will explore methodological approaches of both UAV and satellite imagery for wildlife counts. One key recommendation for the project is that using the eBee X platform for small colonies is difficult as the platform was designed for surveying large areas of agricultural land. Small colonies can be surveyed more easily using quadcopter platforms (e.g., DJI Mavic pro 3).

Efforts were made to employ automated machine learning approaches to count wildlife, based on previous work undertaken in collaboration with some team members. It became clear that this approach was not developed enough to apply to the species surveyed for this project. The original machine learning approach was developed using imagery of Adélie penguins and significant work would have been needed to adapt it for other species of penguin, meaning even more work would have been needed to adapt it for seals (if this was even possible). There were no funds in the project to undertake this work and no team members with the skillsets to develop the machine learning approach. At the time we began to count imagery, there were also no collaborations for citizen science platforms available within the project team (due in part to changes in the team composition). As an alternative to these two approaches, manual counts were used for a large number of species and sites that were deemed easy to count (i.e., not too large, Annex 5.3). For colonies that were too large to manually count (e.g., king penguins at St Andrews bay ~ 133,000 pairs), several approaches were taken, such as subsampling colonies using quadrats to estimate colony density which was then used to extrapolate a colony count. Alongside the quadrat counting method, a new counting technique was developed with the Mapping and Geographic Information Centre (MAGIC) team at BAS. This approach uses the high-resolution digital elevation models (DEMs) created by the eBee X to automatically count penguins, based on their height off the ground and shape using ArcMap (widely available software). This approach has several distinct advantages over other automated counting methods (e.g., machine learning) as it is fast, requires no model ‘training’ to be effective which can often be extensive, and crucially it uses the DEM rather than imagery to count. This means that the counts aren’t affected by shadows and differences in light conditions. This counting method has become a key output from the project and is the central finding of the king penguin paper which is currently under review. A workflow of this method can be found in Annex 5.4. This DEM approach has also been applied to imagery of wandering albatross to ‘correct’ the counts by enabling the identification of nesting birds. The height and shape of the nests allows them to be identified in the DEM, which allows the counter to disregard non-nesting animals (see Figure 4).

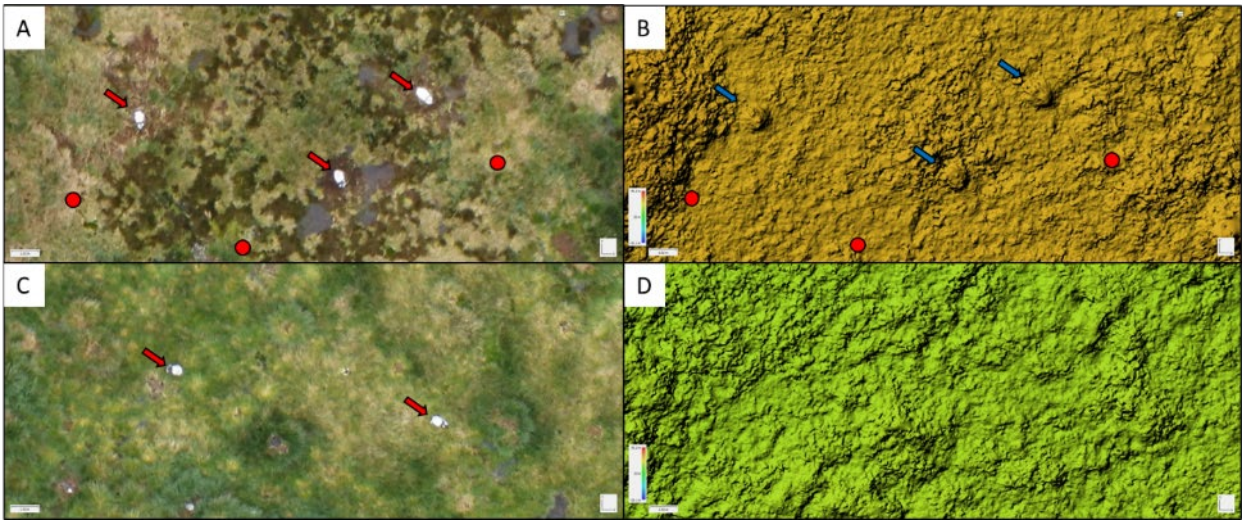

Figure 4. A comparison of UAV (A & C) and DEM images of nesting (A & B) and loafing (C & D) wandering albatross. Red arrows indicate visible *D. exulans* in UAV imagery. Blue arrows indicate visible nest mounts in DEM imagery. Red dots indicate GPS locations of nests from prior surveys.

Now the counting of imagery has been completed a final summary report has been produced for GSGSSI and a summary paper will be submitted to the CCAMLR (Commission for the Conservation of Antarctic Living Resources) working group on Ecosystem Monitoring and Management (WG-EMM) in July 2024.

During the project development, it was assumed that image counting would be easily achievable using automated machine learning approaches, meaning minimal staff time was included to undertake this portion of the project. When it became clear this was not going to be possible, additional funds were sought to undertake much of this analysis as well as fieldwork. This money was awarded by GSGSSI and greatly increased the capacity of the project team to complete the set outputs. Jamie Coleman was hired on a part-time basis for a period of 18 months. For future surveys, other avenues for counting could be explored, such as third-party image analysis companies which would need to be costed into plans.

Output 4: *Documented workflow provided to GSGSSI to allow repeat surveys of monitoring sites to be undertaken on a regular basis into the future.*

A peer reviewed paper detailing the methods used during this study has been submitted (annex 5.5), along with a final summary report to GSGSSI. A fieldwork report for both seasons was submitted to GSGSSI following the final field season. The workflow for this project from initial site selection, through the field work all the way to final counts is detailed across these reports and papers.

As detailed in section 2 and previous annual reports, no GSGSSI staff could be identified to undertake fixed wing pilot training. There are several reasons for this, largely focussed on a change in recruitment structure for government officers in GSGSSI. This change meant that no one person would be available to undertake training/survey work. Other staff members at GSGSSI were identified and we again struggled to find a time when training could be completed, eventually the window for this training within the project closed. The time burden for completing field work would also have been difficult to fit into the schedules for these staff members, although one GSGSSI staff member (Vicki Foster) was able to join the field team for the surveys at Gold Harbour and Undine.

The BAS scientific staff at KEP are trained in the use of quadcopter UAVs and will be able to help with future surveys using the fixed wing platform (although they will not be able to fly the platform themselves). These staff are only employed on 2-year contracts and would not be available to complete this work themselves due to many other existing demands on their time.

It is clear that future surveys will have the most success as a collaboration between BAS and GSGSSI and other potential external partners with an interest in the work. Drone pilot training for staff on short-term contracts either at GSGSSI or BAS will result in substantive regular training expenses and the potential for inconsistent survey technique year-to-year. Excellent capacity for these survey techniques has been developed within BAS during this project which should be utilised going forward. BAS can provide fixed-wing UAV pilots and expertise in image analysis whilst GSGSSI can facilitate fieldwork, similar to the way this project was organised.

Output 5: *Increased scientific understanding of change at South Georgia*

As stated in previous sections, several scientific manuscripts are in submission, the abstracts of these papers can be seen in annex 5.5. One overview paper details the methods used for this study, along with a summary of the findings from the project:

"*The application of autonomous fixed-wing drones operating beyond visual line of sight to enable large area population monitoring of key species in a changing environment*."

A final project report has also been completed and submitted to GSGSSI which contains recommendations regarding which sites should be prioritised in the future, what species should be targeted, when in the year the surveys should occur, how regularly surveys should be undertaken and what survey approach should be used (Annex 5.6).

Other papers have been produced detailing individual species such as king penguins:

"*A comparison of established and novel counting methods to determine population estimates for king penguin colonies, using fixed wing drones and satellite imagery."*

And fur seals:

"*Use of Thermal Detection from Fixed-wing Drones to Enable Large-area, Time Efficient Monitoring of a Critical Southern Ocean Apex Predator*."

A final paper is in development investigating the population of southern elephant seals. To this end, all available historical population data for this species has been collated from BAS data holdings as well as the purchasing of satellite imagery to compare current populations to imagery from recent years to investigate change over time. Further papers are planned to present the survey data and methodological approaches for counting wandering albatross and fur seals.

Output 6: *Outreach to other UK OTs and to interested scientists.*

The work undertaken during this project has been presented at several meetings, conferences and stakeholder events. Nathan Fenney and Adrian Fox gave a presentation to GSGSSI to give them a summary of the completed work following the January 2022 field season. The same talk was also given to BAS staff at the King Edward Point Station and BAS Cambridge on separate occasions. An overview of the project was presented to the Marine Predator research group at the University of Tasmania by Jamie Coleman in September 2023. Five presentations on the

project work were also given by team members (Jamie Coleman and Nathan Fenney) on board passenger cruise ships in December 2022, February 2022, March 2022, November 2023 and February 2024 (National Geographic Explorer and National Geographic Endurance). Nathan Fenney also presented the project at a conference (GIS Update) at the University of Edinburgh in 2022.

Key outputs of the project were presented in an invited talk at the GSGSSI MPA symposium in June 2023. This symposium was designed to showcase the science in support of the MPA as part of the 5-year review, highlighting the importance of this project to GSGSSI.

Two articles were also written for the South Georgia Association Quarterly newsletter:
Fixed-wing UAV surveys South Georgia's wildlife. Hollyman, Fenney; May 2022.

Update on Darwin plus science project 'Initiating monitoring support for the SGSSI-MPA Research and Monitoring Plan.' Fox, Fenney, Coleman; November 2022.

A website for the project was developed (https://www.bas.ac.uk/project/fixed-wing-wildlife-surveys-at-south-georgia/) and a press was developed with the BAS communications team following the second field season (https://www.bas.ac.uk/media-post/drones-survey-wildlife-populations-in-remote-sub-antarctic-island/).

Discussions are underway with several research groups to develop automated counting methods using the imagery collected during this project (Output 6.1), but thus far these have not yielded any results.

A meeting was held on 19th of March to discuss potential funding of future surveys with the South Georgia Heritage Trust. The SGHT have indicated a willingness to raise funds for such surveys in future, subject to further discussions with BAS and GSGSSI.

3.2 Outcome

The original outcome for the project was stated as:

Establishment of a rigorous, multi-species, baseline reference dataset for seabird and seal colonies at South Georgia, used to inform policy decisions by GSGSSI and CCAMLR.

Based on the SMART indicators outlined in the log frame, this project has undoubtedly delivered the desired outcome. Looking at the SMART indicators in turn

0.1 Creation of a list by Q3Y1 of high priority, long-term monitoring sites, for which the baseline reference data will be collected.

This indicator was completed on time in year 1 with a report submitted to GSGSSI. We delivered our fieldwork plans, including maps showing proposed monitoring sites (completed in Y1 and reported in 2022 annual report). More detail on this point can be found in section 3.1, Output 1.

0.2 Completion of field data collection at each monitoring site. To be undertaken over three campaigns and completed by Q2Y3.

The field work was completed over one long (Nov 2021 – Feb 2022) and one short (Oct 2022) field season. The fieldwork was a success, with 17 of the original sites visited and 35 surveys undertaken. A formal fieldwork report was submitted to GSGSSI and can be found on the project website (https://www.bas.ac.uk/project/fixed-wing-wildlife-surveys-at-south-georgia/).
A detailed overview of this work can be found in Section 3.1, Output 2.

0.3 Detailed description and maps / orthorectified imagery, defining spatial extent of each long-term monitoring site. To be complied by Q3Y3.

Each surveyed site now has associated orthorectified imagery and colony extent data available. All imagery generated during the project is currently being migrated to the Polar Data Centre and will be fully accessible for GSGSSI. A version of this report will be submitted to CCAMLR WG-EMM in June 2024. A more detailed discussion of this work can be found in Section 3.1, Output 2.

0.4 Baseline count data derived for each species at each monitoring site. To be completed by Q4Y3.

Baseline count data has been generated for every species and colony surveyed. The details of these counts are included in the final project report submitted to GSGSSI (and CCAMLR later this year), a peer reviewed publication currently in submission (Annex 5.5) and summary tables can also be found in annex 5.3. A more detailed discussion of this work can be found in Section 3.1, Output 3.

0.5 Documentation of the methodology / workflow used to undertake surveys to allow future monitoring to be conducted by GSGSSI as part of a long-term monitoring programme. To be completed by Q4Y3.

Detailed documentation of the various methodologies used throughout this project can be found in the reports submitted to GSGSSI (fieldwork report and final report), as well as the various peer reviewed manuscripts in submission (Annex 5.4 & annex 5.5). The final project report to GSGSSI also includes recommendations for which sites should be prioritised in the future, what species should be targeted, when in the year the surveys should occur, how regularly surveys should be undertaken and what survey approach should be used (Annex 5.6).

3.3 Monitoring of assumptions

Both outcome and output level risks and assumptions were monitored throughout the project. These will be listed and discussed in turn.

Outcome:

Assumption 0.1: Expert knowledge from BAS scientists.

Both BAS scientists, and scientists from the wider South Georgia community fed into the development of the site list.

Assumption 0.2: Expert knowledge from BAS Mapping and Geographic Information Centre (MAGIC).

Two members of the original project team are from the MAGIC team and were fundamental for completing all outputs.

Assumption 0.3: Successful access to each of the proposed long-term monitoring sites.

Not all sites from the original list could be accessed (see section 3.1), this centred on a lack of available ship support. Regardless of this, comprehensive surveys of 5 out of the original 7 species were completed.

Output 1:

Assumption 1.1: Expert knowledge from BAS scientists.

See above

Assumption 1.2: Buy-in from GSGSSI both during this process and of the resulting output is key as they will ultimately be responsible for maintaining the monitoring programme after the project has ended.

Good engagement with GSGSSI was maintained throughout the project especially during the fieldwork planning/site selection stage. GSGSSI have been very interested in the outputs of this project and the project team have held preliminary discussions with SGHT regarding funding of ongoing surveys based on the recommendations of this project.

Output 2:

Assumption 2.1: Survey sites are accessible via land, IAATO vessel or via MV Pharos SG.

We were able to access sites via a range of routes: via land, via the MV Pharos SG and by small boat landing from King Edward Point, confirming the sites could be accessed using a range of approaches that would be site-dependant.

Assumption 2.2: Fieldwork deployment takes into account potential for weather related delays.

Weather caused UAV flights to be called off several times due to either excessive rain, wind or both. Even so, seventeen sites were fully surveyed over two field seasons. When based aboard the Pharos, weather was the deciding factor in making a small boat landing to attempt to survey a site.

Assumption 2.3: Field activities can be rescheduled if delayed by significant weather events / operational disruptions during grant period.

Operational issues that caused the original October 2021 season to be postponed were also encountered in October 2022 (i.e., a lack of berths on Pharos SG). However, through engagement with GSGSSI and BAS, these issues were overcome.

Assumption 2.4: BAS will have the same or an equivalent platform to the proposed fixed-wing UAV (SenseFly ebee X) that can be used as a backup system while operating in the field.

A second Sensefly eBee X was provided by BAS for all fieldwork campaigns.

Assumption 2.5: BAS will provide GNSS base stations to enable Post processed kinematic (PPK) processing.

GNSS base stations were provided by BAS for all fieldwork campaigns.

Output 3:

Assumption 3.1: Each monitoring site identified in Output 1 was successfully surveyed during the fieldwork.

Only 17 of the 26 sites originally outlined were visited, regardless of this, large scale surveys of 5 key species were still completed (king penguins, wandering albatross, fur seals, elephant seals and Gentoo penguins).

Assumption 3.2: Ability to determine population using automated methods. Penguins for example, make an ideal candidate due to the regular spacing between the nests. However, elephant seals lie on top of each other, so in this case, counting may have to be undertaken manually, or by citizen science.*

There are significant difficulties in training automated counting methods to count new species and the framework we thought would be available was not developed enough to use with other species (see section 3.1, Output 3). Manual counts of imagery were completed for a large number of species and locations (Annex 5.3), but a key output was a novel automated DEM-based counting method developed for this project (see section 3.1, Output 3) which was applied to both king penguins and wandering albatross.

Assumption 3.2: To determine an accurate baseline population, surveys must have been undertaken during a specific time period for each species, otherwise data will not be representative.

Effort was made to only survey populations at the correct time of year. Even so, there is a chance that the optimal time for each species/population was not utilized (as this may be a short window of a few days and there may be many sites to visit). This will be taken into account in any subsequent analysis.

Output 4:

Assumption 4.2: Expert knowledge from BAS scientists.

No appropriate GSGSSI staff were identified within the lifetime of the project (See section 4.1, Output 4). This raises concerns about the legacy of the project. However, we propose that rather than relying on staff employed on short term contracts (which would incur regular training costs and potentially inconsistent survey techniques), staff in permanent roles within BAS and GSGSSI undertake future surveys. This capacity has already been developed within the BAS staff in Cambridge. Future surveys should be a collaboration between BAS, GSGSSI and other interested parties to extend the work undertaken within this project.

Assumption 4.3: Expert knowledge from BAS mapping team.

See above.

Assumption 4.4: GSGSSI and KEP Project able to identify most appropriate personnel to receive training.

BAS have ensured that KEP staff are familiar with UAV survey techniques for their own long-term monitoring work. No appropriate GSGSSI staff were identified within the lifetime of the project (See section 4.1, Output 4).

Output 5:

Assumption 5.1: Historical data available for long term monitoring sites. Not technically required but would add value.

A good range of historical UAV, count and satellite imagery data is available for a wide range of the surveyed species. Historical imagery spanning back to 2010 has been purchased to investigate elephant the elephant seal colony at St Andrews Bay over time. Long-term data collections at KEP, BI and more broadly within BAS have historical data for elephant seals, fur seals, wandering albatross and king penguins.

Assumption 5.2: Selected journal approves paper.

Papers are currently in review. If papers are rejected, we have several alternatives to which we will submit the rejected manuscripts.

Output 6:

Assumption 6.1: Collaborations with either US or Norwegian colleagues actually develop.

Potential collaborative projects are being discussed regarding follow up projects using the methods detailed here.

4 Contribution to Darwin Plus Programme Objectives

Several aspects of this project contribute towards the Darwin Plus programme objectives. Fundamentally, this project aimed to identify key sites of ecological importance for species key to the biodiversity of South Georgia (DI-C08, Annex 5.1). This was completed successfully, with a list of sites compiled and surveyed for different outputs of the project. We determined baseline population counts for each of our surveyed sites, using the imagery collected during UAV surveys.

The methodology we used for this has been extensively documented and has resulted in workflows for undertaking surveys of the same kind in the future (DI-C01, e.g., Annex 5.4). These workflows could easily be moulded to fit other OTs and should ensure a lasting legacy of the project. To highlight these workflows, we have submitted several papers for peer reviewed publication (DI-C17, Annex 5.5) which present several different aspects of the work undertaken, there are several more papers in the early stages of development. We have also written two reports for GSGSSI, detailing the fieldwork and overall project findings (DI-C19) and a working group paper of this work will be submitted to the CCAMLR WG-EMM in June 2024.

Finally, the data and imagery generated during this project are in the process of being archived in the NERC polar data centre (PDC). Whilst this was not an original output of the project, we feel it is important for these data to be accessible. The process has taken longer than expected as there was no framework for storing UAV imagery and the resulting processed files within the PDC. As such, the data generated from this project are being used to create the architecture for this for future UAV submissions to the PDC.

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

The overall aim of this project is ‘Initiating monitoring support for the SGSSI-MPA Research and Monitoring Plan’. This monitoring plan is reviewed on a 5-year basis, with the most recent science symposium for the review held in June 2023. The project was approached to present the work undertaken so far as GSGSSI recognise the potential contribution this project will have. This contribution has been established not only through the development of long-term monitoring sites for key higher predator species, but also via the development of UAV survey techniques at South Georgia.

We have proposed a list of important sites for monitoring into the future using the fixed wing platform (Annex 5.6). We hope that if this monitoring is maintained, it will be of crucial importance for future 5-year MPA reviews at South Georgia, focussing on species that currently don’t have established widespread population monitoring. The establishment of long-term monitoring of this type is of paramount importance, allowing scientists to detect impacts from environmental change (such as climate change) into the future.

The findings of this project will directly feed into the ongoing review of the CCAMLR Ecosystem Monitoring Program (CEMP). This program monitors key life-history parameters of selected krill dependant species in an attempt to record significant changes in the marine ecosystem within the CCAMLR area, and distinguish between changes due to environmental variability and fishing pressure of living resources on which predator species rely (e.g., Antarctic krill). Several species are designated as CEMP indicator species including Antarctic fur seals, gentoo penguins, chinstrap penguins and Macaroni penguins. The data collected during this project (and through continued UAV surveys) will feed directly into CEMP and a crucial juncture whilst the program is under review. Data from this project will be presented at WG-EMM in June 2024 which will aid in the review of CEMP.

4.2 Gender equality and social inclusion

BAS are committed to equality, diversity and inclusion see (https://www.bas.ac.uk/jobs/working-for-bas/our-cultural-values-equality-and-diversity/) and aims to embrace diversity in all its forms and provide staff with a sense of belonging regardless of their characteristics, culture, experience, education or economic background.

Please quantify the proportion of women on the Project Board[1].	0
Please quantify the proportion of project partners that are led by women, or which have a senior leadership team consisting of at least 50% women[2].	100

5 Monitoring and evaluation

As part of the project, we hold frequent team meetings to discuss different aspects of the implementation and future direction of work. These meetings include all scientists involved in the project. This ensures that all participants are aware of ongoing plans and any necessary changes. It gives participants opportunity to evaluate and comment on all decisions.

Some slight deviations to the log frame were made in relation to fieldwork due to logistical restrictions of ship availability. As stated above, the October 2021 field season was moved to October 2022 and was completed successfully. The December 2021 field season was combined with the January 2022 season so that there was no change to the scope of the project. A report both field seasons was completed and submitted to GSGSSI. In advance of this Nathan Fenney and Adrian Fox gave a summary report to GSGSSI in Stanley in the form of a presentation, following the completion of the 2021/22 field season.

The majority of meetings have been held virtually, liaison with GSGSSI and with others has also been virtual, or by email. Where possible meetings are undertaken in person as this often results in more fruitful discussions.

Financial oversight has been undertaken by the BAS Finance Team, who have communicated with the Project personnel through virtual meetings and email.

The use of virtual meetings has not been a barrier to progress, and all work has been completed. Although in-person meetings are preferable, virtual meetings have allowed work to continue and

[1] A Project Board has overall authority for the project, is accountable for its success or failure, and supports the senior project manager to successfully deliver the project.

[2] Partners that have formal governance role in the project, and a formal relationship with the project that may involve staff costs and/or budget management responsibilities.

therefore have been a suitable approach. More recently, several in-person meetings of the team have taken place following the recent fieldwork trip.
The key indicators of achievement are those detailed in the log frame and section 3 of this report.

6 Actions taken in response to Annual Report reviews.

There are two outstanding queries from the last annual report. The first refers to the lack of quantitative language used throughout the last report:

"The reporting language should be more precise with use of exact numbers instead of less accurate words like 'several' or 'many'."

We hope that this final report contains all of the detail required to accurately assess whether the project has delivered on the outputs listed in the log frame. Care has been taken to include values wherever possible and a large amount of extra data has been added into several annexes.

The second point query refers to the reasons behind why the original automated counting methods were not available:

"*Review in greater detail the reasons for which your designed options for data analysis (automated count or citizen science) did not work out despite your assurances at proposal stage*."

This point has been outlined in detail in section 3.1, output 3. Along with the methods we employed in their stead and suggestions for future surveys.

7 Lessons learnt.

Regular contact with GSGSSI proved to be essential for both the planning and completion of fieldwork on both a scientific and operational level. The building of good working relationships in this regard was essential for the success of the project. The change in availability of ship support caused difficulties during both field campaigns and was only mitigated through the existing working relationships between members of the project team and GSGSSI, as well as other logistics providers such as cruise ship companies. In 2022, the significant effort spent planning the fieldwork and building in redundancy proved crucial. Despite encountering a number of significant challenges during the planning of fieldwork including but not limited to; lack of vessel support for science and a lack of vessels to transport staff to/from South Georgia, the season was successfully delivered.

8 Risk Management

As the last 12 months have been largely image analysis and writing, no further significant risks were identified above those discussed in previous annual reports.

9 Sustainability and Legacy

Our planned exit strategy remains valid. At the end of the Project, we intend to pass control of the UAV to the KEP Project at BAS, so that work can continue into the future. Discussions with GSGSSI and SGHT are ongoing to determine how this work may be funded into the future.
As detailed above, the best approach for future surveys would be a collaborative endeavour between GSGSSI and BAS where the skills and capacity for this work have has already been developed.
We have also participated in writing three peer-reviewed papers that include details of our selected monitoring sites. This is so scientists external to the project, understand our objectives and can contribute where they have capacity. A methods paper focussed on the use of the fixed wing platform for wildlife monitoring at South Georgia is currently in submission (Annex 5.6).

10 Darwin Plus Identity

GSGSSI is very aware of the value of the Darwin Initiative as is BAS.
All presentations from the project have displayed the Darwin logo prominently. As identified in our log frame, we will continue to undertake relevant outreach about the outputs that we deliver. The Darwin logo is present on the project webpage and has been included in all talks resulting from the project.
Darwin has been listed as the research funder on all submitted peer reviewed papers (Annex 5.5).

11 Safeguarding

Has your Safeguarding Policy been updated in the past 12 months?		No
Have any concerns been investigated in the past 12 months		No
Does your project have a Safeguarding focal point?	Yes, we have a safeguarding lead across BAS	
Has the focal point attended any formal training in the last 12 months?	Yes	
What proportion (and number) of project staff have received formal training on Safeguarding?		Past: 50 % (3 staff members. Collins, Hollyman & Fenney) Planned:0 %
Has there been any lessons learnt or challenges on Safeguarding in the past 12 months? **None**		

12 Finance and administration

12.1 Project expenditure

Project spend (indicative) since last Annual Report	2023/24 Grant (£)	2023/24 Total actual Darwin Plus Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs	[redacted]			Extra salary costs were distributed to the remaining team members following Adrian Fox's retirement (and subsequent change request). With other commitments to a variety of other projects, several team members were unable to use the extra time o the project. This in no way impacted the delivery of the final project outcomes.
Consultancy costs				
Overhead Costs				See above.
Travel and subsistence				A charge for a flight for one of the team members (Fenney) was unexpectedly placed in this financial year. This is because his trip was extended meaning the return leg of the original flight was in the new financial year.
Operating Costs				
Capital items				
Others				
TOTAL				

Staff employed (Name and position)	Cost (£)
Phil Trathan	[redacted]
Nathan Fenney	
Adrian Fox	
Martin Collins	
Philip Hollyman	
Field worker (Jamie Coleman)	
TOTAL	**148,343**

Consultancy – description and breakdown of costs	Other items – cost (£)

TOTAL	

Capital items – description	Capital items – cost (£)
Fixed wing UAV platform	[redacted]
TOTAL	

Other items – description	Other items – cost (£)
TOTAL	

12.2 Additional funds or in-kind contributions secured

Source of funding for project lifetime	Total (£)
Waived overheads	[redacted]
2x Trimble geodetic GNSS units for the fieldwork	
Specialist 3D modelling computer for the data analysis.	
Fixed wing UAV platform	
Funds from Blue Belt (via GSGSS) for additional work (continuing the employment of Jamie Coleman).	
TOTAL	**133,442**

Source of funding for additional work after project lifetime	Total (£)
Discussions underway with GSGSSI and South Georgia Heritage Trust to fund future work.	
TOTAL	

12.3 Value for Money

This project delivered a comprehensive series of field campaigns, undertaking spatially extensive UAV surveys of a range of key higher predator species. A substantive amount of in-kind funding was secured during the lifetime of the project, ensuring all aspects of the fieldwork and analysis could be completed in an efficient manner. As the project was operated through the British Antarctic Survey, it benefitted from the extensive logistical apparatus of this organisation. This helped with shipment of equipment, organisation of travel and accommodation for team members and the use of base and field hut facilities on South Georgia. The use of the Pharos SG (with permission from GSGSSI) greatly increased the range of the survey work, this was not charged as vessel time (which would have constituted 10's of thousands of pounds), but rather just as single berth rates for team members.

13 OPTIONAL: Outstanding achievements of your project (300-400 words maximum). This section may be used for publicity purposes.

I agree for the Biodiversity Challenge Funds Secretariat to publish the content of this section (please leave this line in to indicate your agreement to use any material you provide here).

File Type (Image / Video / Graphic)	File Name or File Location	Caption, country and credit	Online accounts to be tagged (leave blank if none)	Consent of subjects received (delete as necessary)
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No

Annex 1 Project's full current logframe as presented in the application form (unless changes have been agreed)

Please insert your project's logframe (if your project has a logframe), including indicators, means of verification and assumptions. 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 BCF-Reports@niras.com if you have any questions regarding this.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: Strategic long-term scientific monitoring project addressing ecosystem change relationships for important land-based predator species, forming an important contribution to the SGSSI MPA Research and Monitoring Plan.			
Outcome: Establishment of a rigorous, multi-species, baseline reference dataset for seabird and seal colonies at South Georgia, used to inform policy decisions by GSGSSI and CCAMLR.	0.1 Creation of a list by Q3Y1 of high priority, long-term monitoring sites, for which the baseline reference data will be collected.	0.1 Formal report submitted to GSGSSI.	Expert knowledge from BAS scientists.
	0.2 Completion of field data collection at each monitoring site. To be undertaken over three campaigns and completed by Q2Y3.	0.2 The generation of a fieldwork report, detailing sites visited and data collected.	Expert knowledge from BAS Mapping and Geographic Information Centre.
	0.3 Detailed description and maps / orthorectified imagery, defining spatial extent of each long-term monitoring site. To be complied by Q3Y3.	0.3 Formal report and supplementary maps and image data submitted to both GSGSSI and CCAMLR.	Successful access to each of the proposed long-term monitoring sites.
	0.4 Baseline count data derived for each species at each monitoring site. To be completed by Q4Y3.	0.4 Formal report submitted to both GSGSSI and CCAMLR.	
	0.5 Documentation of the methodology / workflow used to undertake surveys to allow future monitoring to be conducted by GSGSSI as part of a long-term monitoring programme. To be completed by Q4Y3.	0.5 Methodology provided to GSGSSI. Methodology paper submitted to an open-access peer reviewed journal and receipt received.	

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Outputs: **1**. Creation of a list of high priority, long-term monitoring sites at South Georgia for species targeted as ecosystem indicators (king, macaroni and gentoo penguins, elephant and fur seals, and albatross species).	1.1 Discussion with GSGSSI and members of the wider South Georgia scientific community to consider potential sites or long-term monitoring. Discussion to be undertaken during Q2Y1. 1.2 Final list of proposed long-term monitoring sites to be complied Q3Y1. To include information such as location, access information, species, priority and temporal requirements (optimum period for data collection). 1.3 Working paper justifying species / sites selected, including important ecological aspects underpinning choice of species to be documented. To be completed before end of Y1.	1.1 Evidence of communication such as emails and minutes from meetings. 1.2 Formal report submitted to GSGSSI. 1.3 Formal report submitted to GSGSSI.	Expert knowledge from BAS scientists. Buy-in from GSGSSI both during this process and of the resulting output is key as they will ultimately be responsible for maintaining the monitoring programme after the project has ended.
2. High resolution, georeferenced, fixed-wing UAV aerial survey of each of the monitoring sites identified in Output 1 for the purpose of creating baseline	2.1 Completion of aerial survey / field data collection at each monitoring site. Three periods of fieldwork have been defined based on the requirements of the species being monitored, October 2021, January 2022 and December 2022. 2.2 Initial photogrammetric analysis to be undertaken after data collection. To be completed by Q2Y3*.	2.1 Fieldwork report to be completed for each deployment. 2.2 3D models (output by the photogrammetric processing) available for each site.	Survey sites are accessible via land, IAATO vessel or via FPV Pharos. Fieldwork deployment takes into account potential for weather related delays.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
reference datasets.	2.3 High resolution (2.5 cm), georeferenced, orthorectified (geometrically corrected), aerial imagery mosaics for each monitoring site to be created. To be completed by Q2Y3*. 2.4 Georeferenced outlines defining the current spatial extent of each colony / site. To be completed by Q2Y3*. *Q2Y3 represents when the data collected during the last deployment will need to be processed by. Data collected during the earlier deployments will be processed as soon as possible upon return to the UK.	2.3 Orthophotos available for each site. 2.4 Georeferenced outlines for each site available.	Field activities can be rescheduled if delayed by significant weather events / operational disruptions during grant period. BAS will have the same or an equivalent platform to the proposed fixed-wing UAV (SenseFly Ebee X) that can be used as a backup system while operating in the field. BAS will provide GNSS base stations to enable Post processed kinematic (PPK) processing.
3. Population counts for each of the monitoring sites identified in Output 1 using the aerial survey datasets and input into the relevant national and international governing bodies (such as GSGSSI and CCAMLR).	3.1 Investigate most appropriate method for deriving population counts for each species (either automated image processing software or citizen science platform). This is to account for the different spatial distributions exhibited by penguins and seals while on land. To be determined by end of Q2Y2. 3.2 Determine baseline populations for each of the monitoring sites, using the orthorectfied imagery acquired during the aerial surveys. To be completed by Q3Y3.	3.1 Report progress to GSGSSI. 3.2 Outputs submitted in a formal report to both GSGSSI and CCAMLR.	Each monitoring site identified in Output 1 was successfully surveyed during the fieldwork. Ability to determine population using automated methods. Penguins for example, make an ideal candidate due to the regular spacing between the nests*. However, elephant seals lie on top of each other, so in this case, counting may have to be undertaken manually, or by citizen science.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
			To determine an accurate baseline population, surveys must have been undertaken during a specific time period for each species, otherwise data will not be representative. *Although this does vary between different species.
4. Documented workflow provided to GSGSSI to allow repeat surveys of monitoring sites to be undertaken on a regular basis into the future.	4.1 Produce a methodology paper documenting the workflow developed to both undertake the aerial surveys and determine the population. This is key as it would also allow for the methodology to be applied to other UKOT's. To be completed by Q4Y3.	4.1 Methodology provided to GSGSSI. Methodology paper submitted to a peer-reviewed journal and receipt received.	GSGSSI have already included project in KEP 2019-2024 science plan.
	4.2 Train at least two GSGSSI field assistants regarding the data collection and data analysis aspects of the project, to allow GSGSSI to maintain long-term monitoring of the sites. To be completed by Q4Y3.	4.2 GSGSSI field assistants able to demonstrate ability to undertake the required data collection and data analysis steps. Training report submitted to GSGSSI, which will include an assessment of the field assistants ability to implement the data collection and analysis aspects of the project.	Expert knowledge from BAS scientists.
	4.3 Train at least one GSGSSI field assistant to operate the fixed-wing UAV / flight planning software. To be completed by Q4Y3.	4.3 GSGSSI field assistant able to demonstrate ability to use flight planning software. Training report submitted to GSGSSI, which will include an assessment of the field assistants ability to operate the UAV flight planning software.	Expert knowledge from BAS mapping team.
	4.4 At least one GSGSSI field assistant to undertake the Remote Pilot Qualification – small (RPQ-s) for fixed-wing UAV's (<20 kg), to allow GSGSSI to maintain long-term monitoring of the sites. To be completed by Q4Y3.	4.4 GSGSSI field assistant successfully acquires RPQ-s for fixed-wing platforms weighing <20 kg. Please note, this qualification is the same level as the qualification required to fly mutli-copter UAVs, which GSGSSI already operate.	GSGSSI and KEP Project able to identify most appropriate personnel to receive training.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
5. Increased scientific understanding of change at South Georgia.	5.1 Produce peer-reviewed scientific papers to consider what the project outputs tell us about South Georgia. To be completed by Q4Y3. The solution proposed (for undertaking large-scale, high resolution, repeatable aerial surveys using fixed-wing UAV's) has significant application across a number of UKOTs and as such, the intention is to publish separate methodology papers for both the geomatics (aerial survey) and image analysis aspects.	5.1 Submitted to peer-reviewed journal and received receipt of submission.	Historical data available for long term monitoring sites. Not technically required, but would add value. Selected journal approves paper.
6. Outreach to other UK OTs and to interested scientists.	6.1 Undertake seminars / talks to further disseminate methods and lessons learned with colleagues (both internal and at least 4 external to BAS) who undertake science at the UKOTs through Blue Belt and through ODA. 6.2 Follow up initial approach from both Norwegian and US colleagues who are interested in the methods we are developing for this project. Potential collaborations include using fishing vessels to access remote penguin colonies, otherwise inaccessible from existing national infrastructure in the Antarctic / BAT.	6.1 Evidence seminars / talks have taken place, e.g. listing in agendas for Blue Belt symposium series (if such coordinated symposia again take place in the future). List of seminars included in annual project reports to Darwin Plus, and in reports to GSGSSI. We anticipate at least 4 seminars external to BAS, including one at a Blue Belt symposium, assuming one takes place. 6.2 Report to CCAMLR detailing any resulting collaboration with the Norwegians.	Collaborations with either US or Norwegian colleagues actually develop.

Activities (each activity is numbered according to the output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1)

Output 1
1.1. Identify list of potential reference sites to be included in the monitoring programme.
1.2. Discuss proposed sites with GSGSSI and scientists in the wider South Georgia community.
1.3. Determine final list and submit to GSGSSI for signoff.

Project summary	Measurable Indicators	Means of verification	Important Assumptions
1.4. Produce a report detailing final list of long-term monitoring sites along with justification. Output 2 2.1. Determine requirements for aerial survey (species / site dependant). 2.2. Produce fieldwork plan. 2.3. Work with GSGSSI and BAS to arrange logistics. 2.4. Ship equipment for fieldwork. 2.5. Deploy staff to South Georgia to undertake fieldwork. 2.6. Undertake data collection (for each monitoring site). 2.6.1. Run GNSS base station. 2.6.2. Undertake UAV survey. 2.6.3. Review data for quality control. 2.7. Undertake GNSS processing (for each monitoring site). 2.7.1. PPK processing of on-board UAV GNSS unit. 2.8. Undertake photogrammetric analysis (for each monitoring site). 2.8.1. Import and alignment of photos collected during the UAV survey. 2.8.2. Import PPK GNSS output to provide georeferencing. 2.8.3. Generate digital elevation model (DEM). 2.8.4. Generate orthophoto. 2.9. Prepare othrophotos for population count. Output 3 3.1. Determine optimal counting method for each species. 3.2. Determine specific software to undertake image analysis / platform for citizen science count if required. 3.3. Process the prepared orthophotos to determine population counts. 3.4. Produce a report detailing the final counts at each of the sites for GSGSSI and input into CCAMLR. Output 4 4.1. Document methodology used to undertake aerial survey and determine population at each site. 4.2. Produce a methodology paper and submit to peer reviewed journal. 4.3. Train GSGSSI KEP Project field assistant to undertake data collection and analysis. 4.4. Arrange for GSGSSI KEP Project field assistant to undertake RPQ-s qualification. 4.5. Train GSGSSI field assistant to operate fixed-wing UAV and flight planning software. Output 5 5.1. Review outputs. 5.2. Consider other historical datasets for the sites where available. 5.3. Produce a scientific paper and submit to GSGSSI and CCAMLR. 5.4. Submit papers to peer reviewed journal. Output 6 6.1. Outreach activities.			

Annex 2 Report of progress and achievements against final project logframe for the life of the project (if your project has a logframe)

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
Impact: Strategic long-term scientific monitoring project addressing ecosystem change relationships for important land-based predator species, forming an important contribution to the SGSSI MPA Research and Monitoring Plan.		
Outcome Establishment of a rigorous, multi-species, baseline reference dataset for seabird and seal colonies at South Georgia, used to inform policy decisions by GSGSSI and CCAMLR.	0.1 Creation of a list by Q3Y1 of high priority, long-term monitoring sites, for which the baseline reference data will be collected. 0.2 Completion of field data collection at each monitoring site. To be undertaken over three campaigns and completed by Q2Y3. 0.3 Detailed description and maps / orthorectified imagery, defining spatial extent of each long-term monitoring site. To be complied by Q3Y3. 0.4 Baseline count data derived for each species at each monitoring site. To be completed by Q4Y3. 0.5 Documentation of the methodology / workflow used to undertake surveys to allow future monitoring to be conducted by GSGSSI as part of a long-term monitoring programme. To be completed by Q4Y3.	0.1 A list was created in collaboration with GSGSSI and the wider South Georgia science community. A formal report was submitted to GSGSSI. We delivered our fieldwork plans, including maps showing proposed monitoring sites (completed in Y1 and reported in 2021 annual report). 0.2 All fieldwork was completed successfully. The initial dates were altered (due to covid) enabling two field campaigns to be combined into one (November 2021 – January 2022) with the final campaign completed in October/November 2022. Some of the identified sites (0.1) were not visited due to logistical and time constraints (discussed in section **). 0.3 Detailed imagery and maps are available for each surveyed site and have been submitted to GSGSSI. A paper detailing the results of the study will be submitted to CCAMLR meetings in 2024. 0.4 Baseline count data have been developed for all sites and species aside from Gentoo penguins. These results have been submitted to GSGSSI as a formal report and a paper detailing the results of the study will be submitted to CCAMLR meetings in 2024. 0.5 The methodology/workflow for the fieldwork and subsequent processing has been provided to GSGSSI and also developed into a peer reviewed publication, submitted to the International Journal of Remote Sensing (open access).

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
Output 1. Creation of a list of high priority, long-term monitoring sites at South Georgia for species targeted as ecosystem indicators (king, macaroni and gentoo penguins, elephant and fur seals, and albatross species).	1.1 Discussion with GSGSSI and members of the wider South Georgia scientific community to consider potential sites or long-term monitoring. Discussion to be undertaken during Q2Y1. 1.2 Final list of proposed long-term monitoring sites to be complied Q3Y1. To include information such as location, access information, species, priority and temporal requirements (optimum period for data collection). 1.3 Working paper justifying species / sites selected, including important ecological aspects underpinning choice of species to be documented. To be completed before end of Y1.	Output 1 was completed on time with the compiled site list shared with GSGSSI, along with a report of maps for each species to be surveyed. Sites were discussed with GSGSSI in relation to site access and other environmental considerations. A detailed hierarchy of site 'difficulty' was developed with GSGSSI along with a testing structure that was required to be completed before the wider survey was undertaken was key to ensuring safe flight operations.
Activity 1.1. Identify list of potential reference sites to be included in the monitoring programme.		Site list compiled in consultation within BAS and externally.
Activity 1.2. Discuss proposed sites with GSGSSI and scientists in the wider South Georgia community.		GSGSSI were heavily involved in an iterative process to discuss feasibility of sites.
Activity 1.3. Determine final list and submit to GSGSSI for signoff.		List of sites along with rating criteria for each site (to determine preferential sites) submitted to GSGSSI and agreed.
Activity 1.4. Produce a report detailing final list of long-term monitoring sites along with justification.		Detailed overview of all proposed sites submitted to GSGSSI including maps of each site, ranking of site preference and detailed agreed procedure (testing structure) for fixed wing operations at South Georgia (developed alongside GSGSSI)
Output 2. High resolution, georeferenced, fixed-wing UAV aerial survey of each of the monitoring sites identified in Output 1 for the purpose of creating baseline reference datasets.	2.1 Completion of aerial survey / field data collection at each monitoring site. Three periods of fieldwork have been defined based on the requirements of the species being monitored, October 2021, January 2022 and December 2022.	Output 2 was successfully completed with two field campaigns (Nov 2012 – Feb 2022 and Oct 2022). 17 of the original 26 sites were surveyed, with 35 surveys undertaken in total. Processing of all imagery has been completed. This has resulted in in the production of high-resolution, georeferenced, orthorectified (geometrically corrected), aerial imagery mosaics for each monitoring site. The fieldwork report for both seasons was completed and delivered to GSGSSI. A report of

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
	2.2 Initial photogrammetric analysis to be undertaken after data collection. To be completed by Q2Y3*. 2.3 High resolution (2.5 cm), georeferenced, orthorectified (geometrically corrected), aerial imagery mosaics for each monitoring site to be created. To be completed by Q2Y3*. 2.4 Georeferenced outlines defining the current spatial extent of each colony / site. To be completed by Q2Y3*. *Q2Y3 represents when the data collected during the last deployment will need to be processed by. Data collected during the earlier deployments will be processed as soon as possible upon return to the UK.	the fieldwork was presented to both GSGSSI and BAS in the form of an in-person presentation (two separate occasions).
Activity 2.1. Determine requirements for aerial survey (species / site dependant).		Detailed fieldwork plan produced and shared with GSGSSI – including the development of testing requirements for drone use in the field.
Activity 2.2. Produce fieldwork plan.		Detailed fieldwork plan produced and shared with GSGSSI – this plan was used to undertake the second field season and contained many contingencies in the event of inclement weather.
Activity 2.3. Work with GSGSSI and BAS to arrange logistics.		Early discussions were had with BAS to arrange logistics for shipment of equipment and GSGSSI to arrange logistics for ship support and the use of KEP resources.
Activity 2.4. Ship equipment for fieldwork.		All equipment was shipped on time and arrived in advance of fieldwork.
Activity 2.5. Deploy staff to South Georgia to undertake fieldwork.		All staff were deployed in good time in advance of the fieldwork.
Activity 2.6. Undertake data collection (for each monitoring site).		17 of the original 26 sites were visited.
Activity 2.6.1. Run GNSS base station.		The project used Trimble geodetic GNSS receivers provided by MAGIC / BAS to operate as base stations throughout the fieldwork. For redundancy a pair of

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
		receivers was shipped to South Georgia. The receivers operated without issue.
Activity 2.6.2. Undertake UAV survey.		The project operated two SenseFly eBee X fixed-wing RPAS platforms during the course of the second field season. For redundancy the platforms were an identical pair. All flight operations were conducted BVLOS with the platform reaching distances of up to 3 km from the pilots. This allowed the field team to successfully survey large areas form a single take-off / landing position. For example, one flight over St Andrews Bay lasted 56 minutes with a total flight distance of 42.8 km. The SenseFly eBee X excelled over the largest sites due to its speed and efficiency during data capture, allowing the team to take advantage of small breaks in the weather. This 'ability' has proven decisive especially given the extreme nature of South Georgia's weather allowing us to for example survey 4.3 km of shoreline around Husvik Harbour in just over 15 minutes. As with the first season, both the weather and topography in South Georgia provided a significant challenge at times, however, a combination of the experience of the field team (especially the local knowledge) and excellent support provided by FPV Pharos SG and KEP ultimately lead to a series of successful RPAS surveys.
Activity 2.6.3. Review data for quality control.		Both the RPAS survey and GNSS data was reviewed after each flight. Operating in higher wind speeds while trying to make the most of the limited gaps occasionally necessitated re flying a site to ensure data was of an acceptable quality.
Activity 2.7. Undertake GNSS processing (for each monitoring site).		GNSS processing has been completed all sites surveyed. The processing is undertaken in two stages; first by determining an accurate position for the base station using PPP (precise point positioning) and then using the position calculated to undertake PPK (post-processed kinematic) processing of the on-board RPAS GNSS receiver. The processing conducted so far has been undertaken without issue. Due to the more precise GNSS receiver carried by the SenseFly eBee X, data collected by the platform can be used to post-process earlier aerial surveys of the sites which has the potential to unlock older datasets.
Activity 2.7.1. PPK processing of on-board UAV GNSS unit.		The PPK processing undertaken on the data collected by the on-board RPAS GNSS receiver has met expectations with the positional accuracy of the unprocessed image centre data reported to be in the order of several metres, improved to 3 – 5 cm after processing.

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
Activity 2.8. Undertake photogrammetric analysis (for each monitoring site).		The photogrammetric analysis of the data collected at the monitoring sites visited during the first field season has been completed. The initial outputs from the analysis are promising and appear to closely match what was expected.
Activity 2.8.1. Import and alignment of photos collected during the UAV survey.		Photogrammetry projects for all of the sites surveyed have been established.
Activity 2.8.2. Import PPK GNSS output to provide georeferencing.		Photogrammetry projects for all of the sites surveyed have been established.
Activity 2.8.3. Generate digital elevation model (DEM).		DEM's from all of the sites surveyed have been established.
Activity 2.8.4. Generate orthophoto.		Orthophotos from all of the sites surveyed have been created.
Activity 2.9. Prepare othrophotos for population count.		Completed.
Output 3. Population counts for each of the monitoring sites identified in Output 1 using the aerial survey datasets and input into the relevant national and international governing bodies (such as GSGSSI and CCAMLR).	3.1 Investigate most appropriate method for deriving population counts for each species (either automated image processing software or citizen science platform). This is to account for the different spatial distributions exhibited by penguins and seals while on land. To be determined by end of Q2Y2. 3.2 Determine baseline populations for each of the monitoring sites, using the orthorectfied imagery acquired during the aerial surveys. To be completed by Q3Y3.	3.1 Discussions are ongoing with several research groups on the best approach to apply automated counting techniques to the imagery. As these techniques were not readily available during the project and no funds were allocated to develop them, other methods of counting were pursued. Manual counting methods were used for the majority of species and sites. Alongside this we developed a novel automated DEM counting method for large king penguin colonies which should have wide utility more broadly. Sub-sampling and density based methods were also trialled for large king penguin colonies. 3.2 Population counts are now available for each species surveyed, aside from gentoo penguins. Due to difficulties in surveying small colonies with the eBee X, gentoo counts were not completed. A recommendation from this project is that smaller quadcopter methods are used to survey small colonies (e.g. < 1000 individuals).
Activity 3.1. Determine optimal counting method for each species.		Manual counting methods were used for the majority of species and sites (annex 5.3). DEM based automated counting was used for all large penguin colonies.
Activity 3.2. Determine specific software to undertake image analysis / platform for citizen science count if required.		ArcMap, Metashape and Pix4D were used to process imagery and count the animal populations.

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
Activity 3.3. Process the prepared orthophotos to determine population counts.		Completed for all species aside from gentoo penguins.
Activity 3.4. Produce a report detailing the final counts at each of the sites for GSGSSI and input into CCAMLR.		Now the project is complete a final report has been prepared for GSGSSI and will also be submitted to CCAMLR.
4. Documented workflow provided to GSGSSI to allow repeat surveys of monitoring sites to be undertaken on a regular basis into the future.	4.1 Produce a methodology paper documenting the workflow developed to both undertake the aerial surveys and determine the population. This is key as it would also allow for the methodology to be applied to other UKOT's. To be completed by Q4Y3. 4.2 Train at least two GSGSSI field assistants regarding the data collection and data analysis aspects of the project, to allow GSGSSI to maintain long-term monitoring of the sites. To be completed by Q4Y3. 4.3 Train at least one GSGSSI field assistant to operate the fixed-wing UAV / flight planning software. To be completed by Q4Y3. 4.4 At least one GSGSSI field assistant to undertake the Remote Pilot Qualification – small (RPQ-s) for fixed-wing UAV's (<20 kg), to allow GSGSSI to maintain long-term monitoring of the sites. To be completed by Q4Y3.	
Activity 4.1. Document methodology used to undertake aerial survey and determine population at each site.		A detailed fieldwork report was submitted to GSGSSI and a methods paper from the project is currently in submission (annex 5.5).

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
Activity 4.2. Produce a methodology paper and submit to peer reviewed journal.		A methods paper has been submitted to the International Journal of Remote Sensing (open access, annex 5.5)
Activity 4.3. Train GSGSSI KEP Project field assistant to undertake data collection and analysis.		KEP marine biologists are currently already trained to undertake UAV surveys using quadcopter UAVs.
Activity 4.4. Arrange for GSGSSI KEP Project field assistant to undertake RPQ-s qualification.		All KEP marine biologists undertake the A2CofC and GVC qualifications (successor to the RPQ-s qualification).
Activity 4.5. Train GSGSSI field assistant to operate fixed-wing UAV and flight planning software.		There are currently no GSGSSI staff available to train on the use of the fixed wing platform. The KEP marine biologists are trained to use other types of UAV, but are only on short term contracts. Several detailed discussions have taken place regarding the training of GSGSSI staff but none were identified within the life of the project. One main obstacle to this is the contract length and workload of the GSGSSI staff who could potentially be trained.
Output 5. Increased scientific understanding of change at South Georgia.	5.1 Produce peer-reviewed scientific papers to consider what the project outputs tell us about South Georgia. To be completed by Q4Y3. The solution proposed (for undertaking large-scale, high resolution, repeatable aerial surveys using fixed-wing UAV's) has significant application across a number of UKOTs and as such, the intention is to publish separate methodology papers for both the geomatics (aerial survey) and image analysis aspects.	Three separate scientific papers based on the results of the two field seasons have already been developed and submitted, with a fourth in development. The first paper looks at counting methods for King penguin colonies, comparing several types of manual counts (of UAV imagery) against satellite imagery. The second paper details the use and success of thermal imaging for identifying and counting fur seals. The final completed paper synthesises the methods and outputs of the project. The fourth, will look at inter-annual variability of elephant seal populations at key sites around South Georgia, including St Andrews where a time series of satellite imagery had been obtained, extending back to the year 2010.
Activity 5.1. Review outputs.		
Activity 5.2. Consider other historical datasets for the sites where available.		All historical data for king penguin and elephant seal populations contained within BAS archives has been obtained in order to look at changes in key sites over time. We have also purchased a time series of satellite imagery to look at the elephant seal population at St. Andrews bay between 2000 and 2022 and king penguins at key sites over the same time period as the surveys.
Activity 5.3. Produce a scientific paper and submit to GSGSSI and CCAMLR.		One scientific paper detailing the king penguin surveys and subsequent counting methodologies (including a comparison to satellite data) is in submission (Remote Sensing in Ecology and Conservation). One paper

Project summary	Measurable Indicators	Progress and Achievements for the life of the project
		detailing the use and success of thermal imaging for identifying and counting fur seals has been written and is in submission (International Journal of Remote Sensing). A third paper detailing the methodological approach to the project and a summary of findings has also been developed and submitted (International Journal of Remote Sensing). A fourth paper looking at inter-annual variability in elephant seals is currently being developed for submission by June 2024. Copies of all submitted papers have been sent to GSGSSI and a summary paper will be submitted to CCAMLR's EMM working group in June 2024.
Activity 5.4. Submit papers to peer reviewed journal.		See 5.3.
Output 6. Outreach to other UK OTs and to interested scientists.	6.1 Undertake seminars / talks to further disseminate methods and lessons learned with colleagues (both internal and at least 4 external to BAS) who undertake science at the UKOTs through Blue Belt and through ODA. 6.2 Follow up initial approach from both Norwegian and US colleagues who are interested in the methods we are developing for this project. Potential collaborations include using fishing vessels to access remote penguin colonies, otherwise inaccessible from existing national infrastructure in the Antarctic / BAT.	The work was presented to GSGSSI following the first field season (2021/22). This talk was also delivered at King Edward Point research station and at BAS Cambridge. Two articles updating the progress of the project have been submitted to the South Georgia Association newsletter, most recently in November 2022. A website for the project has also been developed. Nathan Fenney presented work from this project GSGSSI MPA workshop in June 2023. The work was presented to audiences on board passenger cruise ships five times between Feb 2022 and Feb 2024. The work has also been presented to the Marine Predators group at the University of Tasmania. Discussions are ongoing with several international groups in order to develop collaborations for future work utilizing these platforms. We are also in discussion with several research groups regarding the automated counting approaches for the imagery.
Activity 6.1. Outreach activities.		

Annex 3 Standard Indicators

Table 1 Project Standard Indicators

DPLUS Indicator number	Name of indicator using original wording	Name of Indicator after adjusting wording to align with DPLUS Standard Indicators	Units	Disaggregation	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
DI-C17	Produce peer-reviewed scientific papers to consider what the project outputs tell us about South Georgia. To be completed by Q4Y3. The solution proposed (for undertaking large-scale, high resolution, repeatable aerial surveys using fixed-wing UAV's) has significant application across a number of UKOTs and as such, the intention is to publish separate methodology papers for both the geomatics (aerial survey) and image analysis aspects.	Number of unique papers submitted to peer reviewed journals	Number				3	3	3
DI-C08	Determine baseline populations for each of the monitoring sites, using the orthorectfied imagery acquired during the aerial surveys. To be completed by Q3Y3.	Areas of importance for biodiversity identified	Number				12	25	25
DI-C01	Produce a methodology paper documenting the workflow developed to both undertake the aerial surveys and determine the population. This is key as it would also allow for the methodology to be applied	Number of best practice guides and knowledge products published and endorsed	Number				1	1	1

DPLUS Indicator number	Name of indicator using original wording	Name of Indicator after adjusting wording to align with DPLUS Standard Indicators	Units	Disaggregation	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
	to other UKOT's. To be completed by Q4Y3.								
DI-C19	Two reports have been produced for GSGSSI over the life of the project, one a report on the fieldwork and one a final report of the project findings	Number of other publications produced	Number			1	1	2	2
DI-C16	All project data will be archived in the NERC Polar Data Centre This is ongoing and is an added bonus as this was not part of the original project plan.	Number of records added to accessible databases.							0

Table 2 Publications

Title	Type (e.g. journals, manual, CDs)	Detail (authors, year)	Gender of Lead Author	Nationality of Lead Author	Publishers (name, city)	Available from (e.g. weblink or publisher if not available online)

Is the report less than 10MB? If so, please email to BCF-Reports@niras.com putting the project number in the Subject line.	Yes
Is your report more than 10MB? If so, please discuss with BCF-Reports@niras.com about the best way to deliver the report, putting the project number in the Subject line.	No
If you are submitting photos for publicity purposes, **do these meet the outlined requirements (see section 10)?**	No
Have you included means of verification? You should not submit every project document, but the main outputs and a selection of the others would strengthen the report.	Yes
Do you have hard copies of material you need to submit with the report? If so, please make this clear in the covering email and ensure all material is marked with the project number. However, we would expect that most material will now be electronic.	No
If you are submitting photos for publicity purposes, do these meet the outlined requirements (see section 13)?	No
Have you involved your partners in preparation of the report and named the main contributors	Yes
Have you completed the Project Expenditure table fully?	Yes
Do not include claim forms or other communications with this report.	