Darwin Plus Main: Annual 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: 30th April 2024

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

Darwin Plus Project Information

Project reference	DPLUS187
Project title	Using satellite technology to monitor seabird populations at South Georgia
Territory(ies)	South Georgia and South Sandwich Island
Lead Partner	British Antarctic Survey
Project partner(s)	RSPB
Darwin Plus grant value	£489,579.00
Start/end dates of project	01/12/2023 – 30/11/2026
Reporting period (e.g. Apr 2023-Mar 2024) and number (e.g. Annual Report 1, 2)	01/12/2023 – 30/04/2024, Annual Report 1
Project Leader name	Peter [redacted]
Project website/blog/social media	Website: South Georgia seabirds from space - British Antarctic Survey (bas.ac.uk) Twitter: @BAS_NEWS, @WildlifeSpace
Report author(s) and date	Peter [redacted], Marie [redacted], Richard [redacted], Ellen [redacted] 30 April 2024

1. Project summary

Globally important populations of seabirds breed at South Georgia (**Figure 1**), but because of the size and remoteness of these islands, monitoring is limited to a few locations. This project will assess the feasibility of using satellite imagery to monitor the status of seabirds across the island group, provide baselines to showcase the recovery of burrowing petrels following the eradication of rodents and reindeer in the mid-2010s, and develop methods that could replace expensive and logistically challenging ground surveys across numerous remote islands worldwide.

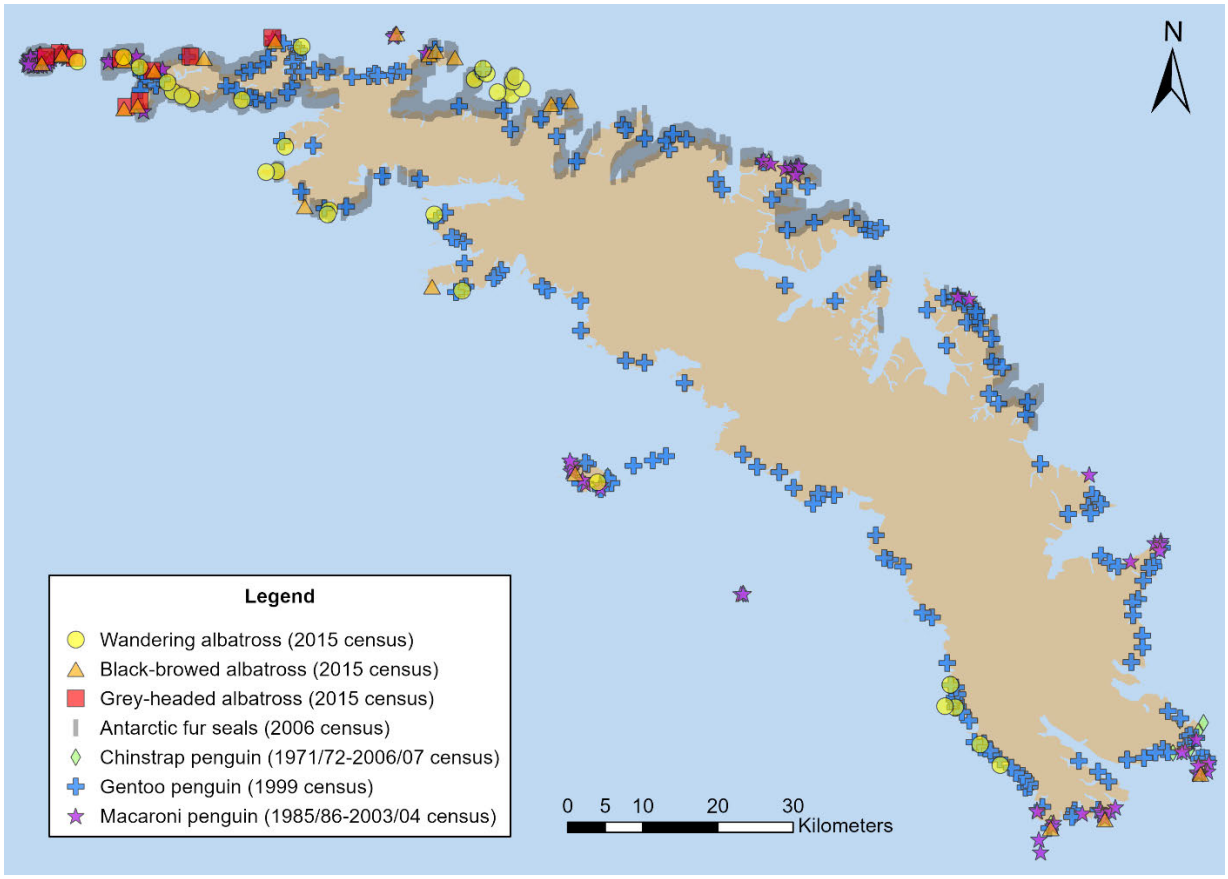

Figure 1. Map of South Georgia with distribution of known seal and seabird breeding locations for this study.

2. Project stakeholders/partners

Our project is led by the British Antarctic Survey (BAS), with GSGSSI as the primary UKOT stakeholder. Other project stakeholders include the South Georgia Heritage Trust (SGHT), Royal Society for the Protection of Birds (RSPB), BirdLife International, South Georgia Surveys, Agreement on the Conservation of Albatrosses and Petrels (ACAP), and other countries and territories which host populations of the seabird species targeted in the proposed project.

The project began in December 2023 when the DPLUS132 project had concluded. Since the start of the project, we have held three in-person meetings with all BAS researchers named on the project (26th January 2024, 28th February 2024 and 24th April 2024; see **Annex 4.1, 4.2** and **4.3 for meeting minutes**). These meetings gave an opportunity for researchers to provide feedback on results and discuss next steps in the research.

Project engagement with GSGSSI has been achieved through regular email correspondence with their Head of Environment, Jennifer Black. We have also been in regular contact with Sally Poncet from South Georgia Surveys, who along with Jen Black, was closely involved in the 2023/24 all-islands surveys of wandering albatrosses. No stakeholder meetings have been held yet as we decided it would be beneficial to wait until analyses were completed for the 2023/24 albatross surveys.

All stakeholder representatives listed in Output 0.4 (BirdLife International, GSGSSI, ACAP, SGHT and RSPB) will be: (i) contacted in May 2024 to ask if they would like to be informed of project progress, (ii) invited to biannual hybrid stakeholder meetings and, (iii) asked if there are others in their organisations that they think might also like to be kept informed or invited to meetings (see **Table 1** for contact list). Each representative was provided with a link to the project BAS webpage '[South Georgia Seabirds from Space]' to help inform their decision. The stakeholder meetings are planned for July and December this year.

The stakeholder representatives that often attend the BAS office in Cambridge (see **Table 1**) will be invited to a separate in-person meeting in May to discuss plans for the project.

Table 1. People contacted to see if they want to be informed of progress or invited to stakeholder meetings. Individuals that often attend BAS Cambridge office are marked with an asterisk.

Name	Stakeholder
Ashley Bennison *	BAS
Martin Collins *	BAS
Jaimie Cleeland *	BAS
Nathan Fenney *	BAS
Jonathan Davies	BirdLife International
Tim Stowe	SGHT
Ken Passfield	South Georgia Surveys
Sally Poncet	South Georgia Surveys
Jennifer Black	GSGSSI
Mark Belchier *	GSGSSI
Sue Gregory *	GSGSSI

3. Project progress

3.1 Progress in carrying out project Activities

Output 1 An assessment of whether burrowing petrels can be detected using satellite imagery based on spectral analysis of vegetation colour at Bird Island.

Existing data on burrowing petrel distribution and abundance at Bird Island (BI) located off the north-west tip of South Georgia, and new data that we collected specifically for this project at the Thatcher Peninsula around the BAS research station of King Edward Point (KEP) on the north coast of South Georgia were collated (Activity 1.1). We produce a map from the survey of white-chinned petrel burrow densities at BI in 2016/17 (**Figure 2**). Information on the number of occupied and unoccupied burrows, and whether seals were present were available for each quadrat (census data in **Annex 4.4** and see Supporting Information in Annex 4 for details of survey methodology).

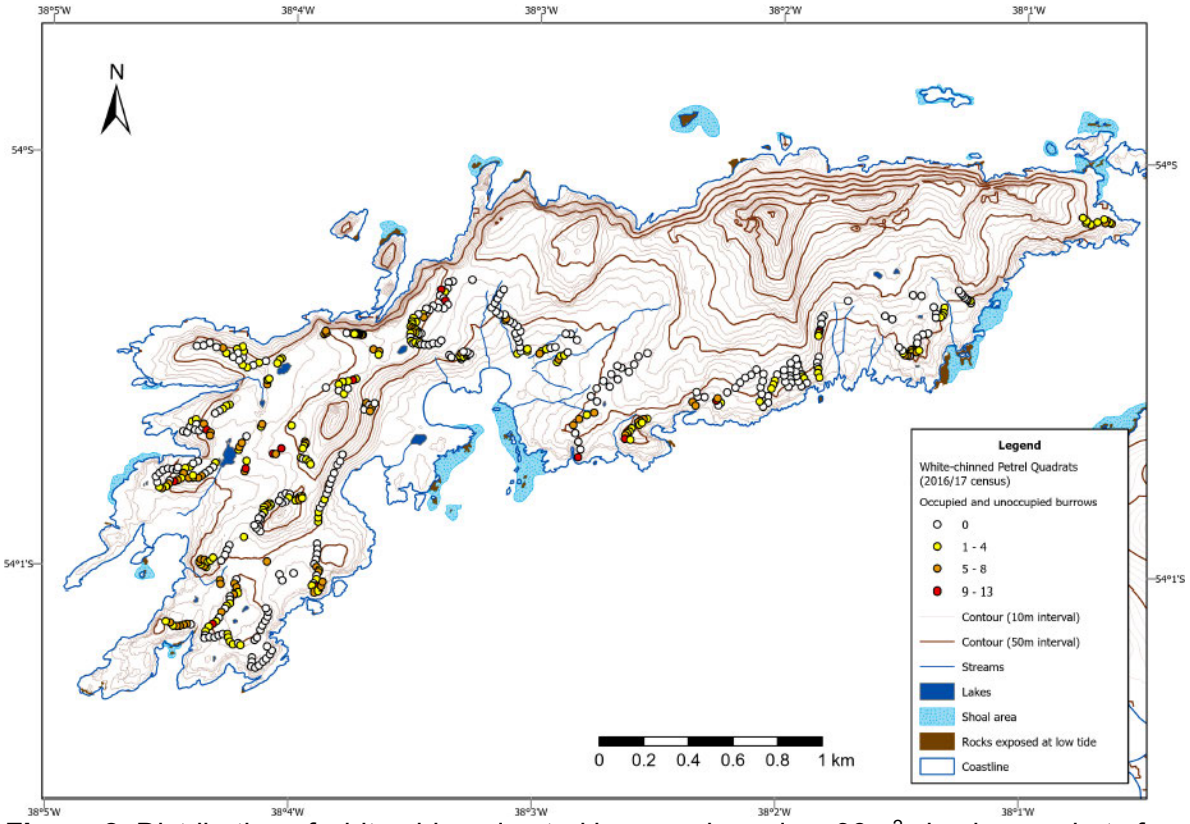

Figure 2. Distribution of white-chinned petrel burrows based on 36m^2 circular quadrats from 2016/17 census.

The distribution of white-chinned petrel colonies at the Thatcher Peninsula in austral summer 2022/23 was determined specifically for this project (**Figure 3**) from a field survey of burrow locations mapped using a handheld GPS (**Annex 4.5**) and annotated photos of other areas that were also visited in that season (**Annex 4.6**). These data may allow us to differentiate between fertilised vegetation surrounding burrows versus fertilised vegetation from seals or run-off in satellite images. Archived 30 cm 8 band satellite imagery of BI and 30 cm and 40 cm 8 band resolution imagery of the Thatcher Peninsula have been purchased (see **Section 3.1 Table 2** for list and **Annex 4 Figure S1-S2** for imagery). Imagery of these areas will also be tasked from December 2024 to January 2025 (Activity 1.2 and 3.2). Any areas with no cloud-free imagery from this tasking window will be tasked again the following season (December 2025 to January 2026).

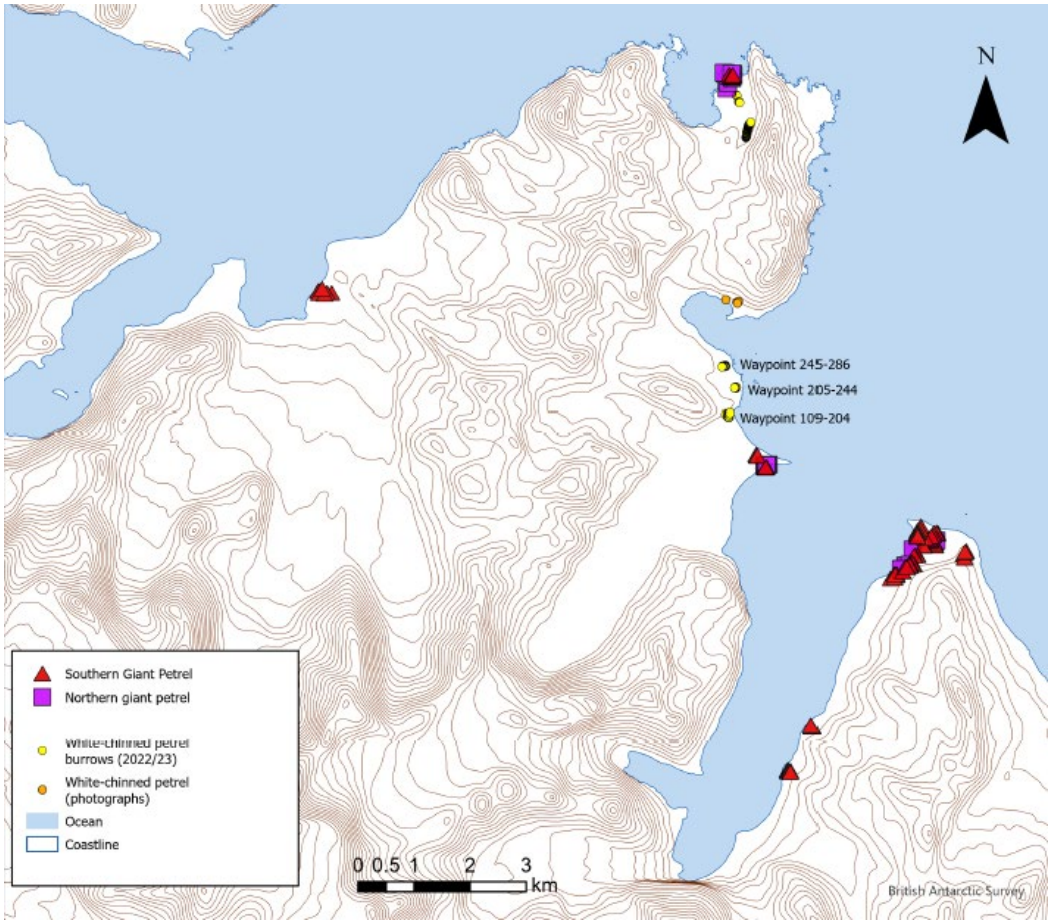

Figure 3. Distribution of northern giant petrels, southern giant petrels and white-chinned petrels on King Edward Point using data collected during the 2022/23 survey.

Table 2. Satellite imagery acquired to validate methods at Bird Island (BI) and King Edward Point (KEP). Site, bands, catalogue identification (Cat ID), date captured (dd/mm/yyyy) and purchased Ground sampling distance (GSD) in cm. All images are primarily cloud-free.

Site	Bands	Site description	Date captured	Cat ID	Sensor	GSD
BI	3	Entire island except East tip	06/12/2021	1040010070A59100	WV-03	30
BI	4	Entire island	17/03/2022	1040010075438E00	WV-03	30
BI	8	Entire island	10/01/2015	10400100066C1E00	WV-03	30
BI	8	Entire island	28/12/2019	1040010056021B00	WV-03	30
BI	8	Entire island	09/12/2019	104001005746C400	WV-03	30
BI	8	West side only	18/12/2017	1040010036438A00	WV-03	30
BI	8	Bird Island and Cape Alexandra	06/03/2023	104001008210F900	WV-03	30
KEP	8	All KEP	28/01/2024	1040010091B7CF00	WV-03	32
KEP	8	East side	26/12/2019	104001005423B900	WV-03	40
KEP	8	East Side	27/11/2015	1040010014004F00	WV-03	40
KEP	8	North end	20/01/2017	1040010027495C00	WV-03	40
KEP	8	West side	27/11/2015	10400100141E9F00	WV-03	40
KEP	8	East Side	10/02/2021	104001006563D400	WV-03	40
KEP	8	East side	10/11/2021	ACQ_PNEO3_00820900784026	Pléiades Neo	31

We will test whether the Normalised Difference Vegetation Index (NDVI) derived from satellite sensors can be used to predict the distribution of burrowing petrels across South Georgia. For NDVI, the -1 to 1 scale is generally used to indicate the 'greenness' of vegetation. 'Green' vegetation reflects less visible red wavelength light and more of the near-infrared thereby producing higher NDVI values. Conversely, low NDVI values represent lower levels of 'green' vegetation (Huete *et al.* 2002). There was a single image available for 2015 (January), 2017 (December), 2022 (March), 2023 (March) and two satellite images taken 19 days apart in December 2019 (**Figure S1-S2**).

The quadrats with burrows from the 2016/17 survey had high tussock cover (70-100%) (**Table S2, Figure S3**), with rocks and moss covering the remaining ground. All other classification categories (seals present, burrows and seals present, and burrows and seals absent) were filtered to include quadrats with at least 70% tussac ground cover to compare spectral signatures. Here we summarise the results for each satellite image using the NDVI created using NIR1, as these values were similar to the NDVI created using NIR2 (**Figure 4-5**). A one-way ANOVA showed significant differences in quadrate average NDVI values between the four categories (**Table S2**). A Tukey's post hoc test indicated that vegetation is significantly greener (based on NIR-NDVI) in areas with both burrows and seals compared to areas where only burrows or seals are present, as well as areas where both species are absent based on satellite imagery from 9th and 28th December 2019 and 10th January 2015 (**Table S3**). Satellite imagery captured on 28th December 2019 and 10th January 2015 also showed that NDVI was also significantly higher in areas occupied by seals or burrows only compared to areas where seals and burrows were absent. NIR1-NDVI was significantly different between areas containing seals only and burrows only based on images from 10th January 2015 and 6th March 2023, but the direction of this effect was inconsistent. Based on the image captured on 6th March 2023, areas with both burrows and seals present had significantly higher NIR1-NDVI than areas with only seals present (p<0.001) and burrows and seals absent (p=0.02). Overall, these findings suggest that the NDVI signature of vegetation where seals or burrowing petrels are present peaks in December to January. Unique NDVI signatures are present for fertilised vegetation at the start of December in areas where both seals and burrows are present and are apparent by late December for areas with only burrows or seals. Therefore, future tasking of South Georgia should prioritise the purchase of cloud-free images from late December and January.

Within-season changes in spectral profiles of vegetation areas occupied by burrowing petrels at Bird Island will be confirmed using UAV based spectrometer in this coming summer (Activity 1.4). A spectrometer camera mounted on a UAV is being used instead of a hand-held spectrometer as the UAV will be able to cover more ground and can be used to calibrate the satellite imagery.

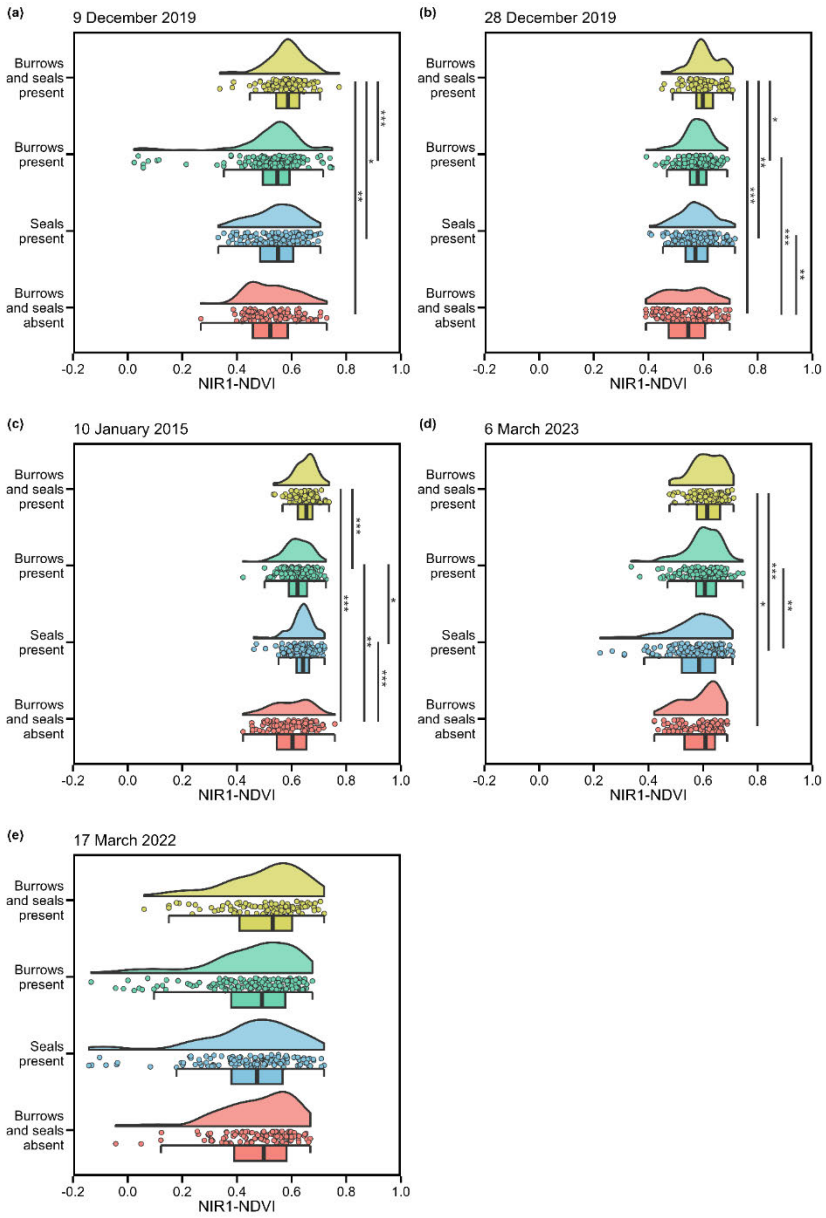

Figure 4. Normalised Difference Vegetation Index (NDVI) density plots from 2016/17 burrowing petrel survey on Bird Island. Quadrats were classified based on burrow and seal presence-absence. The NDVI was created using NIR1 and red bands from a 30-cm resolution satellite image captured on (a) 10 January 2015, (b) 9 December 2019, (c) 28 December 2019, (d) 6 March 2023, and (e) 17 March 2022.

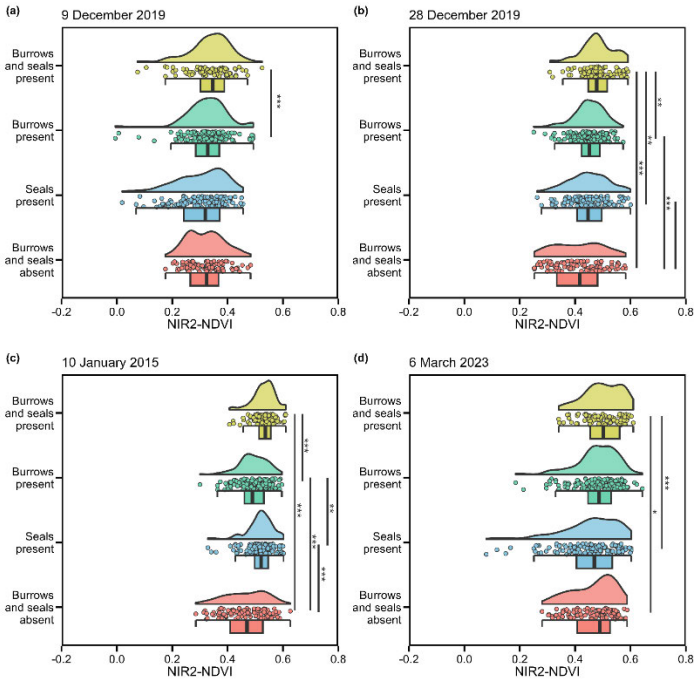

Figure 5. Normalised Difference Vegetation Index (NDVI) density plots of circular quadrats (36 m^2) from 2016/17 burrowing petrel survey on Bird Island. Quadrats were classified based on burrow and seal presence-absence. The NDVI was created using NIR2 and red band from a 30-cm resolution satellite image captured on (a) 10 January 2015, (b) 9 December 2019, (c) 28 December 2019 and (d) 6 March 2023.

Output 2. An assessment of long-term changes in the distribution and densities of burrowing petrels across SG using satellite imagery.

1. Data on burrowing petrel distribution and abundance were collated for BI and the Thatcher Peninsula (Activity 2.2, **Figure 2-3**). Archived satellite imagery will be analysed to determine if vegetation and landscape features can be used to accurately identify areas known to be occupied by white-chinned petrels. If this technique is effective, the method will be expanded across SG. The resulting distribution data will be compared to 5 x 5 km presence-absence distribution map from the 1980s in *South Georgia: An Ecological Atlas* (Trathan *et al.* 1996) (**Figure 6**, Activity 2.1). We have contacted BAS Archives to source the presence-absence spreadsheets used to create **Figure 6**.

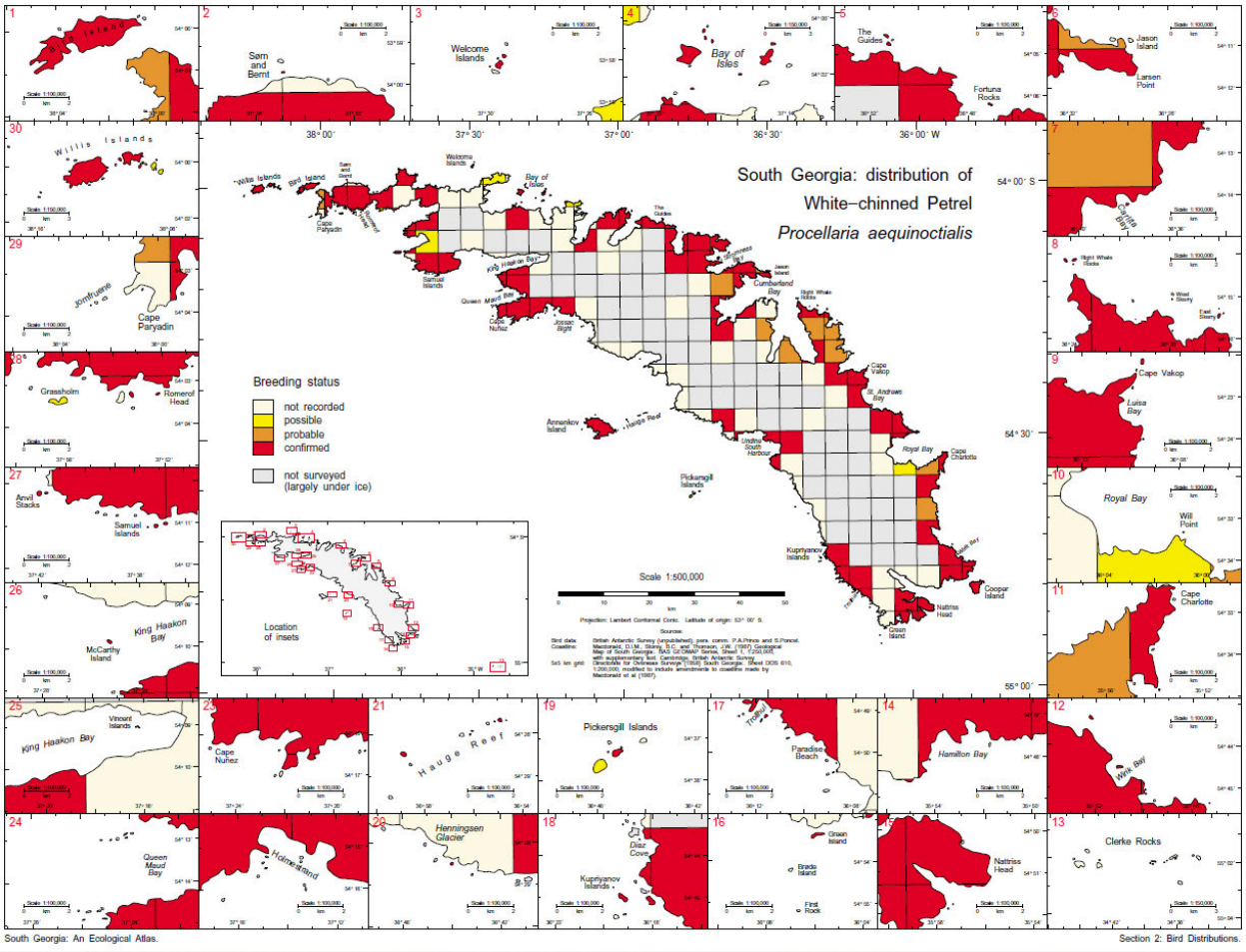

Figure 6. Distribution of white-chinned petrels as 5 x 5 km units from surveys in 1985-87 surveys. The map is from *South Georgia: An Ecological Atlas*. Species may not necessarily be evenly distributed over the whole unit. Some inland units contain a substantial amount of rock and ice and were either not visited or were visited infrequently.

2. We have investigated the most cost-effective procedure for purchasing archived imagery and tasking new imagery of South Georgia. The two main 31 cm commercial satellite providers are Maxar and Airbus. Each provider has recently released new online ordering platforms: MGP Pro and OneAtlas, respectively. We have used the trial version of both ordering platforms and found that Airbus' OneAtlas has very few archived images of South Georgia, but remains an option for tasking. MGP Pro has a good range of archive and new imagery and is most advantageous for tasking and purchasing archive imagery of smaller areas. The minimum order quantity (MOQ) on MGP Pro is (1) 1 km^2 for purchasing archive imagery, (2) 50 km^2 for tasking low demand countries, (3) 100 km^2 for tasking large demand countries. South Georgia is a low demand area; therefore we would benefit from the 50 km^2 MOQ for tasking. Offline order requires at least 25 km^2 ordered for archived imagery and 100 km^2 for tasking imagery, however this includes a 30% educational discount. Therefore, most tasking will be carried out using Maxar's offline order for the 2024/25 breeding season (Activity 2.3 & 4.2). We also plan to subscribe to MGP Pro for 2 years, or until the project ends in December 2026, adding £10k worth of credits on the platform to spend on tasking smaller areas.

   The areas to be tasked on MPG Pro will include multiple images of Bird Island and KEP over the 2024/25 breeding season to confirm within-season changes in vegetation spectral profiles (Activity 1.4). Maxar will be contacted to confirm whether this is possible using the allocated budget.

3. A 2 m resolution digital terrain model (DTM) of South Georgia was created using the Reference Elevation Model of Antarctica (REMA). REMA is open source, accessible at https://www.pgc.umn.edu/data/rema/. This has been used to extract elevation, slope

and aspect data for all 36 m^2 circular quadrats included in the 2015/16 white-chinned petrel census on Bird Island.

4. Habitat suitability models for white-chinned petrels are currently being developed for Bird Island and the Thatcher Peninsula using spectral and landscape features. If successful, the habitat model will be expanded across SG (Activity 2.4).

Output 3. An assessment of whether VHR satellite imagery can be used to count mollymawks (black-browed and grey-headed albatrosses), SG shags and giant petrels, and to identify colonies of Wilson's storm petrels and SG diving petrels at Bird Island and elsewhere at SG where ground-truthing data are available.

We collated data on abundance or distribution of mollymawks, SG shags, giant petrels, Wilson's storm petrels and SG diving petrels at Bird Island (**Figure 7**) and the Thatcher Peninsula (**Figure 3**) (Activity 3.1). Visual inspection of satellite imagery was used to assess which species could be detected directly (see below for details). Expert annotations of species directly detectable in satellite imagery will commence later this year to develop automated detection methods (Activity 3.3).

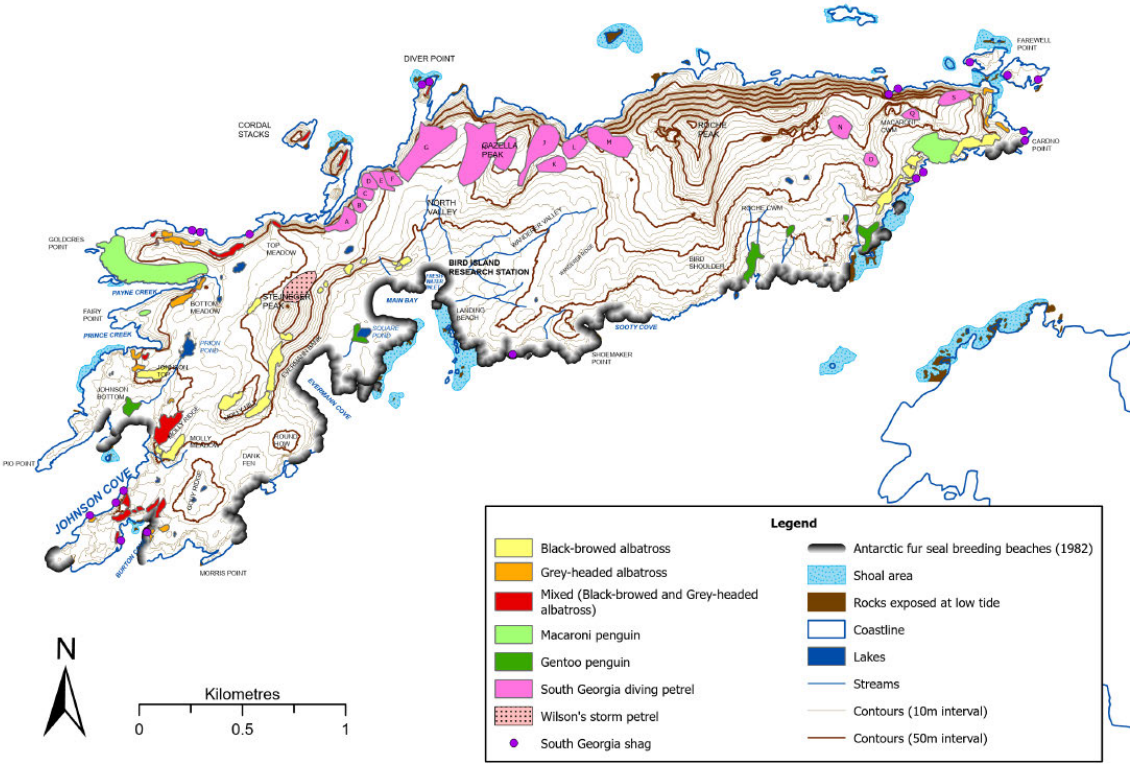

Figure 7. Distribution of mollymawks, penguins, South Georgia diving petrels, South Georgia shags and Antarctic fur seals on Bird Island based on previous land-based surveys. Colony extents for mollymawks are based on the 2014/15 survey but will now be smaller. Sarah Manthorpe will be able to provide georeferenced nest locations for the subset of mollymawk colonies at Bird Island (and elsewhere at South Georgia) which were surveyed with UAV in December 2023. Colony extents for macaroni penguins based on 1985/6-2003/4 censuses. Colony extents for gentoo penguins are based on Trathan 1999 and were processed by Herbert D (BAS) in 2007. The red dots show the location of South Georgia shag colonies, which occur along the coastline. These shag colonies will be very small.

<u>Seabird species that can be detected in 31 cm resolution satellite imagery:</u>

1. <u>Mollymawks:</u> Black-browed and grey-headed albatross colonies are usually situated in tussac on steep slopes of the mainland and offshore islands. There is some indication that black-browed and grey-headed albatrosses are visible in 30 cm satellite imagery, (**Figure 8**).

We will use texture analysis to identify the location of mollymawk colonies. To accomplish this, we will resize the image to the area of interest then use the co-occurrence measures tool (under 'filter' in ENVI GIS software) to create a texture composite consisting of three layers; homogeneity, variance and mean.

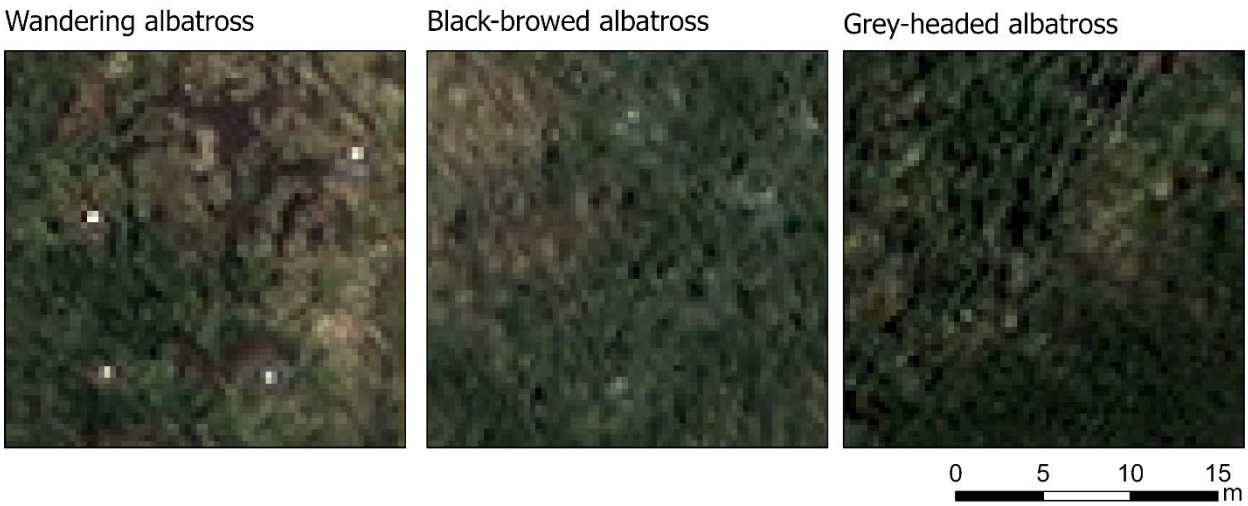

Figure 8. Example of wandering albatross, black-browed albatross and grey-headed albatross breeding areas at Bird Island in 31 cm satellite imagery captured on 28 December 2019. Individual birds are shown as bright white dots for wandering albatross. Individual black-browed albatross and grey-headed albatross appear as faded grey dots based on visual inspection of satellite imagery but will need to be confirmed through comparisons with ground-truthed data.

Seabird species that cannot be detected in 31 cm resolution satellite imagery

- **Giant petrel:** We were unable to see individual giant petrels in 31 cm satellite imagery of Bird Island; therefore, we will no longer be including giant petrels in our investigation.

- **Antarctic Prion, blue petrel and common diving petrel:** Antarctic prions often breed in tussac in same areas as white-chinned petrels. In other habitats, e.g., gravel plains at Hestesletten, Antarctic prions breed at low densities, and given the smaller volume of guano produced, the areas of enriched vegetation are small and patchily distributed (see example below in **Figure 9**). There is therefore a lower likelihood of detection using VHR imagery. Antarctic prions will therefore be excluded from the current analyses, although will potentially revisit later in the project. Same applies to blue petrels and common diving petrels, which also nest in vegetation.

Figure 9. Small area of enriched vegetation around Antarctic prion burrow at Hestesletten, South Georgia in late December 2023.

Differentiation between seabird species and seals using spectral and topographic data (Activity 3.6)

Going forward, we have decided to use satellite imagery and landscape classifications/features to attempt to distinguish between the following classes:

1) Fertilised inland tussac (likely indicating white-chinned petrel burrows)
2) Non-fertilised vegetation
3) Other green vegetation (moss or other vegetation; may be enriched by run-off from melting snow or other nutrient sources, and not necessarily from guano)
4) Mollymawk colonies
5) Fertilised coastal vegetation (from seal scats)
6) Shag colonies
7) Penguin colonies

Differentiation between these classes will be tested by extracting extents of areas based on these classes into separate polygons, then use features from each area (i.e., NDVI, slope, distance from coast, soil indices) as training data to determine if the resulting classifications are similar to what we expect. Feature extraction is the process finding and extracting specific objects of interest from VHR satellite imagery based on the object's spatial, spectral and texture characteristic.

We will attempt to use a geographic object-based image analysis (GEOBIA) approach to detect and delineate mollymawk, shag, burrowing petrel and penguin colonies (Witharana & Lynch 2016). The GEOBIA-driven methodological framework integrates spectral, textural and semantic information to extract fine-scale boundaries of seabird colonies from VHR images and closely examine the degree of transferability of knowledge-based rulesets across different study sites. All satellite images for this trial have been orthorectified, pansharpened and spatially registered to the WGS 84 datum 24S projection.

We will attempt to differentiate between shags and penguins based on:

1) Guano colour.
2) Nest density (penguins > shags).

Output 4. An archipelago-wide VHR satellite survey of wandering albatrosses, mollymawks and SG shag breeding colonies on SG using methods developed in Output 3.

We have collated data on the abundance or distribution of albatrosses, penguins and Antarctic fur seals from past surveys (Activity 4.1, **Figure 1**). Seabird presence-absence data across South Georgia are available as 5 x 5 km^2 grids in the *South Georgia: An Ecological Atlas* for all target species (i.e., wandering albatross, black-browed albatross, grey-headed albatross, southern giant petrel, northern giant petrel, South Georgia shags and white-chinned petrel) (Activity 4.2 and 4.5). This dataset is primarily based on surveys in the 1980s and 1990s. We did not include giant petrels, Antarctic prions, blue petrels, common diving petrels and Wilson's storm petrels as these species cannot be detected in 30 cm satellite imagery.

We have all tiles (image chips) and crowd counts used in the Albatrosses from Space campaign from DPLUS132 project. We intend to publish this dataset, pending approval from Maxar satellite technologies, in the same format used for past Whales from Space dataset (see https://www.nature.com/articles/s41597-022-01377-4). Within this publication, we plan to include updated AI methods for detecting wandering albatrosses across South Georgia (Activity 4.2). The approach developed will also be tested for mollymawks if individuals can be directly detected and counted. Other methodologies currently being developed as part of Activity 3.3 and 3.4 will applied across South Georgia next year, if these methods are successful in detecting seabird populations (Activity 4.2).

The 2023/24 all-islands albatross surveys were commissioned by GSGSSI (Activity 4.3), with fieldwork on wandering albatrosses led by GSGSSI and South Georgia Surveys, and on mollymawks by British Antarctic Survey. The data are being analysed by BAS. Nest locations of all wandering albatrosses and a subset of colonies of black-browed and grey-headed albatrosses will be available as ground-truthing data for our project by end July 2024, and will be used to test and validate analyses of satellite imagery (Activity 4.3).

Output 5. Dissemination and application.

We will contact all potential stakeholder representatives that would be interested in being involved to ask if they would like to attend the biannual stakeholder meetings or wish to be further involved (Activity 5.1). They will be given a link to the South Georgia seabirds from space website, outlining the project, to assist with their decision.

We intend to publish the dataset (image chips and crowd/expert annotations) from the Albatrosses from Space campaign (DPLUS132 project) through the NERC Polar Data Centre repository (see https://www.bas.ac.uk/data/uk-pdc/data-deposit/ for further information), pending approval from Maxar (Activity 5.4). This dataset will be used to further develop AI methods for wandering albatross, which if successful, will be submitted to *Scientific data* (Activity 5.2). This dataset will follow a similar format to the Whales from Space dataset and annotations for the purpose of training machine learning models (Cubaynes & Fretwell 2022).

All in-person meetings with BAS researchers have been documented (**Annex 4.1-4.3**), and these meetings will be continued monthly (Activity 5.3). Minutes from stakeholder meetings will be created and distributed to all stakeholders via email after each biannual meeting (Activity 5.3).

Marie Attard and Peter Fretwell will each be attending an international conference in August this year (SCAR, International seabird group conference and Ecological Society of America conferences) to discuss results from the Albatrosses from Space project (DPLUS132) and our current research to assess the viability of detecting other seabird species in South Georgia using satellite imagery (DPLUS187) (Activity 5.5). A summary of our results will be made available via the South Georgia seabirds from space webpage for public dissemination (Activity 5.6) as each stage of this project is published in peer-reviewed journals.

Results from our study will be of benefit to the BIOPOLE project (https://www.bas.ac.uk/project/biopole/) by identifying glacial water sources in South Georgia

that are likely to be contaminated by faecal matter (i.e., seal excrement and bird guano). Information on known seabird and seal distributions that we have collated has been passed to their project leader, and any progress on our project will be reported to them.

3.2 Progress towards project Outputs

Outputs:

1. **An assessment of whether burrowing petrels can be detected using satellite imagery based on spectral analysis of vegetation colour at Bird Island.**

Considering that the project has only been running since December 2023, we have made excellent progress. We have used most recent census data for white-chinned petrels on Bird Island to compare spectral profiles between vegetation fertilised by white-chinned petrels and seals, as well as areas where neither species have been reported. This will be repeated for white-chinned petrels on KEP using information gathered during the 2022/23 survey. As there is a risk of spectral profiles of vegetated areas occupied by seals being misidentified as burrows in satellite imagery, we will be combining spectral information with landscape characteristics (slope, distance from coastline, elevation, and aspect) as part of our feature classifications to identify areas where white-chinned petrels are likely to be present. A separate raster has been created for distance to coastline for Bird Island using a 2m DEM model. ENVI software automatically extracts the other attributes (e.g., slope, aspect) from the DEM when extracting features from the imagery. We will also be testing and comparing different algorithms and models using training datasets at the Thatcher Peninsula or Bird Island to determine which provides the best fit.

2. **An assessment of long-term changes in the distribution and densities of burrowing petrels across SG using satellite imagery.**

Good progress has been made in preparation for assessing long-term changes in burrow petrel distributions and densities using satellite imagery. The viability of using satellite imagery to detect areas of burrowing petrels is currently underway, using Bird Island and KEP as our initial study areas (see Objective 1). If successful, these methods will be expanded across SG using imagery to be tasked for the 2024/25 breeding season. In preparation for this, we have (1) collated survey data (abundance and presence-absence) for burrowing petrels around the Thatcher Peninsula, Bird Island and across SG, and (2) reviewed different options for tasking imagery for the 2024/25 breeding season.

We will be placing multiple tasking orders for large areas (>100 km^2) along the South Georgia coastline. Each order will be less than £10k to comply with BAS purchasing regulations. In addition, we plan to subscribe to MGP Pro to task smaller areas (<50 km^2) in 2024/25 and 2025/26 breeding seasons. All tasking requests for the 2024/25 breeding season will be submitted by October 2024 to allow time for processing and approval by Maxar.

3. **An assessment of whether VHR satellite imagery can be used to count mollymawks (black-browed and grey-headed albatrosses), SG shags and giant petrels, and to identify colonies of Wilsons' storm petrels and SG diving petrels at Bird Island and elsewhere at SG where ground- truthing data available.**

We have visually inspected the available satellite imagery for any signs of mollymawks in areas where they breed on Bird Island. To verify whether the grey dots in these areas are mollymawks (**Figure 7**), Sarah Manthorpe has agreed to provide mollymawk nest GPS coordinates using UAV imagery collected in December 2023. Sarah is currently annotating the data and is aiming have the data ready by May. The annotated data will be superimposed over the imagery to determine if we can see each species. As mollymawk nesting areas sometimes kill the vegetation around it (per. observations) we will also investigate whether these colonies can be identified using textural analysis.

Ellen Bowler will be investigating whether the crowd and expert annotation data of wandering albatrosses from the Albatrosses from Space campaign (funded by DPLUS132) using satellite

imagery from 2015- 2022 across South Georgia can be used as training dataset to develop automated detection methods for this species, and potentially mollymawks. This will depend on whether Maxar approves the publication of this dataset (our request is currently under consideration). The automated detection methods Ellen Bowler developed for her PhD (completed in 2023) on wandering albatrosses will be reevaluated using the larger campaign dataset. Alternative automated detection methods will be considered for development if they are more suitable.

We will investigate imagery of Bird Island to determine if there are spectral signatures of colonies of Wilson's storm petrels and SG diving petrels. This will be based on visual inspection of satellite imagery using different spectral settings. South Georgia diving petrels will be resurveyed on Bird Island if we can see them in satellite imagery. As these birds produce very small strips of guano and have a patchy distribution, there is a slight chance they can be detected in satellite imagery.

4. An archipelago-wide VHR satellite survey of wandering albatrosses, mollymawks and SG shag breeding colonies on SG using methods developed in Output 3.

Maxar provided us with all annotations and image chips (i.e., satellite images divided into a grid) of South Georgia from the Albatrosses from Space campaign (total 11,839 image chips, 150 x 150 m dimensions each with 5 m overlap) as georeferenced tiffs (700 x 700 pixels). We are requesting permission from Maxar to use the image chips to further develop AI methods to count wandering albatross. If successful, the same approach may be used for mollymawks if this species can be individually detected and counted. Texture analysis will concurrently be tested as a potential method to detect mollymawk colonies. Polygons representing mollymawk breeding areas based on recent census have been created for Bird Island.

South Georgia: An ecological atlas has presence-absence data from the 1980s for wandering albatross, mollymawks and South Georgia shag breeding colonies. We compiled South Georgia shag distributions at Bird Island and near KEP from more recent surveys. We were unable to see individual South Georgia shags in 30 cm satellite imagery on Bird Island, which may be due to their small colony size. We will investigate whether they can be detected in satellite imagery of KEP, which have larger colonies (approximately 30-40 individuals). We will also assess whether the South Georgia shag colonies can be indirectly detected based on the colour of their guano.

5. Dissemination and application.

We have held three in-person meetings with the main BAS researchers on this project (see **Annex 4.1-4.3**). To address the disconnect with stakeholders, we will be organising an in-person meeting in June with all stakeholders that regularly attend BAS Cambridge (see **Section 1 Table 1**). A hybrid stakeholder meeting will be organised shortly afterwards, where all stakeholder representatives will be invited to attend. The minutes from both meetings will be recorded and distributed via email to the partners and stakeholders.

To increase public engagement, a twitter account (@WildlifeSpace) and webpage has been created for the DPLU187 project. Results will be summarised for public dissemination on the website and through media posts upon publication in a peer-reviewed journal. Marie is presenting albatross results at the Ecological Society of America conference in August 2024. This project will be included in three conference presentations this year; the International Seabird Group conference (Portugal), SCAR (Chile) and Ecological Society of America conference (California), presented by Marie Attard and Peter Fretwell.

We are planning to publish two datasets over the coming year:

1. Existing seabird distribution/census data across South Georgia will be summarised in a spreadsheet and made available alongside any distribution data added to the SGGIS data portal (https://sggis.gov.gs//) by the end of the project.
2. We are currently preparing the Albatrosses from Space campaign dataset from DPLUS132 for the NERC Polar Data Centre repository, pending approval from Maxar.

Our intention is to reuse this dataset to develop automated detection methods for wandering albatrosses across South Georgia for the current project.

3.3 Progress towards the project Outcome

Outcome: Baseline abundance data, distribution maps, and new satellite-monitoring protocols are established for multiple species of seabirds across the entire South Georgia (SG) archipelago, improving species management and advocacy.

The first five months of the project included collating abundance and presence-absence data for all study species across South Georgia and purchasing satellite imagery to test different detection methods for multiple flying seabird species at KEP and Bird Island. Using satellite imagery, we have found support that areas with white-chinned petrel burrows have a statistically higher NDVI value compared to areas with no burrows or seals. It is not possible to differentiate between areas occupied by burrows to those occupied by seals based on spectral signatures alone, therefore spectral and landscape characteristics will be used together to create habitat maps for burrowing petrels. Visual inspection of mollymawk colony locations in satellite imagery suggest that it may be possible to detect individual birds. The proportion of individuals that can be detected is currently unknown, but will be tested using UAV imagery from December 2023, which is currently being annotated. We were unable to visually see any South Georgia shag colonies on Bird Island, most likely because these colonies are very small. We have a higher probability of detecting South Georgia shags on KEP as their colonies are larger (~30-40 individuals). We have finalised procedures to tasking satellite imagery across South Georgia for the 2024/25 breeding season to complete an island-wide census of species that can be indirectly or directly detected in satellite imagery. It is, however, too early to know whether the satellite-monitoring approaches being developed will work for mollymawks, shags and burrowing petrels for a full delivery of the outcome at this stage.

3.4 Monitoring of assumptions

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The start of the project was delayed until 1st December 2023 while we completed the DPLUS132 project, which ended on 30th November 2023. As such, the Project Implementation Timetable in the DPLUS132 application was shifted back by 6 months. As several months noticed is required for tasking imagery, tasking imagery across South Georgia was postponed until the 2024/25 breeding season.

Assumption 1: Cloud-free satellite imagery will be available in 2023/24 and 2024/25. Images will be tasked in 2025/26 for sites that require additional imagery.

Comments: As tasking was postponed until the 2024/25 and 2025/26 breeding seasons, we do not yet know if there will be cloud-free imagery available. Some cloud-free imagery is available for South Georgia, which can be purchased from the archive if additional imagery is required.

Assumption 2: Fieldwork will be undertaken at Bird Island and around KEP for ground truthing (Outputs 1 and 2).

Comments: Fieldwork was undertaken at KEP in the 2022/23 breeding season to record GPS coordinates of white-chinned petrel colonies and take photographs of the colonies at the coastline from a boat. Fieldwork is being planned to fly a UAV-mounted hyperspectral imaging system over white-chinned petrel colonies at KEP and Bird Island during the 2024/25 breeding season to use as ground truthing. The imagery will be used to calibrate satellite imagery in both locations.

Assumption 3: Stakeholders will engage with the project and attend project meetings. We are confident of strong stakeholder engagement, as this project builds on existing partnerships, and addresses a priority objective outlined by ACAP and GSGSSI. We will ensure stakeholders are consulted and involved via emails and regular meetings (hosted remotely to ensure maximum attendance).

Comments: We have formed a list of stakeholder representatives that will be contacted by email to ask if they are interested in being involved in the project or be informed of updates by attending project meetings or receiving meeting minutes. The first stakeholder hybrid meeting will be held around July, and an informal in-person meeting with a smaller number of stakeholders will be held in the first two weeks of June. We have been in regular email correspondence with Sally Poncet from South Georgia.

Assumption 4: Fieldwork will go ahead in 2023/24 and 2024/25.

Comments: Fieldwork using hand-held spectrometers is no longer needed as we will now be gathering hyperspectral imaging using a spectrometer and camera mounted to a UAV, which will be flown over a subset of white-chinned petrel colonies in KEP and Bird Island. We have discussed flying the UAV several times over the course of the breeding season to assess changes in vegetation and guano for the areas we are interested in. This will depend on whether qualified personnel will be there to fly it, and if they have time to fly the UAV more than once.

The MAGIC team at BAS have a hyperspectral camera, but we will need to check if we have a UAV capable of flying it. The UAV could be used for both the vegetation/seabird and elephant seal surveys. The equipment would need to be transported to the study sites by ship. The last acceptance date for KEP/Bird Island cargo to SCL Cambridge Warehouse is 6th September 2024.

Nathan Fenney will be flying a UAV over KEP regardless, so he may be able to fly it for us during his fieldwork. If there is a qualified pilot at Bird Island, we will investigate whether the equipment can be sent there from KEP.

Assumption 5: There will be a unique spectral signature for vegetation surrounding seabird burrows, which in combination with data on elevation, aspect and slope can be used to develop automated methods for detecting breeding areas.

Comments: We have extracted the spectral signature for vegetatin surrounding white-chinned petrel burrows, and we have a 2 m resolution DEM to extract other characteristics of these breeding areas (i.e., elevation, aspect, and slope). We will be testing different methods to detect breeding areas using this data over the next several months.

Assumption 6: High classification accuracy and reproducibility to allow burrowing petrel nesting areas to be distinguished from areas used by seals at lower elevations.

Comments: This assumption will be tested using archived satellite imagery from Bird Island and KEP this year.

Assumption 7: Existing 31cm-resolution archival imagery of Bird Island, previously purchased by BAS, will also be used. These are clear cloud-free images of the island taken during the breeding season in 2014/15, 2019/20 and 2021/22, and a 15cm-HD uplifted image in 2021/22.

Comments: Some of these images were purchased as 3 or 4 bands. The 4 band imagery can be used to create a NDVI raster using NIR1, while 8 band is needed to create an NDVI raster using NIR2. We were able to include previously purchased archived imagery with at least 4 bands. We also downloaded several satellite images while using the trial version of MGP Pro and OneAtlas.

Assumption 8: Output 1 will have been achieved, i.e., similar methodology is successful and Bird Island.

Comments: We are on schedule for completing activities for Output 1 and do not know yet if the methodology will be successful.

Assumption 9: Cloud-free imagery at potential burrowing petrel breeding sites will be obtained in 2024/25. Images will be tasked in 2025/26 for sites that require additional imagery. Cloud-free archived imagery will also be purchased.

Comments: This task has been postponed for a year due the change in the project timeline. Tasking of South Georgia, including potential burrowing petrel breeding sites, will commence in December 2024-Januaruy 2025 and December 2025-Januaruy 2026. Cloud-free archived image of KEP and Bird Island have already been purchased.

Assumption 10: Albatross census in 2023/24 will go ahead. If not, existing data will be sufficient for validation.

Comments: This assumption has been met. The 2023/24 census went ahead. A field report has been published by Sally Poncet. Figures showing abundance and distribution are being worked by Richard Phillips and Liz Mackley for publication

Assumption 11: Cloud-free imagery will be available from Bird Island and elsewhere at SG where ground- truthing data are available. A cloud-free 15cm-HD uplifted imagery of Bird Island from 2021/22 is already available.

Comments: There is one cloud-free 30 cm resolution imagery of Bird Island from the 2023/24 breeding season (cat ID: 104001008210F900, date: 6 March 2023), but was captured late in the breeding season.

Assumption 12: For SG shags and giant petrels, individuals can be detected and counted or estimated using VHR satellite imagery. Our preliminary work show that shags can be seen individually in 15cm-HD uplifted satellite imagery and differentiated from penguins by spectral colour based on diet.

Comments: This will be tested in Year 2 of this project.

Assumption 13: Mollymawks mainly breed in single-species colonies. This is correct at Bird Island.

Comments: Although mollymawks mainly breed in single-species colonies, our seabird distribution map of Bird Island (Figure 6) reveal several locations containing both mollymawk species.

Assumption 14: Texture analysis can be used to assess colony sizes of mollymawks, SG shags and giant petrels.

Comments: Texture analysis will be tested this year using known locations of mollymawks, SG shags and giant petrels that have already been collated.

Assumption 15: Spectral analysis can be used to detect guano and hence identify colonies of SG diving petrels in fine scree and Wilson's storm petrels in rocky scree.

Comments: This will be tested later this year.

Assumption 16: Shags and mollymawks are visible in 15cm-HD uplifted or 31cm-resolution imagery and AI or image analysis methods can be applied to these species. Previous studies confirm that wandering albatrosses can be counted using WV-3 imagery.

Comments: Visual inspection of satellite imagery of Bird Island suggest that mollymawks are visible as grey dots, whereas individual shags could not be detected. UAV imagery of Bird Island from December 2023 are currently being used to report the latitude and longitude of individual mollymawks. These annotations will be superimposed over the satellite images to determine whether the grey dots are mollymawks.

Assumption 17: Mollymawks mainly breed in single-species colonies at SG. Can apply species ratios from previous all-islands ground surveys to the few mixed-species colonies, or calculate trends from single-species colonies.

Comments: This will be tested in Year 2 and Year 3 of the project, in accordance with the project timeline.

Assumption 18: Crowdsourced counts of wandering albatross at SG as part of current research project (DPLUS132) using archived imagery are accurate and can be incorporated in training data. This will be confirmed using multiple observers and expert counts.

Comments: We found that the crowdsourced and expert counts of wandering albatrosses using archived satellite imagery across SG are accurate. A draft manuscript has been written, which we aim to submit for publication by July 2024. The dataset (i.e., annotations and image chips) from the campaign will be uploaded to the UK DPC repository, pending approval from Maxar. If approved, Ellen Bowler will attempt to use the image chips and annotations as training data to develop automated detection models for wandering albatross.

Assumption 19: Outputs will be discussed at relevant stakeholder meetings. The decline in populations of ACAP-listed seabirds is a recognised conservation issue for all stakeholders. As such any measures to mitigate further declines in these populations are a priority for many stakeholders, and a consideration for fisheries and management bodies.

Comments: Stakeholder meetings will be organised biannually. The first hybrid stakeholder meeting will be held in July this year, and a separate meeting with several stakeholders will be organised in-person during the first two weeks of June.

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

We are currently in the process of testing new methodologies for species for which there are few, if any data on population trends. This includes burrowing petrels, which are presumed to be expanding in distribution following the rodent and reindeer eradications. So far, we have compared spectral profiles between areas occupied by seals, white-chinned petrels and a combination of both, and have completed a survey at KEP in 2022/23 to identify white-chinned petrel colonies. Photographs have been taken showing long green vegetation where there are white-chinned petrel burrows. Distinctively greener vegetation were also found where there is run-off, which will now be taken into consideration.

This project will contribute to the ACAP Implementation Plan by providing data on seabird population status and trends, including of wandering, black-browed and grey-headed albatrosses at South Georgia, which are among nine global High-Priority populations for ACAP. To achieve this, we have requested permission from Maxar to publish the Albatrosses from Space dataset, which we plan to use to train automated detection models for detected wandering albatrosses. A similar procedure could be applied to mollymawks if we find that individuals can be detected in satellite imagery.

The methodologies currently being tested will ensure minimal disturbance to wildlife and the environment, contributing to net-zero targets by offering a low-carbon alternative to field, boat-based and aerial surveys.

5. Gender Equality and Social Inclusion (GESI)

One of the joint lead investigators for the project is female (Dr Marie Attard), as is another member of the project team from the BAS AI lab (Dr Ellie Bowler).

Please quantify the proportion of women on the Project Board[1].	50% project board (Marie Attard and Ellen Bowler)
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].	Of the partner and stakeholder group 36.4% contacted are women (Jaimie Cleeland, Jennifer Black, Sally Poncet and Sue Gregory) (see Table 1). We will report on gender balance at stakeholder meetings going forward.

GESI Scale	Description	Put X where you think your project is on the scale

[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.

Not yet sensitive	The GESI context may have been considered but the project isn't quite meeting the requirements of a 'sensitive' approach	
Sensitive	The GESI context has been considered and project activities take this into account in their design and implementation. The project addresses basic needs and vulnerabilities of women and marginalised groups and the project will not contribute to or create further inequalities.	
Empowering	The project has all the characteristics of a 'sensitive' approach whilst also increasing equal access to assets, resources and capabilities for women and marginalised groups	X
Transformative	The project has all the characteristics of an 'empowering' approach whilst also addressing unequal power relationships and seeking institutional and societal change	

The project team recognise the importance of diversity of experts with respect to age, gender, cultural background, education and specialism in providing a range of perspectives, including incorporation of local knowledge, and experience necessary for carrying out the project plan. We have an equal proportion of men to women on the project board, including an early-career researcher (Ellen [redacted]), mid-career researcher (Marie [redacted]) and two individuals that lead research groups (Peter [redacted] and Richard [redacted]).

We have been ensuring that people have enough time to prepare for meetings and will be circulating outline agendas in advance of stakeholder meetings and inviting additional items to include. We will be seeking feedback from project partners and stakeholders during these meetings and reviewing the responses within the context of social inclusion. Those that wish to contribute further to the project will be given opportunities for further involvement. Resources produced from this project, such as the species habitat models and distribution data, will be shared on the SGGIS data portal (https://sggis.gov.gs//) and/or on the NERC Polar Data Centre repository (https://www.bas.ac.uk/data/uk-pdc/data-deposit/), providing easily accessible datasets for governments, NGOs and scientific communities to view, download and use.

6. Monitoring and evaluation

Regular project monitoring has so far been conducting through monthly meetings with the named BAS researchers on the project (Peter [redacted], Marie [redacted], Richard [redacted], and Ellen [redacted]) and bimonthly in-person meetings between Peter [redacted] and Marie [redacted]. This will be continued throughout the project. The achievement of milestones has been regularly checked against the 'Implementation Timetable' during these meetings. All our indicators were selected on the basis that they were SMART (specific, measurable, achievable, relevant and time-bound). Part of the monitoring is also the biannual stakeholder meetings which will be held in-person and on zoom. These meetings will start in July this year and stakeholders will receive the minutes of each meeting and presentation slides. Prior to this, we will also be holding an in-person meeting with stakeholders that are able to attend the BAS office in Cambridge. The activities conducted within individual outputs are expected to impact to a considerable degree on the ability to conduct subsequent outputs with regards to whether methodologies (texture analysis, spectral analysis and automated detection methods) are able to detect breeding colonies of each seabird species under investigation. By the end of the project, the team will evaluate the overall effectiveness of applying satellite remote sensing for monitoring each flying seabird species across South Georgia. This will mainly be evidenced by publications in peer-reviewed journals and work reports. We will also discuss with stakeholders a forward work plan to integrate these methods at South Georgia and potentially other areas beyond the life of the current project.

7. Lessons learnt

1. Our initial visual examination of 31 cm resolution satellite imagery suggests that giant petrels, Antarctic prions, blue petrels and common diving petrels cannot be detected. This will be confirmed using different spectral bands.

2. The spectral profile for areas surrounding white-chinned petrel burrows is significantly different to areas containing no seals or petrels. As there is some overlap in spectral profiles in areas where seals are present, we will test whether burrows can be distinguished from seal haul-out areas based on geographical parameters (i.e., slope, elevation and distance from coastline) and soil (patchy bare ground for seals versus homogenous vegetation for burrowing petrels).

3. There are grey dots present in satellite imagery for areas containing mollymawks on Bird Island. We will confirm whether these grey dots are individual birds using annotations from UAV surveys collected in December 2023.

4. We cannot directly detect small colonies of South Georgia shags on Bird Island. We will test whether larger South Georgia colonies are visible at KEP, and if they could be located based on the colour of their guano.

5. Maxar's online platform MGP Pro is ideal for tasking smaller areas (<50 km^2) and purchasing archival satellite imagery less than 25 km^2 but does not include an educational discount.

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

Non-applicable

9. Risk Management

No new risks have arisen in the last 12 months, therefore no significant adaptations to the project design have been made this year to address risk.

10. Sustainability and legacy

The first 5 months of the project have been focused on gathering available abundance and distribution data, and satellite imagery to carry out this year's project objectives. Biannual meetings (starting July 2024) and updates on the project website will be used to generate interest with the UKOTs involved in the project. The value of the project has been recognised by participants during the development of the grant application, with acknowledgement of the need for baseline information on seabird populations to underpin decision-making. Their feedback will be requested and incorporated into analysis to ensure engagement with the project outcomes. Attendance at the meetings will be used as evidence of the interest in the project.

This work builds on existing links with key stakeholders from Darwin Plus project DPLUS132, which focused on satellite surveys of wandering albatross on Sough Georgia using citizen science. In our current project, we are developing a methodological framework that can readily be applied to other islands in the Southern Ocean. The intended sustainability benefits post-project are still valid as remote sensing may provide a non-invasive and cost-effective way to monitor seabirds over large areas and remote island groups. At the end of the project, when we have robust results, we will discuss options with RSPB, SGHT and GSGSSI for setting up long-term satellite monitoring for selected species and sites.

11. Darwin Plus identity

The Darwin Initiative logo was incorporated into the South Georgia seabirds from space webpage on the BAS website and will be used at conferences and presentations. We have created a X (twitter) account (@WildlifeSpace) for this project.

12. Safeguarding

Has your Safeguarding Policy been updated in the past 12 months?		Yes
Have any concerns been investigated in the past 12 months		Yes
Does your project have a Safeguarding focal point?	*Yes we have a safeguarding lead across BAS plus a Health and Wellbeing Manager who will work with the safeguarding lead*	
Has the focal point attended any formal training in the last 12 months?	*Yes the lead has attended a formal training session on her role and responsibilities as safeguarding lead*	
What proportion (and number) of project staff have received formal training on Safeguarding?		Past: % [and number] Planned: % [and number] *30% of our total staff have been trained. They are primarily staff living and working on a research vessel and their managers. More training is planned this year.*
Has there been any lessons learnt or challenges on Safeguarding in the past 12 months? Please ensure no sensitive data is included within responses. *The most challenging part continues to be developing a clear understanding of safeguarding and who it affected. We do not employ staff working with children, however many of our staff live and work in isolated environments and under challenging conditions. These make them more vulnerable than others.*		
Does the project have any developments or activities planned around Safeguarding in the coming 12 months? If so please specify. *More training across all BAS personnel is planned this year.*		

13. Project expenditure

Table 1: Project expenditure during the reporting period (1 April 2023 – 31 March 2024)

Project spend (indicative) in this financial year	2023/24 D+ Grant (£)	2024/25 Total actual D+ Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs	[redacted]			Actual salary costs were higher; capped to budget
Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items				
Others (Please specify)				
TOTAL	£49,403.48	£48,775.61		

Table 2: Project mobilised or matched funding during the reporting period (1 April 2023 – 31 March 2024)

	Secured to date	Expected by end of project	Sources
Matched funding leveraged by the partners to deliver the project (£)	[redacted]		
Total additional finance mobilised for new activities occurring outside of the project, building on evidence, best practices and the project (£)			

14. Other comments on progress not covered elsewhere

15. OPTIONAL: Outstanding achievements or progress of your project so far (300-400 words maximum). This section may be used for publicity purposes.

I agree for the Biodiversity Challenge Funds to edit and use the following for various promotional purposes (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 including description, country and credit	Social media accounts and websites 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: Report of progress and achievements against logframe for Financial Year 2023-2024

Project summary	Progress and Achievements April 2023 - March 2024	Actions required/planned for next period
Impact New methodologies enable cost-effective, long-term satellite remote sensing of population status and trends of albatrosses, petrels and shags at South Georgia, leading to informed conservation actions.	Collation of seal, seabird and rodent distribution underway. Satellite remote-sensing methodologies currently being developed for albatrosses, petrels and shags at South Georgia.	[redacted]
Outcome Baseline abundance data, distribution maps, and new satellite-monitoring protocols are established for multiple species of seabirds across the entire South Georgia (SG) archipelago, improving species management and advocacy.		
0.1 Counts from VHR satellite imagery provide specific abundance estimates for multiple seabirds across the entire SG archipelago by the project end date.	0.1 Not yet started. We started trialling different methods outlined in section 3.1 to verify if VHR satellite imagery can be used to detect and estimate the abundance of different seabird species on Bird Island and KEP.	0.1 Use spectral and landscape characteristics for burrowing petrel breeding areas, and texture analysis of mollymawks and SG shags to test the viability of these methods in detecting colonies in Bird Island and KEP. Use different spectral bands to determine if Antarctic Prion, blue petrel and common diving petrel colonies are visible in satellite imagery.

0.2 By combining spectral classification of vegetation colour and habitat characteristics, maps of areas occupied by burrowing petrels at high densities will be available for the entire SG archipelago by the project end date.	0.2 Ongoing. Compared spectral profiles vegetation in areas with and without burrowing petrels and/or seals on Bird Island (evidence provided in **Figure 4** and **5** in section 3.1).	0.2 Different algorithms and image detection methods (e.g., rule based feature extraction, random forest) will be used to determine if known burrows can be identified on KEP and Bird Island using landscape information including (1) NDVI from 30 cm resolution satellite image to classify vegetation colour, and (2) slope, elevation, and distance from shore from a 2 m resolution DEM representing habitat characteristics. A portion of known breeding areas at the study sites will be used as the training dataset.
0.3 New satellite remote-sensing methods will be developed and assessed for each seabird species. Data and methods will be published to ensure long-term uptake and facilitate use elsewhere.	0.3 Ongoing - started testing satellite remote-sensing methods for each seabird species.	0.3 Complete trials of different satellite remote-sensing methods for each seabird species on KEP and Bird Island.
0.4 Engagement with stakeholders (GSGSSI, ACAP, SGHT and RSPB) throughout the project will lead to a commitment to improve the frequency and coverage of seabird population surveys on SG using satellite remote-sensing.	0.4 Ongoing. Regular discussions via email with Sally Poncet from GSGSSI, who has provided past census data for mollymawks. Drafted list of stakeholder representatives to contact to ask if they would like to be informed of the project's progress and/or be involved in stakeholder meetings.	0.4 Contact all stakeholder representatives to ask what degree they wish to be involved and hold biannual stakeholder meetings in person and on zoom.
Output 1 An assessment of whether burrowing petrels can be detected using satellite imagery based on spectral analysis of vegetation colour at Bird Island.		
Output indicator 1.1 Existing information on burrowing petrel distribution and abundance collated from previous surveys at Bird Island during Y1Q1/2, supplemented by new data collection in December 2023/ January 2024.	1.1 Completed. Collated existing raw data on burrowing petrel distribution and abundance at Bird Island (from 2015/16 census) and KEP (from 2022/23 census). Richard Phillips photographed burrowing areas at KEP from a boat during the 2023/24 season (**Annex 4.6**) to improve accuracy of distribution maps.	1.1 Use collated data to develop habitat models at Bird Island and KEP to detect burrowing petrels (see Output 1.4). Create spreadsheet with sources of all known surveys/censuses for

	Contacted Simon Berrow (corresponding author of Berrow *et al.* 2000 - see doi:10.1017/S0954102000000468) in February 2024 to request raw burrow petrel Bird Island census data from 1995/96, 1996/97 and 1997/98 seasons. After a thorough search for his fieldwork notes and spreadsheets, Simon informed us that the raw census data had been lost. Andy Wood informed us that the data was not stored at BAS. As such, all seal and burrow locations in Figure 2 and 4 in Berrow *et al.* 2000 were georeferenced to provide approximate locations of burrows from those years (**Figure S4**). These marked locations were useful as a general guide, and confirm that burrow locations are relatively similar to the 2015/16 census data. The earliest burrowing petrel survey on Bird Island was conducted in 1982, but the location of each survey quadrat was not reported so cannot be used for this project.	white-chinned petrels at South Georgia.
Output indicator 1.2 Measurements recording spectral profiles of vegetation in areas occupied by different species of burrowing petrels are collected on Bird Island using hand-held spectrometers in December 2023 to March 2024.	1.2 Planning fieldwork. The team decided that obtaining hyperspectral imagery using a UAV flown over burrowing petrel breeding areas at KEP and Bird Island would be better for validation than using a hand-held spectrometer (**Annex 4.3**). We have started making plans for using a UAV during the 2024/25 field season on Bird Island and/or KEP.	1.2 Complete spectral profile measurements of vegetation adjacent to occupied and unoccupied petrel burrows based on UAV imagery collected from Bird Island and/or KEP from December 2024-March 2025.
Output indicator 1.3 Hand-held spectrometer data compared with online spectral libraries to determine if they produce a noticeable difference in reflectance by Y2Q1.	1.3 Ongoing. We have purchased a licence of ENVI, which contains online spectral libraries to compare with spectrometer data to be collected in 2024/25 field season using an UAV with a mounted camera and spectrometer.	1.3 Compare spectral profile measurements of vegetation adjacent to occupied and unoccupied petrel burrows on Bird Island to online spectral libraries based on data collected using a UAV with a mounted camera and spectrometer.
Output indicator 1.4 Geographic object-based analysis (GEOBIA) methods are developed to identify petrel breeding areas on Bird Island by classifying bright green vegetation (resulting from improved growth because of the nutrients in the guano) by Y2Q2.	1.4 Ongoing – recently started applying GEOBIA methods to burrowing petrel breeding areas.	1.4 Finalise development of GEOBIA methods to identify white-chinned petrel breeding areas on Bird Island and KEP by classifying bright green vegetation.

Output 2. An assessment of long-term changes in the distribution and densities of burrowing petrels across SG using satellite imagery.		
Output indicator 2.1. VHR satellite imagery of the entire SG archipelago tasked for December 2024/ January 25. Imagery successfully obtained and purchased by end of Y2.	2.1 Ongoing. Assessed trial versions of Maxar and Airbus online platforms to task imagery. Determined that tasking imagery using offline ordering is more economic for larger areas (>100 km^2), and that MGP pro would be used to task smaller (<50 km^2) areas.	2.1 The entire SG archipelago will be tasked from December 2024 to January 2025 and purchased before the next annual report. The South Georgia coastline will be divided into at least 5 polygons and ordered as separate tasking orders to keep each payment under £10k each. In addition, £10k will be added to the MGP pro platform to task smaller areas over a 2+ year subscription.
Output indicator 2.2 Habitat suitability models incorporating elevation, slope and aspect are produced, to highlight areas of SG away from Bird Island that may be suitable for nesting by burrowing petrels by Y2Q2.	2.2 Ongoing. We used 2 m resolution DEM of South Georgia (downloaded from REMA) to extract elevation, slope and aspect of burrowing petrel areas at Bird Island. Distance to coastline will be incorporated into habitat suitability models to help differentiate burrowing petrel breeding areas from seal haul out sites.	2.3 Habitat suitability models developed and trailed using known locations of burrowing petrels at KEP and Bird Island.
Output indicator 2.3 Methods validated at other sites on SG based on existing knowledge of burrowing petrel distribution at KEP and elsewhere, and new survey data collected during 2023/24	2.3 Ongoing. We purchased 8 band 30 cm resolution satellite images purchased for KEP and Bird Island from Maxar's archive to validate methods. Existing knowledge of burrowing petrel distribution at South Georgia from *South Georgia: An Ecological Atlas*. New survey data collected at KEP from 2022-23 survey – evidence provided in **Figure 3**, **Annex 4.5** and **Annex 4.6**.	2.3 Methods validated using satellite imagery from KEP and Bird Island using existing knowledge of burrowing petrel distribution at these locations.
Output indicator 2.4 Habitat models applied across SG using tasked VHR imagery to map distribution of burrowing petrels at high densities by Y3Q1.	2.4 Not yet started. Habitat models currently being developed for Bird Island and KEP to see they can be used to detect burrowing petrels using purchased satellite imagery.	2.4 Determine whether habitat models can adequately detect burrowing petrels on Bird Island and KEP. If successful, this will be applied across SG after tasked images from the 2024/25 season are purchased.

Output indicator 2.5 Comparison of distributions of burrowing petrels in VHR imagery with presence-absence at 5km-scale across SG mapped in the 1980s [17] by Y3Q3.	2.5 Ongoing. The 5km-scale presence-absence data from the 1985-87 census has been requested from the BAS archive team. Completion of this output indicator pending successful development of satellite remote-sensing methods to locate burrowing petrel breeding areas.	2.5 Burrowing petrel distributions will be assessed using VHR satellite imagery across South Georgia by Y3Q3 if the methods developed are successful.
Output indicator 2.6 Habitat models made available on open access portals and results disseminated at conferences, through peer- reviewed papers and media outreach by project end date.	2.6 Not yet started.	2.6 Habitat models are currently being developed for Bird Island and King Edward Point, and will be applied across South Georgia next year, if successful.
Output 3. An assessment of whether VHR satellite imagery can be used to count mollymawks (black-browed and grey-headed albatrosses), SG shags and giant petrels, and to identify colonies of Wilsons' storm petrels and SG diving petrels at Bird Island and elsewhere at SG where ground- truthing data available.		
Output indicator 3.1 VHR satellite imagery of Bird Island and elsewhere at SG where colony locations are known, supplemented by new imagery collected in December 2023/ January 2024.	3.1 Ongoing. Archived VHR satellite imagery has been purchased for Bird Island and King Edward Point. This will be supplemented by new imagery collected in December 2024/January 2025.	3.1 Complete tasking of South Georgia to purchase 8 band 30 cm satellite imagery by April 2024.
Output indicator 3.2 Satellite images of breeding areas for each species are assessed and annotated by experts, and results compared with known distributions by Y2Q2.	3.2 Ongoing. UAV imagery collected in December 2023 at Bird Island.	3.2 Sarah Manthorpe will provide georeferenced nest locations for the subset of mollymawk colonies at Bird Island (and elsewhere at South Georgia) which were surveyed with UAV in December 2023. Data will be superimposed over satellite imagery to determine whether nesting mollymawks can be detected and accurately counted by Y2Q2.
Output indicator 3.3 For each species which is detectable as individual birds, expert annotations will be used to develop and compare different automated detection methods (e.g., spectral classification, texture analysis, CNNs) by end of Y2.	3.2 Ongoing. The vegetations surrounding burrows of white-chinned petrels are much greener (**Annex 4.6**) and has a significantly different NDVI values compared to areas containing no seals or burrows (**Figure 4 and 5**).	3.2 Wandering albatrosses can be detected as individual birds, and AI methods will be further developed using crowd annotations from the Albatrosses.

Output indicator 3.4 For each species which are detectable, but resolution restricts accurate counting, the feasibility of different approaches (e.g., spectral classification, texture analysis, CNNs) will be assessed by end of Y2. Texture analysis will be used on mollymawks, SG shags and giant petrels. Spectral analysis will be used to detect guano from SG diving petrels in fine scree and Wilson's storm petrels in rocky scree.	3.2 Ongoing. Visual inspection of satellite images reveal penguin colonies. South Georgia shag individuals cannot be visually detected at Bird Island, possibly due to small colony size. Individual mollymawks may be detectable based on visual inspection of imagery, awaiting confirmation based on recently collected UAV imagery from December 2023.	3.2 Texture analysis will be tested for the detection of penguin and South Georgia shag colonies at Bird Island and King Edward Point, and a combination of spectral and landscape classifications will be tested for white-chinned petrels by the end of Y2.
Output 4. An archipelago-wide VHR satellite survey of wandering albatrosses, mollymawks and SG shag breeding colonies on SG using methods developed in Output 3.		
Output indicator 4.1 VHR satellite imagery of the entire SG archipelago tasked for December 2024/ January 2025.	4.1 Preparing to task imagery. Online satellite imagery ordering platforms (MGP Pro and One Atlas) were trialled. Standard offline ordering through Maxar will be used to task larger areas (>100km^2) and MGP Pro will be used to task smaller areas (<50km^2). This is the most cost-effective option for tasking VHR satellite imagery of the entire SG archipelago.	4.1 Submit tasking request to Maxar of the entire SG archipelago by October 2024 for tasking window starting December 2025 to end of January 2025. Purchase cloud-free imagery once tasked imagery becomes available.
Output indicator 4.2 Collate data on abundance and distribution of target species across SG archipelago by Y1Q3.	4.2 Ongoing. Presence-absence 5km-scale data across SG archipelago for all target species in *South Georgia: An ecological Atlas*. The data has been requested from the BAS Archive team. This will be supplemented by more recent species abundance and distribution across SG archipelago.	4.2 Update collated data with 2023/24 SG census data for wandering albatrosses and mollymawks when it becomes publicly available. Create spreadsheet listing sources of data for all target species.
Output indicator 4.3 For species which can be counted individually, use methods developed in output 3.3 to count species across SG by Y3Q2.	4.3 Ongoing. Wandering albatrosses can be counted individuals. Mollymawks in UAV imagery currently being annotated by Sarah Manthorpe from the biological sciences data management team at BAS to use for ground-truthing.	4.3 Provide further validation for species that can be counted individually.
Output indicator 4.4 For species which can be detected indirectly (e.g through detection of guano), use methods developed in output 3.4 to count species across SG by Y3Q2	4.4 Ongoing. We determined that SG shags cannot be counted individually, therefore we will test whether their guano at SG shag colonies can be detected and differentiated from penguin guano in VHR satellite imagery.	4.4 Confirm whether SG shag and penguin colonies can be detected indirectly through detection of guano, using imagery of Bird Island and KEP.

Output indicator 4.5 Validate all island survey results using known distribution data and 2023/2024 all-island albatross census, by Y3Q3.	4.5 Ongoing. SG albatross census completed by South Georgia Surveys during 2023/24, and field report for wandering albatross census results produced by Sally Poncet (**Annex 4.7**). Figures showing abundance and distribution are being worked by Richard Phillips and Liz Mackley for publication.	4.5 Task and purchase VHR satellite imagery across SG to compare with ground-truth data.
Output indicator 4.6 Results and data from the satellite surveys published and made open source by project end date.	4.6 Not yet started. Satellite imagery purchased for Bird Island and KEP to validate methods (**Table 1, Figure S1** & **Figure S2**).	4.6 Task and purchase VHR satellite imagery across SG to compare with ground-truth data.
Output 5. Dissemination and application.		
Output indicator 5.1 Results and recommendations shared with stakeholders to inform their conservation and management frameworks, shared throughout the project at stakeholder meetings and summarised at end of project meeting.	5.1 Ongoing. Created list of stakeholder representatives to ask for their preference for level of involvement (see section 2 for details).	5.1 Stakeholder meetings will be arranged for July and December this year. Additional meetings with individual stakeholders will be arranged where needed.
Output indicator 5.2 Data deposited in global databases by project end date.	5.2 Not yet started. Data is being collated on abundance and distribution of target species across SG archipelago and will be included in a data repository by the project end date.	5.2 Annotated data from satellite imagery will be produced for target species that can be detected directly or indirectly.
Output indicator 5.3 Communication of results at two international conferences during Y2 and Y3.	5.3 Ongoing. Marie Attard is presenting a talk on albatross detection in satellite imagery at the Ecological Society of America in California, August 2024. Peter Fretwell submitted abstract for an oral presentation at SCAR in Chile, August 2024 and the International Seabird Group conference in Portugal, September 2024.	5.3 We will present preliminary results at three international conferences this year. Abstracts for oral presentations will be submitted for at least one international conference in 2025.

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

Project summary	SMART Indicators	Means of verification	Important Assumptions
Impact: New methodologies enable cost-effective, long-term satellite remote sensing of population status and trends of albatrosses, petrels and shags at South Georgia, leading to informed conservation actions.			

Project summary	SMART Indicators	Means of verification	Important Assumptions
Outcome: Baseline abundance data, distribution maps, and new satellite-monitoring protocols are established for multiple species of seabirds across the entire South Georgia (SG) archipelago, improving species management and advocacy.	0.1 Counts from VHR satellite imagery provide specific abundance estimates for multiple seabirds across the entire SG archipelago by the project end date. 0.2 By combining spectral classification of vegetation colour and habitat characteristics, maps of areas occupied by burrowing petrels at high densities will be available for the entire SG archipelago by the project end date. 0.3 New satellite remote-sensing methods will be developed and assessed for each seabird species. Data and methods will be published to ensure long-term uptake and facilitate use elsewhere. 0.4 Engagement with stakeholders (GSGSSI, ACAP, SGHT and RSPB) throughout the project will lead to a commitment to improve the frequency and coverage of seabird population surveys on SG using satellite remote-sensing.	0.1 Data on counts of species in satellite images; results published in peer-reviewed journal; data added to open access portal (e.g. GBIF https://www.gbif.org/). 0.2 Maps added as layers to interactive SG map (https://www.sggis.gov.gs/); results published in peer-reviewed journal. 0.3 Data made open access; methods written up in peer- reviewed journal; code published on open-source repository; independent meeting reports will mention the results of the project and commitment to future satellite surveys. 0.4 Stakeholder meeting minutes and reports; report text to include next steps for updated management recommendations based on new abundance and distribution data.	Cloud-free satellite imagery will be available in 2023/24 and 2024/25. Images will be tasked in 2025/26 for sites that require additional imagery. Fieldwork will be undertaken at Bird Island and around KEP for ground truthing (Outputs 1 and 2). Stakeholders will engage with the project and attend project meetings. We are confident of strong stakeholder engagement, as this project builds on existing partnerships, and addresses a priority objective outlined by ACAP and GSGSSI. We will ensure stakeholders are consulted and involved via emails and regular meetings (hosted remotely to ensure maximum attendance).
Output 1 An assessment of whether burrowing petrels can be detected using satellite imagery based on spectral analysis of vegetation colour at Bird Island.	1.1 Existing information on burrowing petrel distribution and abundance collated from previous surveys at Bird Island during Y1Q1/2, supplemented by new data collection in December 2023/ January 2024. 1.2 Measurements recording spectral profiles of vegetation in areas occupied by different species of burrowing petrels are collected on Bird Island using hand-held	1.1 Literature review and list of data sources; maps showing distribution based on current data. 1.2 Data from hand-held spectrometers; correspondence with field researchers on Bird Island. 1.3 Data files containing spectral readings of vegetation; plots comparing spectral signatures.	Fieldwork will go ahead in 2023/24 and 2024/25. There will be a unique spectral signature for vegetation surrounding seabird burrows, which in combination with data on elevation, aspect and slope can be used to develop automated methods for detecting breeding areas. High classification accuracy and

Project summary	SMART Indicators	Means of verification	Important Assumptions
	spectrometers in December 2023 to March 2024. 1.3 Hand-held spectrometer data compared with online spectral libraries to determine if they produce a noticeable difference in reflectance by Y2Q1. 1.4 Geographic object-based analysis (GEOBIA) methods are developed to identify petrel breeding areas on Bird Island by classifying bright green vegetation (resulting from improved growth because of the nutrients in the guano) by Y2Q2.	1.4 Algorithm results assessed using test images; consult expert opinion and peer review process; publication of manuscript detailing the methods and results of study.	reproducibility to allow burrowing petrel nesting areas to be distinguished from areas used by seals at lower elevations. Existing 31cm-resolution archival imagery of Bird Island, previously purchased by BAS, will also be used. These are clear cloud-free images of the island taken during the breeding season in 2014/15, 2019/20 and 2021/22, and a 15cm-HD uplifted image in 2021/22.
Output 2 An assessment of long-term changes in the distribution and densities of burrowing petrels across SG using satellite imagery.	2.1 VHR satellite imagery of the entire SG archipelago tasked for December 2024/ January 25. Imagery successfully obtained and purchased by end of Y2. 2.2 Habitat suitability models incorporating elevation, slope and aspect are produced, to highlight areas of SG away from Bird Island that may be suitable for nesting by burrowing petrels by Y2Q2. 2.3 Methods validated at other sites on SG based on existing knowledge of burrowing petrel distribution at KEP and elsewhere, and new survey data collected during 2023/24 albatross census. 2.4 Habitat models applied across SG using tasked VHR imagery to map distribution of burrowing petrels at high	2.1 and 2.2 List of archival images compiled and downloaded; models produced; baseline data assessed by experts. 2.2 to 2.4 Map showing distribution; verified at ground survey locations; results assessed by experts.. 2.5 Map data showing the 1980s presence-absence survey; satellite derived map data; comparison statistics; peer review from stakeholders. 2.6 Published papers; conference proceedings; data visible and available to download on open access sites.	Output 1 will have been achieved, i.e., similar methodology is successful at Bird Island. Cloud-free imagery at potential burrowing petrel breeding sites will be obtained in 2024/25. Images will be tasked in 2025/26 for sites that require additional imagery. Cloud-free archived imagery will also be purchased. Albatross census in 2023/24 will go ahead. If not, existing data will be sufficient for validation.

Project summary	SMART Indicators	Means of verification	Important Assumptions
	densities by Y3Q1. 2.5 Comparison of distributions of burrowing petrels in VHR imagery with presence-absence at 5km-scale across SG mapped in the 1980s [17] by Y3Q3. 2.6 Habitat models made available on open access portals and results disseminated at conferences, through peer-reviewed papers and media outreach by project end date.		
Output 3 An assessment of whether VHR satellite imagery can be used to count mollymawks (black-browed and grey-headed albatrosses), SG shags and giant petrels, and to identify colonies of Wilsons' storm petrels and SG diving petrels at Bird Island and elsewhere at SG where ground- truthing data available.	3.1 VHR satellite imagery of Bird Island and elsewhere at SG where colony locations are known, supplemented by new imagery collected in December 2023/ January 2024. 3.2 Satellite images of breeding areas for each species are assessed and annotated by experts, and results compared with known distributionsby Y2Q2. 3.3 For each species which is detectable as individual birds, expert annotations will be used to develop and compare different automated detection methods (e.g. spectral classification, texture analysis, CNNs) by end of Y2. 3.4 For each species which are detectable, but resolution restricts accurate counting, the feasibility of different approaches (e.g., spectral classification, texture analysis, CNNs) will be assessedby end of Y2.	3.1 Images downloaded from Maxar; image quality verified by experts. 3.2 Scientists receive image data; digitized annotation files (point markers and polygons);analysis comparing satellite and ground counts 3.3 and 3.4 Automated method results assessed using test data; consult expert opinion and peer review; publication of results.	Cloud-free imagery will be available from Bird Island and elsewhere at SG where ground- truthing data are available. A cloud-free 15cm-HD uplifted imagery of Bird Island from 2021/22 is already available. For SG shags and giant petrels, individuals can be detected and counted or estimated using VHR satellite imagery. Our preliminary work show that shags can be seen individually in 15cm-HD uplifted satellite imagery and differentiated from penguins by spectral colour based on diet. Mollymawks mainly breed in single-species colonies. This is correct at Bird Island. Texture analysis can be used to assess colony sizes of mollymawks, SG shags and giant petrels. Spectral analysis can be used to detect guano and hence identify colonies of SG diving petrels in fine scree and

Project summary	SMART Indicators	Means of verification	Important Assumptions
	Texture analysis will be used on mollymawks, SG shags and giant petrels. Spectral analysis will be used to detect guano from SG diving petrels in fine scree and Wilson's storm petrels in rocky scree.		Wilson's storm petrels in rocky scree.
Output 4 An archipelago-wide VHR satellite survey of wandering albatrosses, mollymawks and SG shag breeding colonies on SG using methods developed in Output 3.	4.1 VHR satellite imagery of the entire SG archipelago tasked for December 2024/ January 2025. 4.2 Collate data on abundance and distribution of target species across SG archipelago by Y1Q3. 4.3 For species which can be counted individually, use methods developed in output 3.3 to count species across SG by Y3Q2.. 4.4 For species which can be detected indirectly (e.g through detection of guano), use methods developed in output 3.4 to count species across SG by Y3Q2 4.5 Validate all island survey results using known distribution data and 2023/2024 all-island albatross census, by Y3Q3. 4.6 Results and data from the satellite surveys published and made open source by project end date.	4.1 List of purchased imagery; images checked and verified by experts; results of past surveys shared with project team. 4.2 Data showing distribution information; literature review; correspondence with SG research groups 4.4 and 4.5 Results assessed on test images; statistics showing accuracy for each species; report and publish estimated population counts. 4.6 Share point shapefiles (identifying location of each individual bird) and satellite image IDs on open access portals and digital repositories; add data to SGGIS.	Shags and mollymawks are visible in 15cm-HD uplifted or 31cm-resolution imagery and AI or image analysis methods can be applied to these species. Previous studies confirm that wandering albatrosses can be counted using WV-3 imagery. Mollymawks mainly breed in single-species colonies at SG. Can apply species ratios from previous all-islands ground surveys to the few mixed-species colonies, or calculate trends from single-species colonies. Crowdsourced counts of wandering albatross at SG as part of current research project (DPLUS132) using archived imagery are accurate and can be incorporated in training data. This will be confirmed using multiple observers and expert counts.
Output 5 Dissemination and application.	5.1 Results and recommendations shared with stakeholders to inform their conservation and management frameworks, shared throughout the project at stakeholder meetings and summarised at end of project meeting.	5.1 Text from independent meeting reports, and meeting minutes will discuss the results and plants to implement changes to management frameworks; a paper detailing results will be	Outputs will be discussed at relevant stakeholder meetings. The decline in populations of ACAP-listed seabirds is a recognised conservation issue for all stakeholders. As such any measures to mitigate further declines in these

Project summary	SMART Indicators	Means of verification	Important Assumptions
	5.2 Data deposited in global databases by project end date. 5.3 Communication of results at two international conferences during Y2 and Y3.	submitted to working group meetings of ACAP and CCAMLR. 5.2 Datasets made available online in SGGIS. 5.3 Abstracts presented in conference programs; results published in peer-reviewed journals.	populations are a priority for many stakeholders, and a consideration for fisheries management bodies.

Activities

1.1 Collate existing data on burrowing petrel distribution and abundance at Bird Island.
1.2 Organise collection of new data on burrowing petrel distribution and abundance at Bird Island.
1.3 (and 3.2) Task 31-cm image of Bird Island for December 2023.
1.4 Arrange measurements of within-season changes in spectral profiles of vegetation in areas occupied by different species of burrowing petrels at Bird Island using hand-held spectrometer.
1.5 Model relationships between spectral profiles from hand-held spectrometer and satellite imagery, and breeding- habitat preferences to predict presence/absence and relative abundance of burrowing petrels at Bird Island.

2.1 Collate existing data on burrowing petrel distribution and abundance across SG.
2.2 Organise collection of presence-absence data of burrowing petrels in habitat around KEP, and in 2023/24 all-islands albatross census.
2.3 (and 4.2) Task collection of VHR satellite imagery of the entire SG archipelago for December 2024 - January 2025 window.
2.4 Produce habitat suitability models using elevation, slope and aspect to highlight suitable burrowing petrel nesting areas
2.5 Purchase tasked VHR satellite imagery of SG archipelago
2.6 Apply models using relationships between spectral profiles in satellite imagery, and breeding-habitat preferences (developed in Output 1), to predict presence/absence and relative abundance of burrowing petrels across SG.
2.7 Validate distribution models for areas away from Bird Island using available ground-truthing data from elsewhere at South Georgia.
2.8 Compare predicted distributions with presence-absence at 5km-scale across SG mapped in the 1980s.

3.1 Collate data on abundance or distribution of mollymawks, SG shags, giant petrels, Wilsons' storm petrels and SG diving petrels at Bird Island.
3.2 (See activity 1.3)
3.3 VHR satellite images assessed for presence of each species by experts. Annotations of seabird species are produced either as point markers on individuals, or polygons outlining presence and extent.

Project summary	SMART Indicators	Means of verification	Important Assumptions
3.4 Compare expert annotations to ground and UAV survey data to validate results 3.5 For species which are detectable as individual birds (potentially mollymawks, SG shags and giant petrels), use expert annotations to develop automated detection methods 3.6 For species where individuals are not detectable (e.g Wilson's storm petrel, SG diving petrels), test the use of indirect methods such as spectral classification of guano and texture analysis of burrows 4.1 Collate data on abundance or distribution of mollymawks, SG shags, giant petrels, Wilsons' storm petrels and SG diving petrels across South Georgia, including in 2023/24 all-islands albatross census. 4.2 (see activity 2.3) 4.3 Apply methodologies developed as part of 3.3 and 3.4, and in DPLus132 for wandering albatrosses, to count individuals or detect colonies of wandering albatrosses, mollymawks, SG shags, giant petrels, Wilsons' storm petrels and SG diving petrels across South Georgia. 4.4 Validate all island survey results by comparing to existing data on abundance and distribution, and to 2023/2024 all-island albatross surveys. 5.1 Share results and recommendations with stakeholders. 5.2 Deposit data in open access web portals. 5.3 Prepare reports for working groups and stakeholders. 5.4 Prepare manuscripts for publication in peer-reviewed journals. 5.5 Attend national and international conference to present results. 5.6 Make results available via websites for public dissemination			

Annex 3: Standard Indicators

Table 1 Project Standard Indicators

DPLUS Indicator number	Name of indicator	Units	Disaggregation	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project

Table 2 Publications

Title	Type (e.g. journals, best practice manual, blog post, online videos, podcasts, 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)

Annex 4: Onwards – supplementary material (optional but encouraged as evidence of project achievement)

Annex 4.1 Minutes report from in-person BAS team meeting on 26th January 2024.
Annex 4.2 Minutes report from in-person BAS team meeting on 28th February 2024.
Annex 4.3 Minutes report from in-person BAS team meeting on 24th April 2024.
Annex 4.4 White-chinned petrel 2016/17 census data from Bird Island.
Annex 4.5 White-chinned petrel colony GPS co-ordinates at King Edward Point from the 2022/23 survey.
Annex 4.6 Photographs showing seabird distribution at KEP during the 2022/23 breeding season.
Annex 4.7 The Bay of Isles Seabird Monitoring Programme 2024 report.

Checklist for submission

	Check
Different reporting templates have different questions, and it is important you use the correct one. Have you checked you have used the **correct template** (checking fund, type of report (i.e. Annual or Final), and year) and **deleted the blue guidance text** before submission?	
Is the report less than 10MB? If so, please email to BCF-Reports@niras.com putting the project number in the Subject line.	
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.	
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.	
If you are submitting photos for publicity purposes, do these meet the outlined requirements (see section 15)?	
Have you involved your partners in preparation of the report and named the main contributors	
Have you completed the Project Expenditure table fully?	
Do not include claim forms or other communications with this report.	