Department for Environment Food & Rural Affairs

DARWIN INITIATIVE

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Darwin Initiative
Final Report

*To be completed with reference to the Reporting Guidance Notes for Project Leaders (http://darwin.defra.gov.uk/resources/) it is expected that this report will be a **maximum** of 20 pages in length, excluding annexes)*

information

Project Reference	DPLUS002
Project Title	An Autonomous Seabird Monitoring Network for the Southern Ocean
Host Country/ies	British Antarctic Territory, South Georgia and the South Sandwich Islands, Falkland Islands.
Contract Holder Institution	University of Oxford
Partner institutions	Zoological Society of London/ University College London
Darwin Grant Value	Year 1: £137,715 Year 2: £76,633 Year 3: £1,500 (audit only) **Total: £215,848**
Start/end dates of project	Overall: 1/4/2013 - 31/03/2015 (15/16 year 3 audit only)
Project Leader name	Dr Tom Hart
Project website	www.penguinlifelines.org; www.penguinwatch.org
Report author(s) and date	Tom Hart, April 2016

1 Project Rationale

The Scotia Arc region has experienced dramatic increases in air and sea temperature and significant decreases in the extent, concentration, and duration of winter sea-ice over the past half-century (Meredith & King 2005, Stammerjohn et al. 2008). These warming and sea-ice trends also correlate with decreases in biological productivity and the biomass of Antarctic krill (*Euphausia superba*). In addition, an expanding fishery harvests as much as 202,346 tons of krill annually from the Antarctic Peninsula region (CCAMLR 2010) and there has been a three-fold increase in tourist visitation since 2002.

The number of seabird breeding sites monitored under the Antarctic Treaty System has declined and become patchy. In terms of monitoring, we need increases in data on breeding phenology and survival from a much greater area to disentangle the various threats of climate change, fishing and direct human disturbance. The threats to penguins have been identified by numerous separate studies and reviews (Croxall et al., 2002, Trathan et al., 2014).

Rapid advances in the biosciences have typically originated from the ability to measure something new, or by the ability to measure something on a scale that was previously impossible. One such potential step-change in data collection would stem from the ability to efficiently extract wildlife data from imagery. Camera traps (motion triggered cameras) and time-lapse data logger (Harris, 1982) have been used for decades in wildlife research (O'Connell et al., 2011), but have not been widely applied to colonial studies (Southwell and Emmerson, 2015).

Figure 1: *Map to show the location of monitored areas (red dots); species' common names are provided and the number of cameras at each site is shown.*

Whereas a scientific base or camp was necessary to collect data on seabirds, it is now possible using remote cameras. We proposed a network of Seabird Autonomous Monitoring Stations, to fill in these data gaps and assess the impacts of recent changes in climate and krill. Such data collection would bring remote sensing into collaboration with big data science analytical approaches like machine learning, computer vision and network analysis. We now have the network in place, we are increasing the parameters that it can record and speeding up the analysis. We are also working on methods to increase transparency of monitoring, feeding back to stakeholders and to make these tools available to many other researchers worldwide.

2 Project Achievements

2.1 Outcome

	Baseline	Change by 2016	Source of evidence
Outcome 1:	Increase in the number of colonies monitored for breeding parameters		
Indicator 1.1	The placement and successful recording of breeding success by cameras. This should be 52 additional sites if all those budgeted are reached; an approximate doubling of monitoring in the region.	We have added approximately 100 cameras at over 42 locations, plus 20 cameras with collaborators in the Southern Ocean.	1: Table of cameras, locations, target species. Appendix 2: Publication to CCAMLR EGAMM Appendix 3: Advising the Antarctic Treaty on the Antarctic Specially Protected Area.
Outcome 2:	An online database allowing analysis and interpretation of phenological data from images		
Indicator 2.1	A completed data base, which has capacity for at least four projects of similar size and scope to this for use with colonial seabirds across all OTs.	After partnering with the Zooniverse team, we used their cloud storage for images, coupled with a reference database. Penguin Watch launched with Ouroboros and is	www.penguinwatch.org Penguin Watch summary statistics Github repositories that store source code and which are shared with other projects. https://github.com/caseyyoungflesh/pwatch

		now transferring to Mungo DB which is a reference database within Zooniverse that references static links (example) on Amazon cloud storage This approach follows industry standards and is easily scalable to new projects such as Seabird Watch In reality, the database and crowdsourcing are now combined into one solution also referenced for computer vision, automation and reporting to policymakers.	https://github.com/zooniverse/Penguins https://github.com/zooniverse/penguin-watch-fb The Zooniverse project builder (now live and open source, automates building a project and integrating with Amazon Web Services if projects are approved.
Outcome 3	Crowdsourcing image analysis		
Indicator 3.1	A sizable proportion of the online images annotated by volunteers (crowdsourcing) to allow validation of automatic analysis and to generate data from images. A useful benchmark would be over 1000 users capable of annotating at least 20,000 images per year.	At the time of writing, Penguin Watch has had 3.2 million hits, has 400,000 images and 40,000 registered users, with an unknown (but in the 100,000 region) number of unregistered users.	www.penguinwatch.org Penguin Watch summary statistics Letters of support.
Outcome 4	Seeding similar projects with partners.		
Indicator 4.1	Number of partners with cameras deployed in the field and number of users/partners contributing images to the database.	Two partners contributing to the image database; Dr Mike Polito/Heather Lynch from Oceanites and Dr Colin Southwell from AAD.	Cameras out on new projects and new taxa in OTs beyond the Southern Ocean and South Atlantic.
Indicator 4.2	Evidence of a toolkit that can be rapidly applied to other taxa and systems.	Moreover, all of the tools developed for penguinwatch are now available to other projects via the zooniverse project builder. We have pre-emptively built Seabirdwatch; which can accept more generic image data than penguin watch and which collaborators can upload	Letters of support from collaborators and interested parties. We are now rebuilding Penguin Watch on Panoptes, which allows us to more easily collaborate by allowing collaborators to upload images and download results more easily. Seabirdwatch (demo version) is still over development and testing, but will go live here. It will also be live on Panoptes.

		their own images and download their own annotated data.	
Outcome 5	(Additional outcome) Global outreach to public and other researchers about penguins		
	A fringe benefit of the crowd sourcing has been the unexpected scale of outreach.	Outreach is continuing but has proven larger and more sustained than expected, due to the success of Penguin Watch.	The Penguin Watchers (BBC documentary) A year in the life of a penguin colony (BBC news story) Kids involved in citizen science (BBC news story.

The project has achieved it intended outcome of greatly increasing the number of monitored colonies in the Southern Ocean. Moreover, it has produced a nice case study and some generalizable tools for other OTs. In the time since the end of the Darwin funding, we also have greatly increased the applicability of the toolkit to monitoring projects and policy makers worldwide.

The time-lapse cameras now routinely record 1-8,000 images per year. The images can be used to extract parameters that are directly relevant to CCAMLR and CEMP monitoring, including first arrival, egg laying, hatching, crèching, moult and departure dates. The images also have the potential to monitor winter behaviour, nest survival, and, with sufficient frequency, foraging trip and partner exchange durations. However, with large-scale deployments of cameras taking photos at increasing frequency, the ability to process images rapidly exceeds our ability to collect them.

Penguin Watch has demonstrated that crowdsourcing in this context has the ability to process large volumes of imagery into data. The ongoing challenge is how to make this into a more globally relevant toolkit for conservationists worldwide that they will find easy to adopt. After the end of DPLUS02, we have continued to work on how to process the data automatically, so that large amounts of data can be passed to policy makers in near real time.

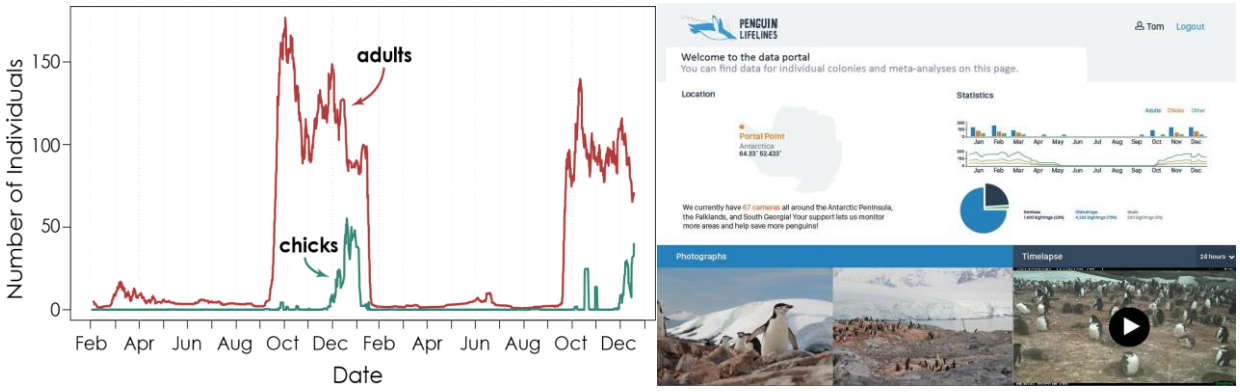

***Figure 2**: Left, consensus summaries for two years of data from the Yalour Islands, Antarctic Peninsula. Data come from 10-20 volunteers clicking on every penguin and chick within each image. Right, the data portal that is still in development will allow policy makers to see summarised data quickly and flexibly according to their needs. We are currently building this to feedback information to volunteers from Penguin Watch, but we hope to build it into a more flexible portal to give new researchers and policy-makers access to summary data.*

Similarly, ZSL's prototype satellite camera Instant Detect, has also developed the ability to live stream data from very remote sites via the Iridium satellite network. This has been trialled in BAT, with more units being deployed in January 2016 and is now also being deployed in BIOT by the FCO to detect illegal fishers. Along with ZSL, we are now working on a much cheaper, open source camera that would greatly reduce the price of entry into monitoring projects.

Figure 3: *Left; A camera overlooking the chinstrap penguin colony on Saunders Island, South Sandwich. This is the first breeding data ever recorded from this entire archipelago, despite containing most of the avian biomass of SGSSI and the largest penguin colony on earth. Right; a camera overlooking Gentoo penguins on Petermann Island, Antarctic Peninsula including an array of snow stakes to measure environmental variables.*

One element that was not completed was the network analysis – Dr Rezek is still recovering from a stroke, meaning that this element will be completed post funding. In the interim, we have tackled this in two ways; by looking for spatial autocorrelation between cameras (Black et al., 2016) and by carrying out a regression of pairwise distances vs (Figure 4, below). We have now published the genetic population structure of Gentoo (Levy et al., 2016) and Chinstrap penguins (Freer et al., 2015) while analyses of all other penguin population structures are ongoing.

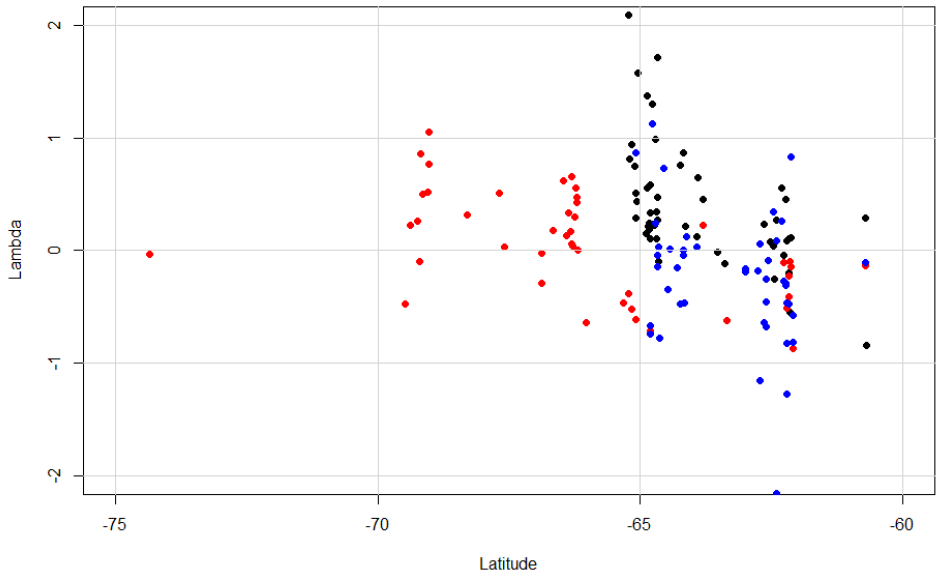

Figure 4: *Output from network analysis, showing little effect of distance vs residual. We intend to repeat this with more sites over more years. It could be that the data set used here was insufficient to detect spatial connectedness.*

2.2 Impact: achievement of positive impact on biodiversity and poverty alleviation

In order to measure changes in biodiversity, we must first measure changes in wildlife populations present. In the Polar Regions, comparative studies are limited in hard-to-reach areas and are often restricted to sites located at or near scientific bases. Our network is recording parameters relevant to understanding the effect of the krill fishery on Antarctic penguins, monitor the effects of tourism on penguin populations, and improving public understanding of these species through the use of citizen science. By working towards these goals, we are able to better understand penguin population dynamics and therefore the biodiversity of the region, as penguins represent a large proportion of biomass in Antarctica and serve as sentinels to the ecosystem using a “top down” approach to measuring large-scale changes.

In particular, we were able to complete the above-mentioned goals using the camera-monitoring network and images produced by the cameras. In the Falklands, our cameras proved successful throughout the field season and have provided valuable information on the phenology and winter behaviour of the species. As analysis continues, we continue to inform Falklands Conservation of our results, which helps them to better understand the species and the islands' ecosystem. Volunteers on Penguin Watch have been annotating images with tourists in, so that we can determine the disturbance pressure on colonies. Coupled with public information on tourism activity from IAATO, we plan to use the data to determine the effects of direct human disturbance on the phenology and survival rate of all *Pygoscelis* penguins across the peninsula. This study will allow us to better understand the impact of increasing tourism on local biodiversity and predict how future increases in human activity will disturb wildlife in time. By studying the provisioning rates of Adélie penguins on Petermann Island, we are able to estimate krill consumption, time at sea foraging, and its effects on both adult and chick survival. We hope that by accomplishing this objective, we are able to better comprehend the influence of krill fisheries on penguin populations and therefore the greater Antarctic ecosystem.

2.3 Outputs

We have tried to avoid repetition with section 2.1, so most of the indicators and evidence are in that table. The output statement was:

"This project will massively increase the number of monitored penguin populations around the Southern Ocean, by deploying autonomous camera units that can record the timing and duration of breeding. This will help to identify threats (for example, by differentiating between the influence of climate change and fisheries on penguin breeding success around the Scotia Arc).

This project will also provide a template and tools for similar monitoring projects elsewhere through the provision of an online database and analysis tool."

Output 1	**Design and deploy a network of SAMS sites around the Scotia Arc.**
1.1	Complete the power analysis of available monitoring sites and couple these with the Lynch et al 2012 sites of high leverage for estimates of krill consumption. Design the network of SAMS sites in relation to these high value colonies for monitoring.
1.2	Order the cameras and components to the Falkland Islands for assembly.
1.3	Beta test a satellite-linked camera for deployment in remote, unvisited areas.
1.4	Deploy the camera trap in the 2013/14 season using Quark vessels and existing fieldwork plans.
Output 2	**Build an online database capable of storing and annotating data from 100 SAMS for this project and 200 SAMS from other projects**
2.1	Test current trial version with multiple user images and users.
2.2	Redesign beta version and go live on www.penguinlifelines.org
Output 3	**Extract breeding parameters from image data and conduct a network analysis.**
3.1	Generate count data and clustering statistics from the data on the image database.
3.2	Pass to Dr Rezek for network analysis to determine network structure.
3.3	Compare the network derived from breeding phenology with estimates of population genetic structure and current management areas to determine areas of conflict.

Outputs 1 and 2 have been met and exceeded in both detail and scope for more detail see section 2.1. Output 3 is still in progress, see section 2.1 and Figure 4.

3 Project Partnerships

Since this project was conceived and funded, we have gained many collaborators and partners. It is hoped that this will continue to grow. At the start, the OT governments were supportive, but not prioritising this work and over time, they have increasingly seen the benefit. However, the impetus has largely come from the organisers and is being slowly adopted. In contrast, researchers and conservationists have been very supportive and have been eager to adopt the strategies and lessons we've learned. There are now four more data partners contributing to Penguin Watch and we hope this will grow with SeabirdWatch.

University College London

Dr Ben Collen moved from ZSL to UCL after this project was awarded, so some elements of the collaboration with ZSL moved to UCL, while aspects of camera technology stayed at ZSL. We will be collaborating on a number of outputs stemming from this project; there are several papers on camera monitoring and indices to come over the next couple of years.

Zoological Society of London

ZSL has been designing and building the satellite linked cameras, which have proven useful, but not transformative. While they work, these cameras are expensive and hard to maintain compared to the non-transmitting but recording cameras. As a spin off from this project, we are building a cheaper, more flexible version of the camera unit that does not transmit but is very power efficient and set in resin so that there are no air spaces. These units could be produced very cheaply and a way forward for monitoring across UKOTs. Al Davies who designed the satellite camera will be visiting one of these cameras in the field in 2016/17 to determine how it can be improved *in situ*.

Falkland Islands Government/ Falklands Conservation

Conservationists and policy makers on the Falkland Islands have identified Southern Rockhopper penguins as a priority for investigation and conservation following a workshop in April 2011. We have been working with Falklands Conservation to deploy one camera on a Gentoo penguin colony and six cameras on rockhopper penguins. We met with Falklands Conservation, the South Atlantic Environmental Research Institute and Falklands Government Environmental Planning department in November to ensure that data collected so far is fed into policy, delivers against their own goals and is sustainable. Also, we are depositing all of the data collected so far with SAERI.

Government of South Georgia and South Sandwich Islands

GSGSSI have been consulted throughout the development of this project, and PI Hart was involved in the Marine Protected Areas consultation meeting in April 2012, which highlighted the gaps in monitoring in areas around South Georgia and the South Sandwich Islands away from the Bird Island and King Edward Point research stations. GSGSSI have donated and are maintaining two monitoring stations at Maivikken on South Georgia and we are working with the predator scientist there to aid placement and data interpretation.

Foreign and Commonwealth Office Overseas Territories Polar Regions Department

Discussions with the Foreign and Commonwealth Office have been productive as to the placement of cameras and the possibility of integrating data derived from the camera network with CCAMLR fisheries data and the selection of candidate MPAs. Furthermore, we have worked with the FCO Overseas Territories department to build and deploy a satellite camera network on Chagos (BIOT) to detect illegal fishing.

Zooniverse, Department of Astrophysics, University of Oxford

The collaboration with the Zooniverse has gone from strength to strength and this will continue in the future. They have been hugely helpful in designing and building Penguin Watch, and they have worked hard to make the tools developed for this project available to other researchers via the project builder and www.seabirdwatch.org. Dr Tom Hart and Professor Chris Lintott are currently recruiting a PhD student to work on elements of the Penguin Watch data.

The Departments of Engineering and Computer Science, University of Oxford

The collaboration with the Zooniverse has to some point circumvented the need for automation; we created a partnership with Zooniverse (www.zooniverse.org) last year, who developed and host Penguin Watch (www.penguinwatch.org) and with which we are working to make the tools from Penguin Watch more widely available. The Zooniverse and the prominence of Penguin Watch is the main strategy for promoting this type of monitoring. We receive weekly requests for advice on setting up cameras and analysis. As a result, we intend to release a more inclusive seabird project next year with many more partners from the OTs.

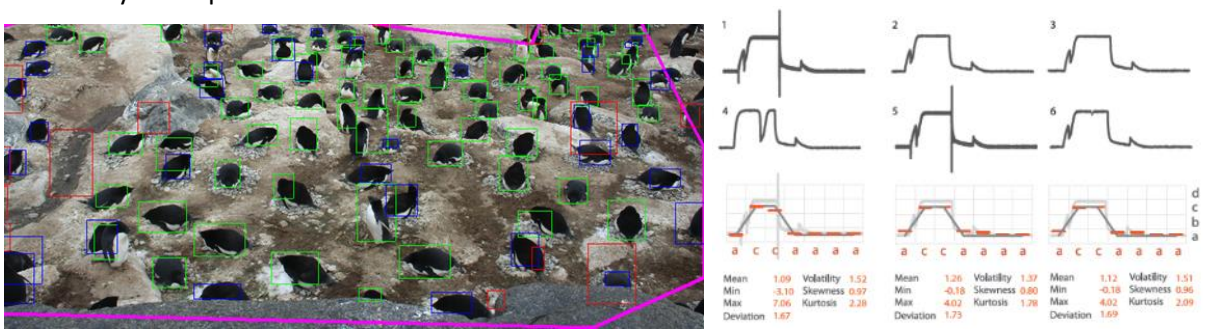

Figure 3: *Left; computer vision testing and Right: analysing different trial motif detectors for automated parameter estimation.*

Cheesemans' Ecology Safaris and Golden Fleece Expeditions ltd.

We formed a two-year arrangement with these partners to carry out month-long expeditions to South Georgia, which will be paid for by 8-10 tourists. This partnership has already resulted in a spin-out albatross survey by GSGSSI and Island Surveys and we are working on a re-survey of the South Sandwich Islands. Last season was extremely successful and has almost entirely eliminated the costs of fieldwork on South Georgia and will allow much more monitoring in South Georgia and South Sandwich.

Tristan da Cunha

We have helped the Conservation Department of Tristan da Cunha to get a penguin monitoring project started. We have donated six reconditioned cameras from Antarctica to them to determine whether photo monitoring is useful and can be analysed in the same framework as our own monitoring.

St Helena

We have helped the Conservation Department of St Helena by donating ten reconditioned or non-standard cameras that did not perform well in Antarctica, so that they can increase their capacity.

4 Contribution to Darwin Initiative Programme Outputs

4.1 Contribution to SDGs

This project has contributed towards SDGs 12 and 14:

Ensure sustainable consumption and production patterns

Namely, the camera network is providing data on whether the krill fishery, tourism, science or climate change is influencing local penguin reproductive success.

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

As above, the camera network is informing the nature and placement of management and MPAs.

4.2 Project support to the Conventions or Treaties (CBD, CMS, CITES, Nagoya Protocol, ITPGRFA))

Agreements such as the Agreement on Albatrosses and Petrels (ACAP) show the urgent need for monitoring of avian predators in Overseas Territories. The CBD and CMS have not been ratified for the Falkland Islands, South Georgia and British Antarctic Territories, but these territories have management plans expressing similar intentions to protect and conserve biodiversity and range. Estimates of population size and the timing of breeding are derived from very few sites near to scientific bases, resulting in very poor statistical power to detect change. This year, we sent left over cameras to Tristan

da Cunha and St Helena, and we have placed cameras in the Falkland Islands over the duration of this project. Low cost, easily-calibrated techniques are needed that could be scaled up across other overseas territories.

We are now in a position to offer support to offer over-wintering data and the influence on arrival dates and reproductive success in the summer. Until now, no over-wintering data has meant that predator input into the fisheries catch limits is based entirely on the previous summer's activity and a few monitored sites.

Secondly, we will be providing monitoring support to GSGSSI to on the CBD as they seek to monitor and promote recovery post rat and reindeer removal. We have already leant cameras to GSGSSI to monitor bait stations post rat eradication and they have now adopted this as part of their strategy.

4.3 Project support to poverty alleviation

NA – this project took place across uninhabited OTs. However, we have made a toolkit that will mean monitoring is much cheaper and accessible to researchers in LDCs.

4.4 Gender equality

NA – this project took place across uninhabited OTs.

4.5 Programme indicators

No management plans for biodiversity were developed, but indicators based on phenology were developed. See appendix, Collen et al.

4.6 Transfer of knowledge

This has helped two people to achieve formal qualifications; Gemma Clucas and Caitlin Black. Caitlin Black is in her third year of a DPhil at Oxford University working on aspects of the camera data and Gemma Clucas is in her fourth year of her PhD at Southampton University. She was a field assistant for two seasons on this project and also collected samples towards her PhD.

The knowledge transfer is a vital component of this project; it was pitched as a way of filling a data deficiency in the Southern Ocean and creating a toolkit for others to use.

At the recent Photo-ID conference in Finland, it was clear that a number of groups worldwide are moving to automation and citizen science and that this project is one of the world –leaders, alongside Image-Based Ecological Information System (IBEIS). Moreover, it is clear that there are two domains in image based monitoring, that of animal id (determining which species is present) and one of timelapse. There is a lot of interest in the timelapse problem for colonial animals. We are reaching out to engage this community via a survey and networking at conferences. See the appended survey for the photo methodology survey.

Figure 4: *Presenting at Photo-ID in Finland.*

Moreover, where possible we have sought to seed projects; both directly with consumables and equipment and with advice and coordination. In particular, we have used two sets of cameras to seed projects in St Helena, Tristan da Cunha and the Falkland islands. These cameras were bushnell cameras, that after one season's trial in Antarctica, were found to be unsuitable.

Figure 5*: Top ridge at Lot's Wife on St Helen, monitoring a colony of Red-footed boobies.*

4.7 Sustainability and Legacy

Two efforts have been made to expand this work, enhance capacity and to ensure long-term funding. Firstly, at the International Penguin Conference, additional partners were sought and a number of new collaborators have agreed to place cameras on penguins within and outside the Southern Ocean. Other contacts within OTs and beyond have been made that should scale up the outputs from this project.

The camera network is highly likely to be a sustained monitoring effort; we are working on the sustainability in terms of collaboration and data collection. Cameras bought and placed under DPLUS02 appear to have a 2-5 year lifespan in Antarctica and have been replaced when they fail or serviced and repaired where possible and donated to other OTs. DPLUS02 has at least a five year legacy for cameras

monitoring animals in a number of OTs. Much of the legacy will come as other projects come to turn their imagery into policy –in particular see Figure 2, which aims to turn the output of penguin watch (and seabird watch) into automatic policy reports.

Some of the most important outputs of this project will come in the years 2016-18, when the system has been reviewed by CCAMLR and when we publish the data from the network as an analysis of phenology and reproductive success.

Tom Hart will continue to run the project through Oxford University and is actively seeking further funding to continue the project in the Southern Ocean, and to expand to other UKOTs.

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Quark Expeditions have raised and donated nearly £100,000 so far. We hope that annual donations around £50k per year will be sufficient to sustain the project at the end of Darwin Plus funding. This is intended to be long-term monitoring and as such there is no exit strategy, but the development of the cameras with solar power means that we should be able to leave cameras for much longer between servicing.

Also see knowledge transfer in 4.6- the toolkit developed will be increasingly used by collaborators.

Two efforts have been made to expand this work, enhance capacity and to ensure long-term funding. Firstly, at the International Penguin Conference, additional partners were sought and a number of new collaborators have agreed to place cameras on penguins within and outside the Southern Ocean. This proved highly successful, and we now advice and send analytical code and support to projects in Argentina, Norway, UK, New Zealand, Australia and South Africa.

5 Lessons learned

Year one was behind schedule due to cameras shipped to the Falklands being delayed in Miami. However, in year 2 we were able to catch up and exceed our expectations, in particular thanks to additional charters with Cheesemans Ecology Safaris. We continue to add value to the network through increasing the number of parameters that each camera can record. In particular, we can now measure the foraging trip duration and the provisioning rate, snow accumulation, and sea ice. We are also working to automate parameter extraction for each of these.

In general, the expertise was right for the project, but it changed in scope substantially with the success of Penguin Watch at the end of Year 1, with an increasing reliance on citizen science and less on computer vision.

It seems like the reporting structure has changed substantially since the project began with more reporting required on sustainable development goals. This is a slight concern for those projects that work in the uninhabited OKOTs, where a massive part of UKOT biodiversity is.

5.1 Monitoring and evaluation

Monitoring and evaluation has been relatively easy against the objectives; the deployment of the network is easily quantifiable and the tools are relatively simple to assess whether they work or not. We are confident that we have met the targets, with the exception that we have not finished some of the network analysis, which will be completed in the coming months.

Additionally, we have exceeded the targets for deployment of the network and for seeding similar projects worldwide. Some of the analytical tools continue to be refined as we work them up for publication.

Main feedback on the projects have come from peer review and from CCAMLR reports. We have had a lot of support from researchers wanting help, but feedback from CCAMLR has been slow.

5.2 Actions taken in response to annual report reviews

The previous feedback indicated that it was key to engaging stakeholders. We have done this, but the project remains somewhat "top down". This is because developing the technology is unfortunately central – i.e.: the technology behind a complex but user-friendly product takes a lot of knowledge and development time. Also, many of the UKOTs didn't know what was possible outside of the conventional monitoring. In particular, GSGSSI and the Falkland Islands Government are increasingly supportive and asking for data from this network. Over the past year, we've engaged with them a lot to gauge requirements and to deal with this feedback.

In particular, in building seabirdwatch and rebuilding penguinwatch, we've allowed for more direct engagement of collaborators in the creation and management of camera networks. We've also built but not fully deployed the feedback portal, which will give all stakeholders access to processed data and control over which parameters feed into reports and comparisons.

The appended survey aims to understand stakeholder and researcher needs so that we can further tailor the front end (cameras and computing) with the back end (citizen science, automation and parameter reporting) to these. Letters of support from researchers already conducting or aiming to conduct similar research speak for the need for this expansion.

6 Darwin identity

The project is publicised on the Penguin Lifelines website (www.penguinlifelines.org) with the Darwin Plus logo, and in all talks, which this year were approximately 15 public talks to approximately 4,000 people and three talks within conferences to approximately 700 people within the conservation community.

The Darwin logo is used explicitly in relation to this project wherever possible http://penguinlifelines.org/ http://www.penguinwatch.org/#/team. In particular, this has been seen by millions of people worldwide with the launch of Penguin Watch. For example, the Smithsonian embedded it in their site http://www.smithsonianmag.com/smart-news/penguins-may-use-poo-melt-snow-breeding-sites-180955120/?no-ist, as did Science http://news.sciencemag.org/sifter/2015/04/watch-penguins-may-use-feces-to-melt-snow-off-breeding-sites.

Further to this, we have attempted to mention the Darwin Initiative in interviews; this has not always been successful in editing.

The UK Government has been recognised in all talks at conferences, and increasingly this is linked to knowledge transfer of the camera network and the statistical methods for remote monitoring. When presenting scientific talks, the Darwin Initiative branding has usually been recognised and well received. Elsewhere, public talks in the Falklands and Argentina, audiences were largely familiar. In the UK and elsewhere, audiences were unfamiliar.

The project has a website, twitter and facebook account. However, these are not very effective as they require constant maintenance.

Figure 6: *Outreach at WOW HOW in Oxford.*

7 Finance and administration

7.1 Project expenditure

Year 2	2014/15 Grant (£)	2014/15 Total actual Darwin Costs (£)	Variance %	Comments (please explain any variance)
Staff costs			4%	
Consultancy costs				
Overhead Costs			0.5%	
Travel and subsistence			54%	Some travel costs were covered by other sources – which facilitated additional field items to be purchased
Operating Costs			100%	Additional Fieldwork consumables were required during the field season
Capital items (see section 7)				
Others (see section 8)				
Current Year's Costs	2014/15 Grant (£)	2014/15 Total actual Darwin Costs (£)	Variance %	Comments (please explain any variance)

			Claimed So Far	Claim for this period	Surrender Amount
TOTAL	76,633 **A**	76,136.35 **B**	57,474.75 **C**	18,661.60 **D**	496.65 **E**

7.2 Additional funds or in-kind contributions secured

Source of funding for project lifetime	Total (£)
Quark Expeditions Ltd 2014	
TOTAL	**49,709**

Source of funding for additional work after project lifetime	Total (£)
Quark Expeditions Ltd 2015	
Quark Expeditions Ltd 2016	
TOTAL	**103,000 (est)**

7.3 Value for Money

Basic value for money

During austerity measures for the UK in terms of science and conservation, but continued interest in polar research, funding is tight and access to Antarctica is restricted in many ways, often limited to access via the British Antarctic Survey to one of several bases. The reduction of the UK polar fleet and the new polar research vessel means that the daily cost of cruise time is in the order of £40,000. We think it unlikely that such long fieldwork periods as this project would or could be supported by the conventional scientific logistics in Antarctica.

All fieldwork on ships during this project has been donated as in kind support from Quark Expeditions, Oceanwide Expeditions and Cheeseman's Ecology Safaris. This project has clearly demonstrated that it is possible to deploy and maintain a sensor network in the most remote places on earth and to process the data streams efficiently. The main costs of the project have been the establishment of the network (primarily the cost of cameras) and staff costs. Now that the network is in place, the project can be run for approximately £15,000 per season (flights, servicing cameras and replacing 10% of the network per year), plus staff costs. Most of the analysis is now being carried out by students, so the full continued running cost of the project is TH's salary plus £20,000 (£15,000 plus £5,000 annual IT costs).

Added value and in-kind support.

In addition to monitoring penguins, the data are providing useful image analysis and machine learning problems to the scientific community. The incidental collection of sea-ice data is proving to be a useful addition and we are also using the network of camera poles to help other researchers place sample collection tubes and other sensors.

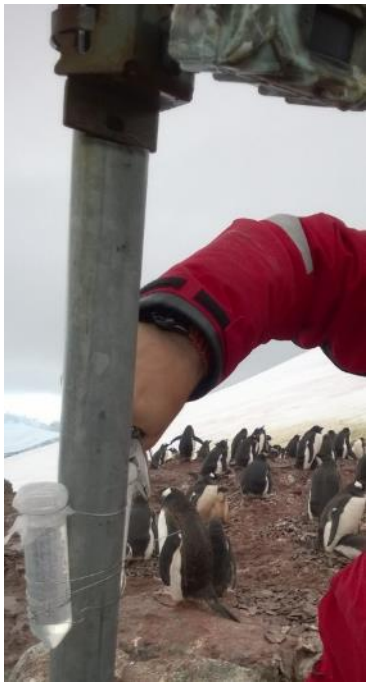

Figure 7: *A camera pole with a trial pollen trap on. These traps consist of sample tubes tied to the camera pole and filled with glycerol. These tubes are covered with a filter and left for one year.*

Annex 1 Project's original (or most recently approved) logframe, including indicators, means of verification and assumptions.

Note: Insert your full logframe. If your logframe was changed since your Stage 2 application and was approved by a Change Request the newest approved version should be inserted here, otherwise insert the Stage 2 logframe.

Project summary	Measurable Indicators	Progress and Achievements April 2013 - March 2014	Actions required/planned for next period
Goal/Impact This project will massively increase the number of monitored penguin populations around the Southern Ocean, by deploying autonomous camera units that can record the timing and duration of breeding. This will help to identify threats (for example, by differentiating between the influence of climate change and fisheries on penguin breeding success around the Scotia Arc). This project will also provide a template and tools for similar monitoring projects elsewhere through the provision of an online database and analysis tool.			
Output 1. Design and deploy a network of SAMS sites around the Scotia Arc.			
Activity 1.1: Complete the power analysis of available monitoring sites and couple these with the Lynch et al 2012 sites of high leverage for estimates of krill consumption. Design the network of SAMS sites in relation to these high value colonies for monitoring.	A report to the FCO and to the Antarctic Treaty showing the placement of cameras and images obtained, analysed for the phenological parameters of breeding required. A manuscript showing power analysis of currently monitored sites versus species and region.	Complete	Submission of this manuscript for publication and a report based on this manuscript to the Antarctic Treaty Consultative Meeting, the South Georgia Government and the Falkland Islands Environmental Planning Department. We continue to add to this network, refine the data collection and to publish results from this network.
Activity 1.2: Order the cameras and components to the Falkland Islands for assembly.	Successful deployment of the network.	Complete	Reports to the OT governments.
Activity 1.3: Beta test a satellite-linked camera for deployment in remote, unvisited areas.	A series of images received onto the Irridium (satellite network) server and placed into Penguin Watch.	Complete	Further deployment of satellite cameras.
Activity 1.4: Deploy the camera trap in the 2013/14 season using Quark vessels and existing fieldwork plans.		Incomplete	One camera remains to be deployed in the 2015/16 season.

Output 2. Build an online database capable of storing and annotating data from 100 SAMS for this project and 200 SAMS from other projects			
Activity 2.1: Test current trial version with multiple user images and users.	Complete – 2.5 million images classified.	Complete, testing of the annotator with additional users was completed and successful.	Publications of citizen science data set, plus survey of field to determine barriers and needs for ecologists who would like to use time-lapse cameras.
Activity 2.2: Redesign beta version and go live on www.penguinlifelines.org	Complete	Images from pilot data and the current network now number an estimated 460,000. In light of this, the performance indicator is inappropriate. We would therefore like to scale this up to all of the data annotated per year. All images prior to 2015 have been analysed.	Validation of crowdsourced data, publication of the phenological indicators.
Output 3. Extract breeding parameters from image data and conduct a network analysis.			
Activity 3.1: Generate count data and clustering statistics from the data on the image database.		Complete	Finish count data interpretation and publish report.
Activity 3.2: Pass to Dr Rezek for network analysis to determine network structure.	A paper and/or an online tool to determine clustering from count data.	Complete	Complete network analysis.
Activity 3.3: Compare the network derived from breeding phenology with estimates of population genetic structure and current management areas to determine areas of conflict.	A methodological paper.	Incomplete, waiting for genetic structure analysis to be completed. A manuscript showing the population structure is appended for Gentoo penguins. We have restarted this for the other penguins with a next- generation sequencing approach to improve precision.	This will be completed after the end of DPLUS002, but pilot data is looking excellent.

Annex 2 Report of progress and achievements against final project logframe for the life of the project

Note: For projects that commenced after 2012 the terminology used for the logframe was changed to reflect DFID's terminology.

Project summary	**Measurable Indicators**	**Progress and Achievements in the last Financial Year** (Insert years e.g., 2015-2016)	**Actions required/planned for next period**
Goal/Impact: Insert **Agreed** project purpose/outcome statement		Report on any contribution towards positive impact on biodiversity or positive changes in the conditions of human communities associated with biodiversity e.g. steps towards sustainable use or equitable sharing of costs or benefits	Do not fill not applicable
Purpose/Outcome Insert **agreed** project purpose/outcome statement	Insert **agreed** purpose/outcome level indicators	Report on progress towards achieving the project purpose, i.e. the sum of the outputs and assumptions	Do not fill not applicable
Output 1. Insert **agreed** outputs with activities relevant to that output in lines below	Insert **agreed** output level indicators)	Report general progress and appropriateness of indicators	
Activity 1.1 Insert activities relevant to this out put		Report completed or progress on activities that contribute toward achieving this output	
Activity 1.2. Etc.			
Output 2. Insert **agreed** output	Insert **agreed** output level indicators	Report general progress and appropriateness of indicator	
Activity 2.1.			
Activity 2.2. Etc.			
Output 3. Etc.			

Annex 3 Standard Measures

We use these figures as part of our evaluation of the wider impact of the Darwin Initiative programme. Projects are not evaluated according to quantity. That is – projects that report few standard measures are not seen as being of poorer quality than those projects which can report against multiple standard measures.

Please quantify and briefly describe all project standard measures using the coding and format of the Darwin Initiative Standard Measures. Download the updated list explaining standard measures from http://darwin.defra.gov.uk/resources/reporting/. If any sections are not relevant, please leave blank.

Code	Description	Total	Nationality	Gender	Title or Focus	Language	Comments
Training Measures							
1a	Number of people to submit PhD thesis	2	GBR, US	F			
1b	Number of PhD qualifications obtained	None yet					
2	Number of Masters qualifications obtained						
3	Number of other qualifications obtained						
4a	Number of undergraduate students receiving training						
4b	Number of training weeks provided to undergraduate students						
4c	Number of postgraduate students receiving training (not 1-3 above)						
4d	Number of training weeks for postgraduate students						
5	Number of people receiving other forms of long-term (>1yr) training not leading to formal qualification(e.g., not categories 1-4 above)						
6a	Number of people receiving other forms of short-term education/training (e.g., not categories 1-5 above)						
6b	Number of training weeks not leading to formal qualification						
7	Number of types of training materials produced for use by						

Code	Description	Total	Nationality	Gender	Title or Focus	Language	Comments
	host country(s) (describe training materials)						

Research Measures		Total	Nationality	Gender	Title	Language	Comments/ Weblink if available
9	Number of species/habitat management plans (or action plans) produced for Governments, public authorities or other implementing agencies in the host country (ies)						Participatory process?
10	Number of formal documents produced to assist work related to species identification, classification and recording.						
11a	Number of papers published or accepted for publication in peer reviewed journals	4					
11b	Number of papers published or accepted for publication elsewhere						Location?
12a	Number of computer-based databases established (containing species/generic information) and handed over to host country	2					
12b	Number of computer-based databases enhanced (containing species/genetic information) and handed over to host country	1					
13a	Number of species reference collections established and handed over to host country(s)						
13b	Number of species reference collections enhanced and handed over to host country(s)						

Dissemination Measures	Total	Nationality	Gender	Theme	Language	Comments

14a	Number of conferences/seminars/workshops organised to present/disseminate findings from Darwin project work	1					
14b	Number of conferences/seminars/ workshops attended at which findings from Darwin project work will be presented/ disseminated.	3					

Physical Measures		**Total**	**Comments**
20	Estimated value (£s) of physical assets handed over to host country(s)	£20,000	
21	Number of permanent educational, training, research facilities or organisation established	0	
22	Number of permanent field plots established	~100	Please describe

Financial Measures		**Total**	**Nationality**	**Gender**	**Theme**	**Language**	**Comments**
23	Value of additional resources raised from other sources (e.g., in addition to Darwin funding) for project work	50,000					

Annex 4 Aichi Targets

Please note which of the Aichi targets your project has contributed to.

Please record only the **main targets** to which your project has contributed. It is recognised that most Darwin projects make a smaller contribution to many other targets in their work. You will not be evaluated more favourably if you tick multiple boxes.

	Aichi Target	Tick if applicable to your project
1	People are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.	Y
2	Biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.	Y
3	Incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.	
4	Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.	
5	The rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.	
6	All fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.	
7	Areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.	
8	Pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.	
9	Invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.	
10	The multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.	
11	At least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.	
12	The extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.	
13	The genetic diversity of cultivated plants and farmed and domesticated animals and	

	of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.	
14	Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.	
15	Ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.	
16	The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation.	
17	Each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.	
18	The traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.	
19	Knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.	
20	The mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.	

Annex 5 Publications

Provide full details of all publications and material that can be publicly accessed, e.g. title, name of publisher, contact details. Mark (*) all publications and other material that you have included with this report

Type * (e.g. journals, manual, CDs)	Detail (title, author, year)	Nationality of lead author	Nationality of institution of lead author	Gender of lead author	Publishers (name, city)	Available from (e.g. web link, contact address etc)
Journal	Black, C., Reya Rey, A. & Hart, T. Locations of non-breeding Gentoo penguins along a latitudinal gradient.	USA	University of Oxford	Female		
Journal	Black, C., Southwell, C., Emmerson, L. & Hart, T. Time-lapse imagery of Adelie penguins reveals a mid-winter phase of site occupation. *Ibis, submitted*	USA	University of Oxford	Female		
Journal	Black, C., Collen, B., Johnston, D. & Hart, T. (2016) Why Huddle? Ecological Drivers of Chick Aggregations in Gentoo Penguins, *Pygoscelis papua*, across Latitudes. doi: 10.1371/journal.pone.0145676	USA	University of Oxford	Female	PLOSOne	doi: 10.1371/journal.pone.0145676
Journal	Younger, J. L. , Clucas, G. V., Kooyman, G., Wienecke, B., Rogers, A. D., Trathan, P. N., Miller, K. J. & Hart, T (2015) Too much of a good thing; sea ice extent may have forced emperor penguins into refugia during the last glacial maximum. Global Change Biology, doi: 0.1111/gcb.12882.	AUS	University of Tasmania	Female	Global Change Biology	doi: 0.1111/gcb.12882.
Journal	Clucas, G. V., Rogers, A. D., Emslie, S., Polito, M., Dunn, M. & Hart, T. A reversal of fortunes: climate change 'winners' and 'losers' in Antarctic Peninsula penguins. (2014) Scientific Reports, 4 doi:10.1038/srep05024	UK	University of Southampton	Female	Scientific Reports	doi:10.1038/srep05024

Journal	Levy, H. J., Clucas, G. V., Rogers, A. D., Leaché, A. D., Ciborowski, K., Polito, M. J., Lynch, H. J., Dunn, M. & Hart, T. Population structure and phylogeography of the Gentoo Penguin (*Pygoscelis papua*) across the Scotia Arc *Ecology and Evolution*. doi: 10.1002/ece3.1929	UK	University of Oxford	Female	Ecology and Evolution	doi: 10.1002/ece3.1929
Journal	Freer, J. J., Mable, B. K., Clucas, G. V., Rogers, A. D., Polito, M. J., Dunn, M., Naveen, R., Levy, H. J. & Hart, T. (2015) Limited genetic differentiation among chinstrap penguin (*Pygoscelis antarctica*) colonies in the Scotia Arc and Western Antarctic Peninsula. Polar Biology, doi: 10.1007/s00300-015-1711-2	UK	University of Glasgow	Female	Polar Biology	doi: 10.1007/s00300-015-1711-2
Journal	Hart, T., Lynch, H. J. & Naveen, R. (2015) Probe effects of krill fishing and climate. Nature 523: 410 doi:10.1038/523410c	UK	University of Oxford	Male	Nature	doi:10.1038/523410c

Annex 6 Darwin Contacts

Ref No	DPLUS02
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