Falkland Islands Seabird Monitoring Programme

Annual Report 2022/2023 (SMP30)

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Summary

The Falkland Islands support seabird populations that are of regional and global importance. Numerically they can influence the global conservation status of individual species, and their abundance also makes them important components of the local marine and coastal terrestrial ecosystems. Falklands Conservation set up the Falkland Islands Seabird Monitoring Programme (FISMP) in 1989, to monitor populations for several important seabird species in the Falkland Islands. This report updates the Programme with data from the 2022/23 season, and highlights key threats and associated conservation actions.

Overall

During the 2022/2023 season, black-browed albatross, gentoo penguin, southern giant petrel, and southern rockhopper penguin showed overall lower numbers of breeding pairs compared to the previous season, but higher rates of breeding success. Meanwhile, relative to last season, brown skua, imperial shag, king penguin and Magellanic penguin showed increases in their respective breeding measures.

The long-term trends of FISMP species are summarised below. For species with >10 years of data, we produced modelled long-term trend estimates. Multi-season oscillations of decline and recovery are evident in some species. Other FISMP species may yet exhibit similar larger-scale oscillating trends with longer monitoring. Understanding such longer-term population characteristics is critical in identifying genuine circumstances for conservation concern. The apparent long-term, consistent decline in breeding success of southern rockhopper penguin is such a situation. Most FISMP species appeared to respond to the strong El Niño event in 2014/2015/2016, with inflexions in trends in estimated breeding population size or breeding success, or both.

The most significant and urgent overarching threat to seabirds in the Islands is the continuing climate crisis. National commitments to restoring and retaining healthy and resilient ecosystems through decarbonisation, ecosystem-based fisheries management and habitat restoration can tackle the greatest threats to the valuable populations of seabirds in the Islands and globally at its source.

Black-browed albatross

Breeding population (Steeple Jason): 2000–2022, increasing; last 10 years, increasing.

Breeding success (Steeple Jason): 2004–2022, stable-decreasing; last 10 years, decreasing.

Brown skua

Apparently Occupied Territories (Steeple Jason): 2016–2022, increasing.

Gentoo penguin

Breeding population (Falkland Islands): 1987–2022, stable; last 10 years, decreasing.

Breeding success (Falkland Islands): 1990–2022, stable; last 10 years, stable-increasing.

Imperial shag

Breeding population (Mideast & Northeast Falklands): 2014–2022, stable-decreasing.

King penguin

Pre-fledged chicks (Volunteer Green): 1980–2022, increasing; last 10 years, increasing.

Magellanic penguin

Burrow occupancy (Gypsy Cove): 2002–2022, stable; last 10 years, decreasing.

Southern giant petrel

Breeding population (Steeple Jason): 2002–2022, increasing; last 10 years, stable-increasing.

Breeding success (Steeple Jason): 2004–2022: stable-decreasing; last 10 years, stable-increasing.

Southern rockhopper penguin

Breeding population (Falkland Islands): 1991–2022, stable; last 10 years, decreasing.

Breeding success (Falkland Islands): 1993–2022, decreasing; last 10 years: stable-decreasing.

Increasing = breeding measure is clearly increasing; Stable-increasing = breeding measure is either stable or possibly increasing; Stable = breeding measure is clearly stable; Stable-decreasing = breeding measure is either stable or possibly decreasing; Decreasing = breeding measure is clearly decreasing.

Introduction

The Falkland Islands support significant seabird populations, including those of global importance, both numerically, and in terms of their conservation status. These include:

- An estimated 72% of the global population of black-browed albatross (*Thalassarche melanophris*) (IUCN Red Listed as 'Least Concern', BirdLife International 2018a);
- An estimated 36–70% of the world's population of brown skua (*Catharacta antarctica*) (IUCN Red Listed as 'Least Concern', BirdLife International 2018b);
- An estimated 30% of the world's population of gentoo penguin (*Pygoscelis papua*) (IUCN Red Listed as 'Least Concern', BirdLife International 2020b);
- An estimated 43% of the global population of southern giant petrel (*Macronectes giganteus*) (IUCN Red Listed as 'Least Concern', BirdLife International 2018d); and
- An estimated 36% of the world's population of southern rockhopper penguin (*Eudyptes c. chrysocome*) (IUCN Red Listed as 'Vulnerable', BirdLife International 2020a).

Trends in Falkland Islands populations are likely to affect the global conservation status of these species. In addition, seabirds play crucial roles in regulating ecosystems such as by acting as higher predators (Brooke 2004, Cury et al. 2011) and as important drivers of nutrient cycling between terrestrial and marine ecosystems (Otero et al. 2018). As they are sensitive to changes in food availability, pollution and other environmental factors, seabirds also serve as indicators of the overall health of the marine environment (Cairns 1987, Velarde et al. 2019). Monitoring seabird population in the Falkland Island is therefore important both in terms of their individual conservation and management, and more generally as a tool to detect changes in the marine environment.

Falklands Conservation initiated the Falkland Islands Seabird Monitoring Programme (FISMP) in 1989. Its initial purpose was to monitor the diet and population dynamics of gentoo penguin, Magellanic penguin (*Spheniscus magellanicus*), southern rockhopper penguin, and black-browed albatross. Diet sampling was discontinued in 2003. Since then, annual population monitoring has continued, with some changes to the original format, such as the addition and loss of monitoring sites and of species. A summary of the current programme is provided in **Table 1**.

The FISMP provides an important long-term dataset on population trends and breeding success. This information serves as a foundation for understanding the health of populations and supports research into species responses to environmental factors and anthropogenic activities. Further, information from the FISMP can inform IUCN Red List assessments, and identify conservation priorities. This report details the monitoring programme results from the 2022/2023 breeding year and provides an update on long-term trends of individual species.

Table 1 Summary of the FISMP seabird study species, survey effort and survey coverage of the estimated national breeding populations.

Species	Annual survey effort	Percentage of national estimate	National estimate Source
Black-browed albatross (*Thalassarche melanophris*)	1 site (5 colonies) + data provided from Dunbar	0.5–0.6% of c. 210,770 pairs. Site represents the most important breeding site globally and 39% of the national population	Crofts 2020
Brown skua (*Catharacta antarctica*)	1 site (multiple colonies)	3–5% of c. 5,000–9,000 pairs	Woods & Woods 1997
Gentoo penguin (*Pygoscelis papua*)	12 sites (17 colonies) + data provided from Bleaker Island	18% of c. 132,000 pairs	Baylis et al. 2013a
Imperial shag (*Leucocarbo atriceps*)	2 sites (3 colonies)	<1% of c. 45,000–85,000 pairs	Woods & Woods 1997
King penguin (*Aptenodytes patagonicus*)	1 site (1 colony)	over 95% of c. 1,500 pairs	Pistorius et al. 2012
Magellanic penguin (*Spheniscus magellanicus*)	1 site (1 colony)	<1% of c.76,000–142,000 pairs	Woods & Woods 1997
Southern giant petrel (*Macronectes giganteus*)	1 site (3 colonies) + data provided from Bleaker Island	8.6% of c. 20,970 pairs	Stanworth & Crofts 2017
Southern rockhopper penguin (*Eudyptes c. chrysocome*)	5 sites (11 colonies) + data provided from Bleaker Island	2.6% of c. 319,000 pairs. Sites include Steeple Jason which holds c. 33% national population	Baylis et al. 2013b

Methods

Within this report, breeding seasons are referred to by the year in which they commenced; e.g. 2022 describes the 2022/2023 austral summer breeding period. 'Site' refers to a named geographical area, such as a settlement, farm or camp, and this may support more than one colony; e.g. Race Point 'site' has gentoo penguin colonies at Rookery Sands and Fanning Harbour. A 'colony' refers to a group or groups (sub-colonies) of birds in close proximity, typically within 50–100 m, and/or with shared or proximate access from the sea.

Data collection of breeding seabirds

Most of the monitoring was carried out by Falklands Conservation and volunteers under Falkland Islands Government (FIG) Research Licences (R21/2017 and R40/2018), with additional data contributed by individual landowners and site wardens. Monitoring sites are shown in **Figure 1**, with individual colonies listed in **Table 2**. GPS locations of monitored colonies are provided in **Appendices 2**–**5.** Where possible, GPS locations were taken due south of the approximate centres, 5 m from the colony edge. Monitoring consisted of various breeding variables, depending on the species' breeding ecology (**Table 2**).

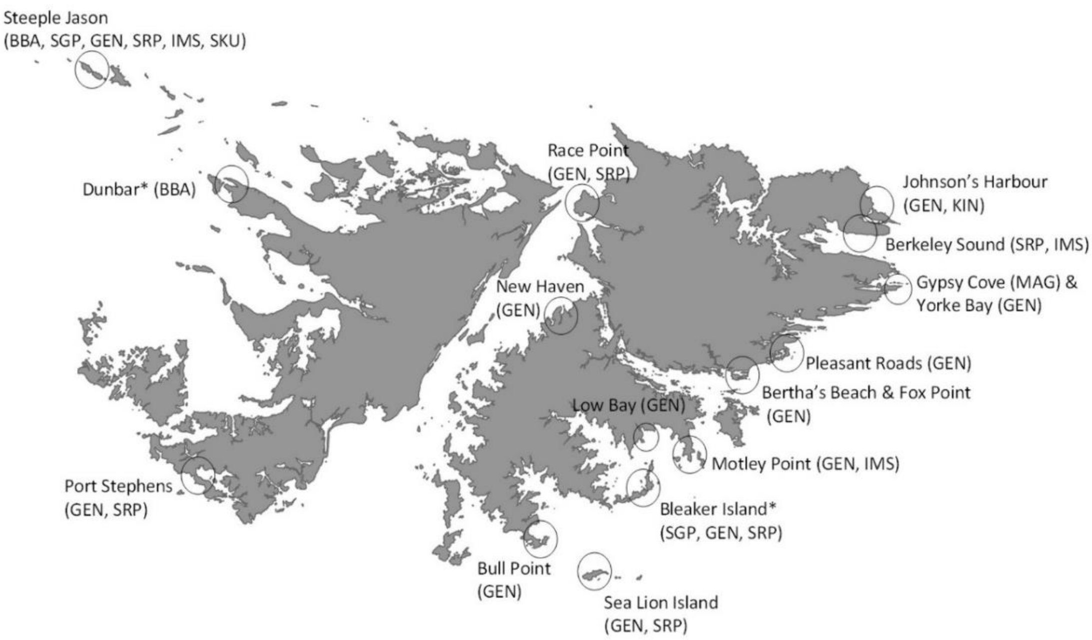

Figure 1 Map of the FISMP monitoring locations. Asterisks* indicate sites where data are provided by respective landowners. BBA = Black-browed albatross; GEN = Gentoo penguin; IMS = Imperial shag; KIN = King penguin; MAG = Magellanic penguin; SGP = Southern giant petrel; SKU = Brown skua; SRP = Southern rockhopper penguin.

Table 2 Species-specific monitoring details. AON = Apparently Occupied Nests; PFC = Pre-fledged Chicks; AOT = Apparently Occupied Territory. We differentiate "Chicks" from PFC as these data were collected during early chick-rearing. Counts at sites denoted with an asterisk * were conducted by landowners or site wardens.

Species	Monitored sites and colonies (in brackets)	Count units	Date
Black-browed albatross	• Steeple Jason (Northwest Flat, Penthouse, S5Tip, Southeast Study and S5 Finger)	AON PFC	18/11/2022 – 19/11/2022 11/03/2023 – 13/03/2023
	NB: The NW Ridge monitoring site has been dropped from the FISMP programme due to the continued and significant encroachment of South American fur seals (*Arctocephalus australis*).		
	• Dunbar (Penguin Point South)*	Chicks	07/01/2023
Brown skua	• Steeple Jason	AOT	23/01/2023
Gentoo penguin	• Johnson's Harbour (Volunteer Green, Cow Bay and Lagoon Sands) • Race Point (Fanning Harbour and Rookery Sands) • Sea Lion Island • New Haven • Bull Point area (Bull Point and Bull Roads) • Motley Point • Low Bay • Bertha's Beach • Fox Point • Pleasant Roads • Steeple Jason (House and Neck) • Yorke Bay	AON PFC	01/22/2022 – 18/11/2022 03/01/2023 – 25/01/2023
	NB: Yorke Bay was monitored for the first time this year as part of the FISMP.		
	• Bleaker Island*	AON	28/11/2022

Imperial shag	• Motley Point • Berkeley Sound (Eagle Hill and Rugged Hill)	AON PFC	08/11/2022 – 11/11/2022 07/01/2023 – 14/01/2023
King penguin	• Volunteer Green*	PFC	October 2022
Magellanic penguin	• Gypsy Cove	Occupancy	14/12/2022
Southern giant petrel	• Steeple Jason (Neck, House Track/House and NW/S of Ridge/West)	AON PFC	18/11/2022 – 21/11/2022 11/03/2023 – 12/03/2023
	• Bleaker Island*	Chicks	15/01/2023
Southern rockhopper penguin	• Steeple Jason (Northwest Flat, S5Tip, Southeast Study and S5 Finger) • Sea Lion Island (Rockhopper Point) • Race Point (Fanning Head North and Fanning Head South) • Berkeley Sound (Diamond Cove, Rugged Hill and Eagle Hill) • Port Stephens (Stephen's Peak) NB: The NW Ridge monitoring site has been dropped from the FISMP programme due to the continued and significant encroachment of South American fur seals (*Arctocephalus australis*).	AON PFC	07/11/2022 – 20/11/2022 09/01/2023 – 22/11/2023
	• Bleaker Island*	AON	30/11/2022

Apparently Occupied Nests (AON) and Pre-fledged Chicks (PFC)

For **black-browed albatross**, **gentoo penguin**, **imperial shag**, **southern giant petrel** and **southern rockhopper penguin**, we counted Apparently Occupied Nests (AON) during the egg-laying / egg-incubation period to obtain an estimate of species-specific breeding pair numbers (**Table 2**). In addition, with the exception of imperial shag, we conducted counts of Pre-fledged Chicks (PFC), generally during mid to late chick-rearing (**Table 2**). AON and PFC counts are used to calculate breeding success (BS) (see Data Analysis).

For **king penguin**, where the breeding cycle extends over a year and consequently is not synchronised to summer breeding as with the other penguin species, the chosen unit of measure is PFC that have survived the winter, with counts conducted in October. This season, these counts were kindly provided by the Volunteer Point warden D. Patterson.

AON and PFC counts made by Falklands Conservation were conducted from drone images whenever possible. If conditions were too adverse for safe drone flying during colony visits, counts were obtained from GoPro images and/or field counts. The various methods employed for each colony are presented in **Appendices 2**–**5.**

Drone counts

DJI Phantom 4 drones were trialled in 2016 to capture aerial images of colonies under FIG Research Licence No: R13/2016. All operations were conducted at a minimum launch distance of 15 m from a colony and reaching a minimum flying altitude of 15 m when directly over colonies. Greater caution was used when operating the drone at flying seabird colonies. There was evidence that birds were aware of the drone but no evidence to suggest disturbance of breeding birds in the colonies using this method (Crofts unpubl. data). Drone use is prohibited by the landowner at Volunteer Point and therefore was not used at this site. The inbuilt camera produces 4000×3000 resolution jpeg format images giving a 94° field of view. Images were downloaded and counted using ImageJ software. Where colonies were too large to fit into a single photograph, markers or natural features were used to subdivide the colonies into sections that could be photographed. Counts were repeated a minimum of four times using at least two counters.

GoPro Counts

A GoPro HD Hero camera was pole mounted and held aloft from a vantage point to a height of approximately 5 m whilst a minimum of three photos were taken in 1920x1080 resolution in jpeg format giving a 127° field of view. Where colonies were too large to fit into a single photograph, markers or natural features were used to subdivide the colonies into sections that could be photographed. There was evidence that nearby birds were aware of the device, but no evidence to suggest disturbance of breeding birds in the colonies using this method (A. Kuepfer pers. obs.). Images were downloaded and counted using ImageJ software. Counts were repeated a minimum of four times using at least two counters.

Field counts (Tally repeated & Tally agreed)

Field counts consisted of counts made by eye. Counts made by Falklands Conservation included (a) 'Tally repeated' counts, where counts were conducted (if possible) at least three times by two or more observers using tally counters in accordance with standard methods (Thompson & Riddy 1993); (b) 'Tally agreed' counts, where count units were sufficiently small that counts could confidently be made without error on a single occasion. Counts conducted by landowners at Dunbar and Bleaker Island were single counts conducted by a single observer; counts at Fitzroy and Sea Lion Island were double counts made by a single volunteer observer.

For the purpose of this report, where multiple counting methods exist for the same colony, the data used were those that exhibited the least error between counts. Where possible the same counting method was used to calculate breeding success for each colony.

Apparently Occupied Territory (AOT)

For breeding **brown skua**, which are later nesting and easily disturbed when approached, the count unit used is Apparently Occupied Territory (AOT), classified as a territory with egg/s and or chick/s observed, or an adult sitting tightly on a nest and assumed to be incubating/brooding. AOT counts are conducted in January.

Burrow Occupancy

As **Magellanic penguins** nest in burrows, population trends for this species are based on burrow occupancy rate at an annually monitored site (Gypsy Cove). Monitoring involved a series of 4-m wide transects at ca. 100-m intervals, spanning from Engineer Point to the car park at Gypsy Cove during chick-rearing (December). Transects started at the shoreline, and ran inland, perpendicular to the shoreline, for a distance of 40 m beyond the last burrow found. GPS locations were taken for the start and end points of each transect and for the last burrow found. Burrows within transects were categorised as either 'occupied', 'unoccupied' or 'unknown' if it was not possible to determine occupancy. Burrow density was derived from each transect as number of burrows in the transect area from the start of the transect to as far as the last recorded burrow.

Contextual data

Environmental data

Global environmental conditions and sea surface temperatures are largely influenced by the natural climate phenomenon of the El Niño Southern Oscillation (ENSO). ENSO is the dominant feature of climate variability on inter-annual timescales (for description see: https://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/el-nino-la-nina/enso-description), and is known to have wide-scale impacts on marine ecosystems, including seabird distribution and demography (Surman & Nicholson 2009, Sprogis et al. 2018). Amongst others, ENSO affects patterns of wind and ocean currents, which have important implications for prey distribution and cost of travel in marine vertebrates like seabirds (Thorne et al. 2016).

We present ENSO data as environmental context for the FISMP using the Multivariate ENSO Index (MEI). The MEI is considered the most comprehensive index for monitoring and quantifying ENSO because it incorporates analysis of multiple meteorological and oceanographic factors (Suhaila 2021). Data and forecasts are taken from the Climate Prediction Center. Any atypical oceanographic features observed at the Falkland Islands were sourced from personal communications with the Falkland Islands Fisheries Department.

Anthropogenic and other impacts at colonies

Measurement of anthropogenic and other impacts involve:

1) Direct evidence of marine plastics observed in and around the colonies;

2) Signs of oiling to seabirds;

3) Evidence of entanglement or ingestion of fishing gear or other items;

4) External signs or symptoms of disease.

Data Analysis

Counts of breeding pairs (Apparently Occupied Nests (AON), Pre-fledged Chicks (PFC) and Apparently Occupied Territories (AOT) were averaged by species and colony to obtain counts as mean ± standard deviation. Breeding success (BS) was calculated as $BS = \frac{PFC}{AON}$ (i.e. number of chicks/ number of breeding pairs).

For species where we have >10 years of data (Bolker et al. 2009), we fitted long-term trend estimates (AON and BS of black-browed albatross, gentoo penguin, southern giant petrel and southern rockhopper penguin; burrow occupancy of Magellanic penguin; PFC of king penguin). For this purpose, current counts were combined with historic counts available from the FISMP and (for rockhopper and gentoo penguins) additional sites from across the Falkland Islands. Apart from Magellanic penguins, colonies with an average population size of <150 breeding pairs were discarded to reduce the influence of smaller population size stochastic fluctuations obscuring the overall trends. Breeding pair data were mean-centred to generate species-specific population indices. This involved subtracting the mean AON counts calculated for each colony across years from the individual annual count, and dividing this by the standard deviation calculated for that specific colony. Occupancy data were logit-transformed.

To assess trends across years, we fitted a series of Generalised Additive (Mixed) Models (GAM, GAMMs), using the 'gam' or 'gamm' function from the *mgcv* package in R (R Core Team 2021). The response variables (either standardised breeding population index, breeding success, or occupancy) were assumed to have either a Gaussian or a Poisson distribution. To capture the non-linear relationship between the response variables and season, we employed a cubic regression spline function. Where more than one colony was included in the model, colonies were defined as a random effect to account for autocorrelation of individual counts within colonies. The fitted models can be expressed as follows:

> Standardised breeding pop. size ~ s(Year) + (1|site), family = gaussian;
>
> Breeding success ~ s(Year) + (1|site), family = gaussian;
>
> Logit-transformed occupancy ~ s(Year), family = gaussian;
>
> Pre-fledged chicks ~ s(Year), family = poisson.

Results

A summary of counts at individual colonies is provided in **Appendices 2**–**5**. Trends are generally described as one of the following:

- Increasing – the breeding measure is clearly increasing;
- Stable-increasing – the breeding measure is either stable or possibly increasing;
- Stable – the breeding measure is clearly stable;
- Stable-decreasing – the breeding measure is either stable or possibly decreasing;
- Decreasing – the breeding measure is clearly decreasing.

Breeding seabirds

Black-browed albatross

During the 2022 season, of the five long-term colonies monitored at Steeple Jason, four showed higher than average number of breeding pairs (overall +6%; **Figure 2**), although the largest colony (S5 Finger) held the lowest count since monitoring commenced there in 2017 (-9%; **Figure 2**). Breeding success was generally close to or below the annual averages at all colonies (overall -22%; **Figure 3**). At Dunbar, chick numbers were above the annual average.

Overall, the number of breeding pairs of black-browed albatrosses at FISMP colonies was lower compared to the previous season (**Figure 5 A**). However, the fitted GAMM continues to show a steady increase in breeding pairs over time, as has been the case for the last two decades (**Figure 5 A**). On the contrary, whilst overall breeding success of black-browed albatross at FISMP colonies surpassed the rate in the previous season, results from the GAMM continue to indicate a downturn in breeding success since 2014/2015 from a stable/stable-increasing trend in the 10 years prior (**Figure 5 B**).

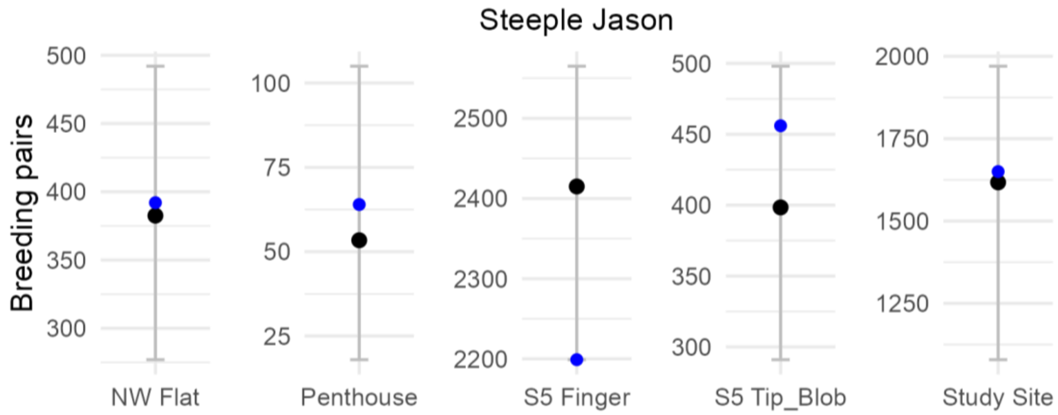

Figure 2 Black-browed albatross estimated breeding pairs at FIMSP locations, Steeple Jason. Bars indicate the minimum, maximum, annual mean (black dot), and the current season's breeding pair counts (blue dot).

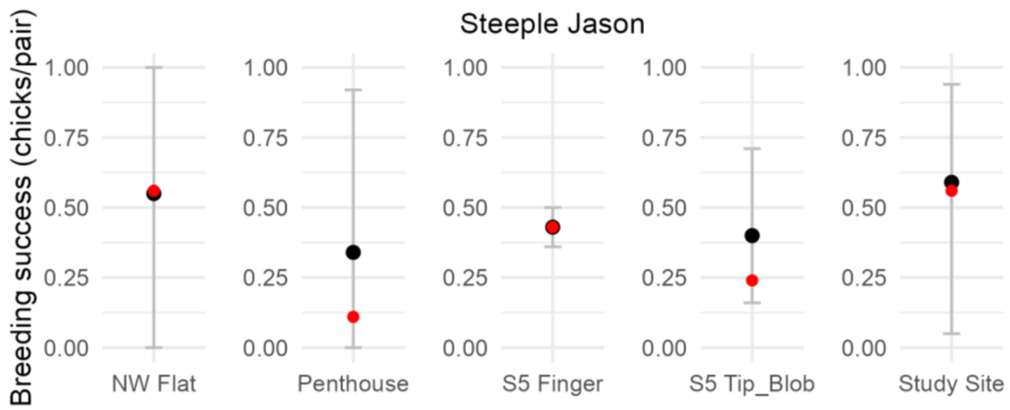

Figure 3 Black-browed albatross estimated breeding success at FIMSP locations, Steeple Jason. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding success (red dot).

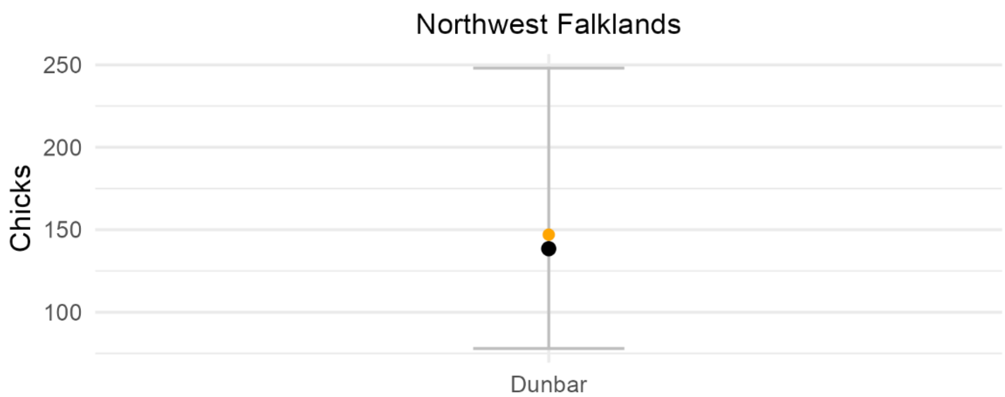

Figure 4 Black-browed albatross chicks counted at Dunbar, Northwest Falklands. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's chick counts (orange dot). Data provided by Dunbar landowners.

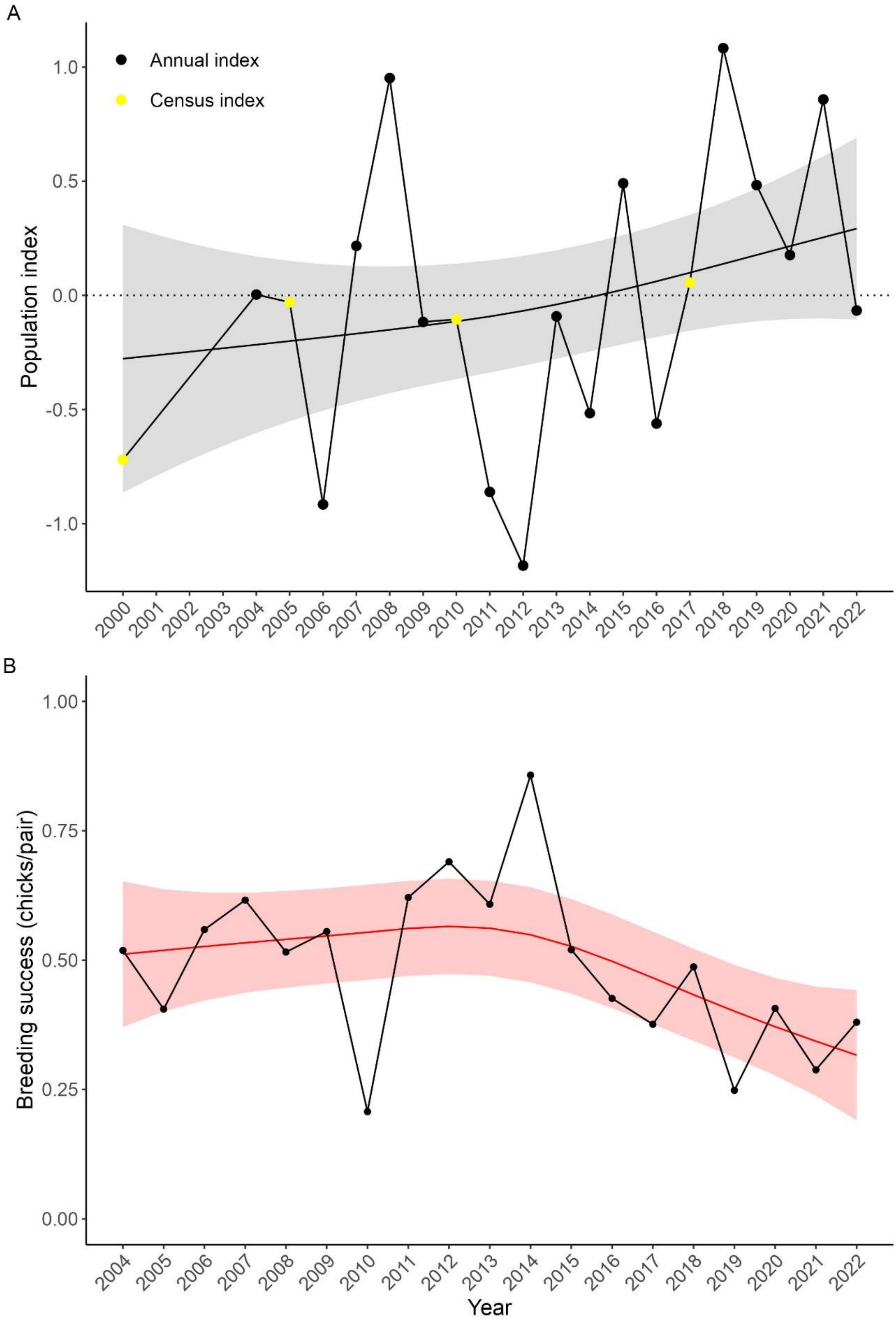

Figure 5 GAMM-based trends (mean ± 95% confidence interval) of black-browed albatross breeding population index (**A**) and breeding success (**B**), using data from FIMSP sites at Steeple Jason.

Brown skua

Apparently Occupied Territories across Steeple Jason have further increased since 2020 by c. 10% (**Figure 6**). This represents a 25% increase since the start of monitoring in 2016. Note that no data were collected in 2021.

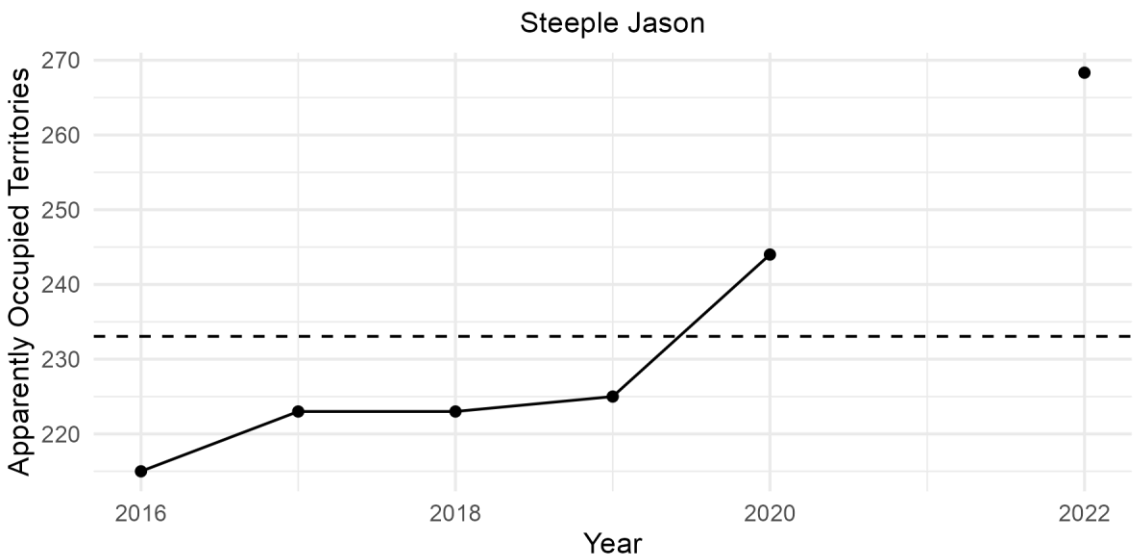

Figure 6 Brown skua Apparently Occupied Territories at Steeple Jason, 2016–2022. The dashed line represents the overall annual mean.

Gentoo penguin

Of 18 long-term gentoo penguin colonies monitored in 2022, 72% (n = 13) showed below annual average breeding pair numbers (**Figure 7**). The largest percentage reductions compared to their annual mean were seen at the Neck (Steeple Jason, -64%), Bull Point (-45%) and Low Bay (-44%) (**Figure 7**). Four colonies held above annual average breeding pair numbers, with particular large increases seen at Cow Bay (+59%) and Pleasant Road (+40%) (**Figure 7**). The colony at Yorke Bay (not plotted), was counted for the first time this season, and held 169 ± 6.98 breeding pairs and a breeding success of 1.15 ± 0.05.

Contrary to breeding pair numbers, breeding success was generally above the annual average (**Figure 8**). Particularly high breeding success compared to their annual average were found at the Neck (Steeple Jason, +115%), Sea Lion Island (+85%), Bull Roads (+82%), Bull Point (+74%) and Rookery Sands (+51%). Four colonies experience below average breeding success, with the highest reductions seen at Bertha's Beach (-12%) and Pleasant

Road (-11%) (**Figure 8**). Breeding success at Volunteer Green and Cow Bay was around the annual average, despite these colonies having lost substantial numbers of chicks, possibly following a storm in January (A. Kuepfer pers. obs., D. Patterson pers. comms.).

Overall, breeding pair numbers this year were lower compared to the previous season (**Figure 9 A**). Results from the GAMM show a continuing decline in the breeding pair index of Gentoo penguins since 2014/2015, but a fluctuating stable trend over the longer term (**Figure 9 A**).

Breeding success of gentoo penguins were on the whole above last year's rate. Over the longer-term, results from the GAMM indicate a fluctuating stable trend across years (**Figure 9 B**), with oscillations running inversely to breeding pair numbers.

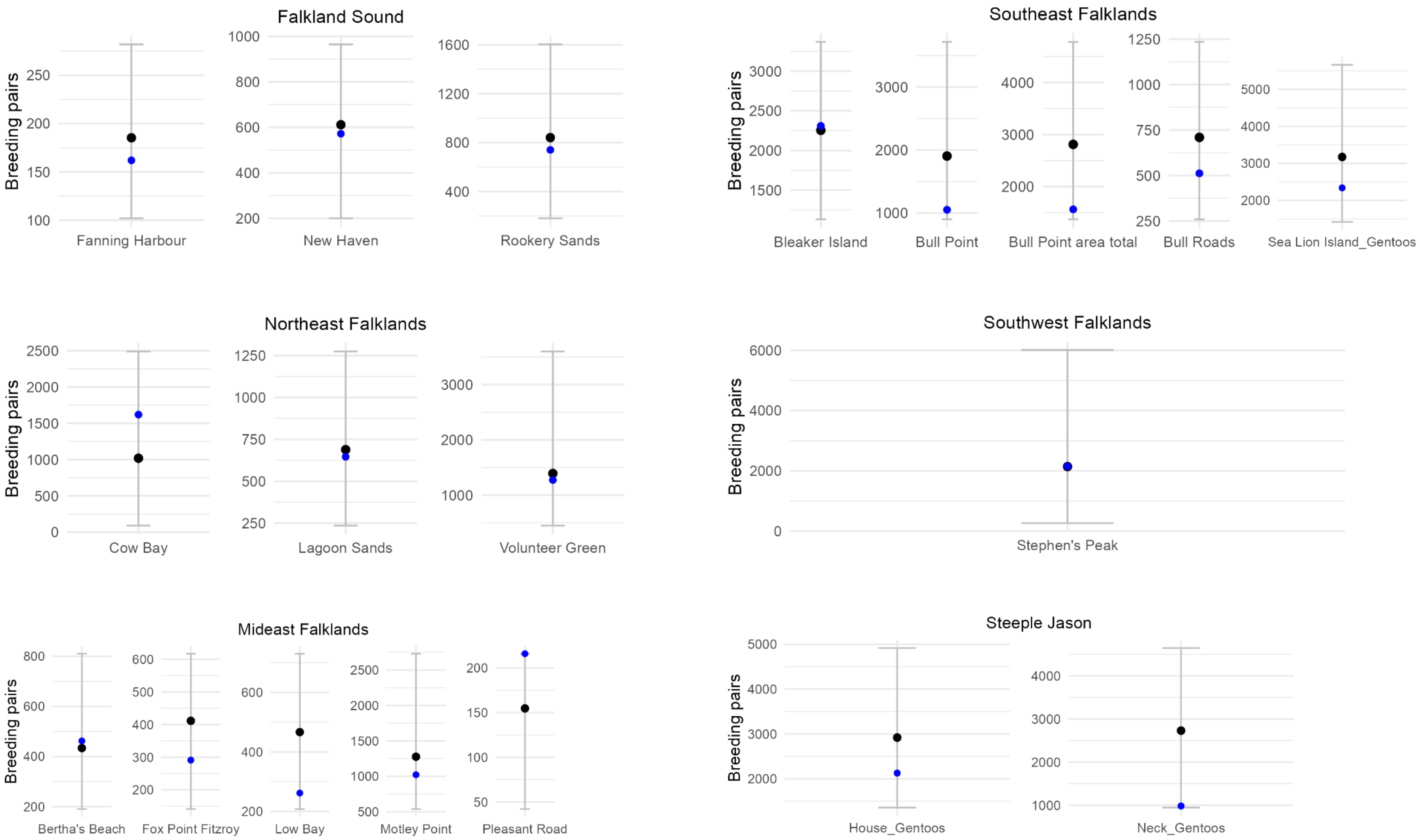

Figure 7 Gentoo penguin estimated breeding pairs at FIMSP sites and Bleaker Island. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding pair counts (blue dot). Data from Bleaker Island provided by landowners.

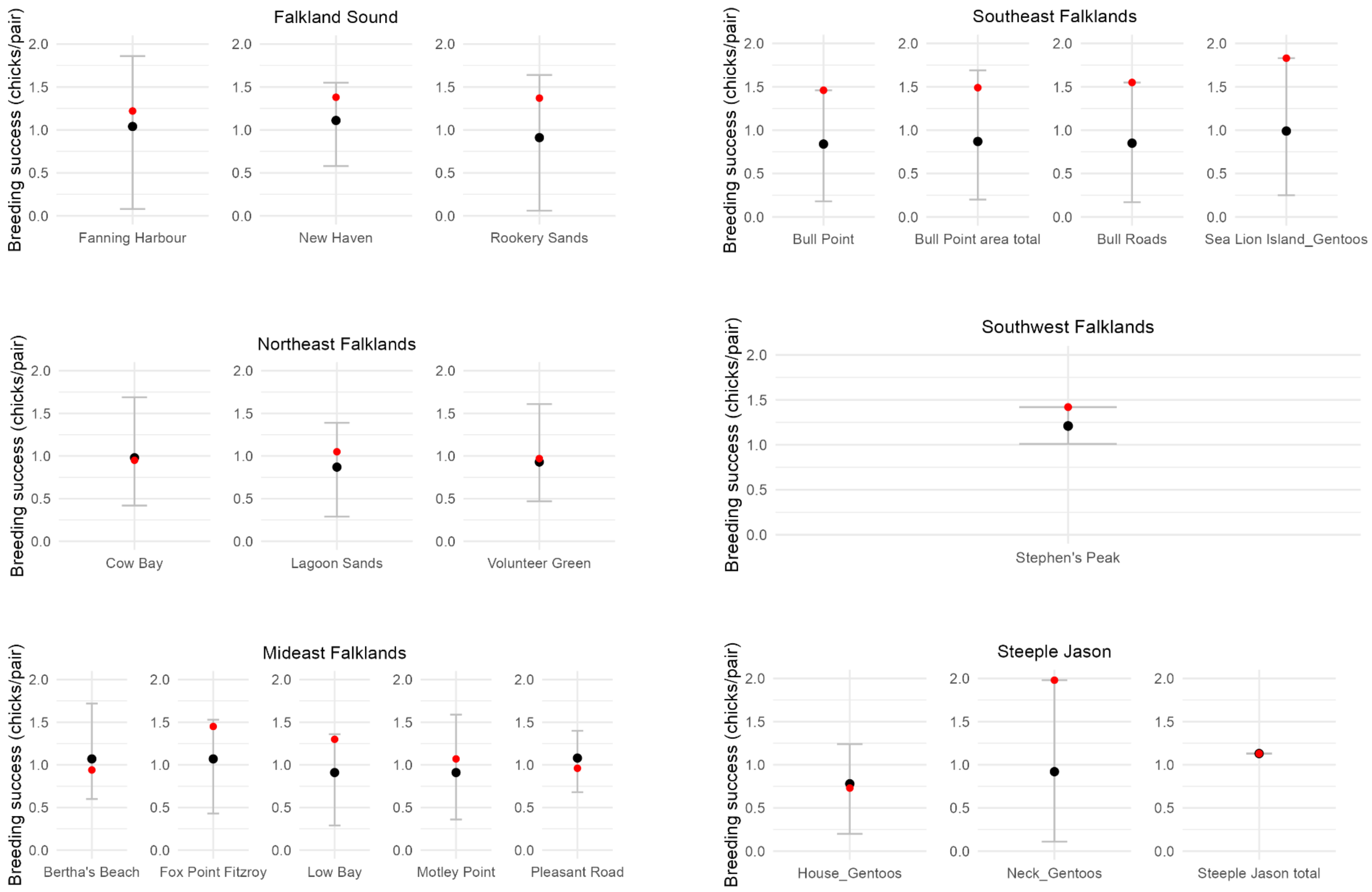

Figure 8 Gentoo penguin estimated breeding success at FIMSP sites. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding success (red dot).

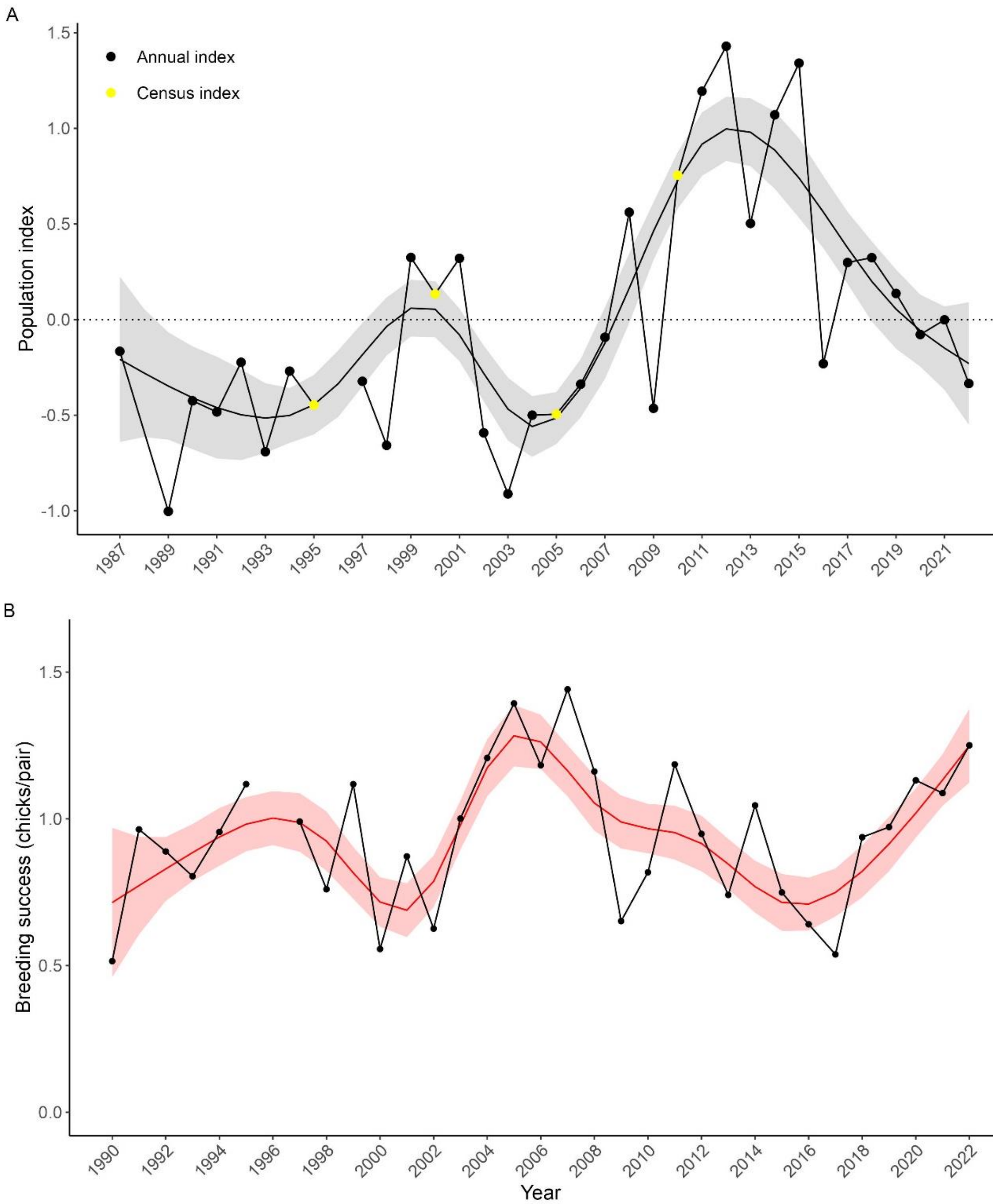

Figure 9 GAMM-based trends (mean ± 95% confidence interval) of gentoo penguin breeding population index (**A**) and breeding success (**B**), using data from sites across the Falkland Islands (n = 85).

Imperial shag

At Motely Point, counts were 32% lower this season compared to their annual average. Counts also dropped by 24% below the annual average at Eagle Hill West, but were 65% above the annual average at Eagle Hill Centre (**Figure 10**). At Rugged Hill, counts were similar to the annual average (**Figure 10**). Overall, the breeding population index based on raw data from colonies in Mideast and Northeast Falklands shows that, although counts were higher this year compared to the previous season, the longer-term pattern is currently stable/decreasing (**Figure 11**).

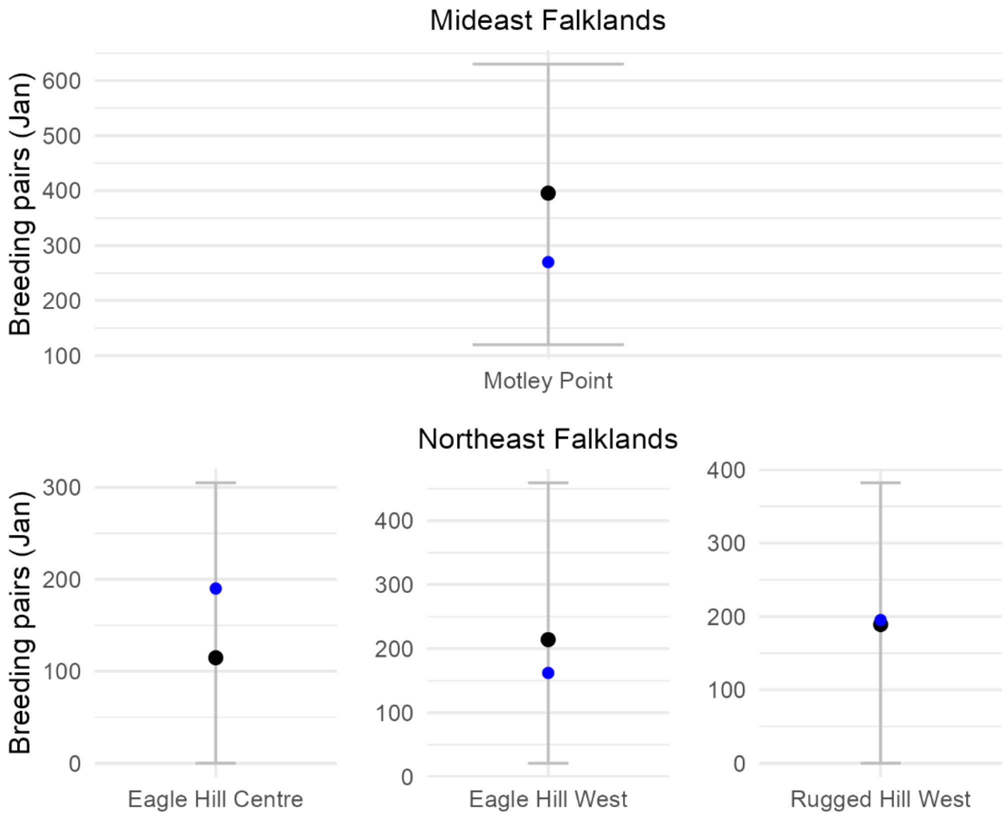

Figure 10 Imperial shag estimated breeding pairs in January at FIMSP sites. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding pair counts (blue dot).

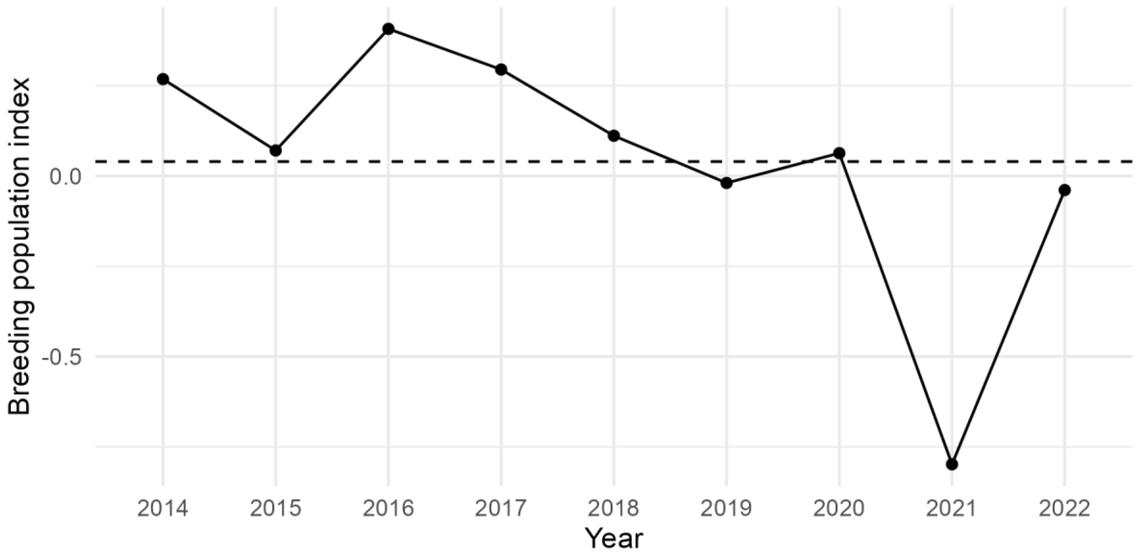

Figure 11 Imperial shag breeding population index, 2014–2022, using current and historic data from Motley Point and Berkley Sound. The dashed line represents the overall annual mean.

King penguin

Pre-fledged chicks of king penguins numbered 987 in October 2022. The GAM estimates show a strong upward trend in king penguin pre-fledged chicks since monitoring started, with periodic stable states every 5–6 years (**Figure 12**). Over the past two seasons, D. Patterson also provided counts from later in the season (April), with a minimum of 850 for the current season – approximately 10% fewer than last year (n = 944). Although direct comparison to the October counts is not appropriate due to the difference in timing, these data will still provide a valuable additional variable in the longer term.

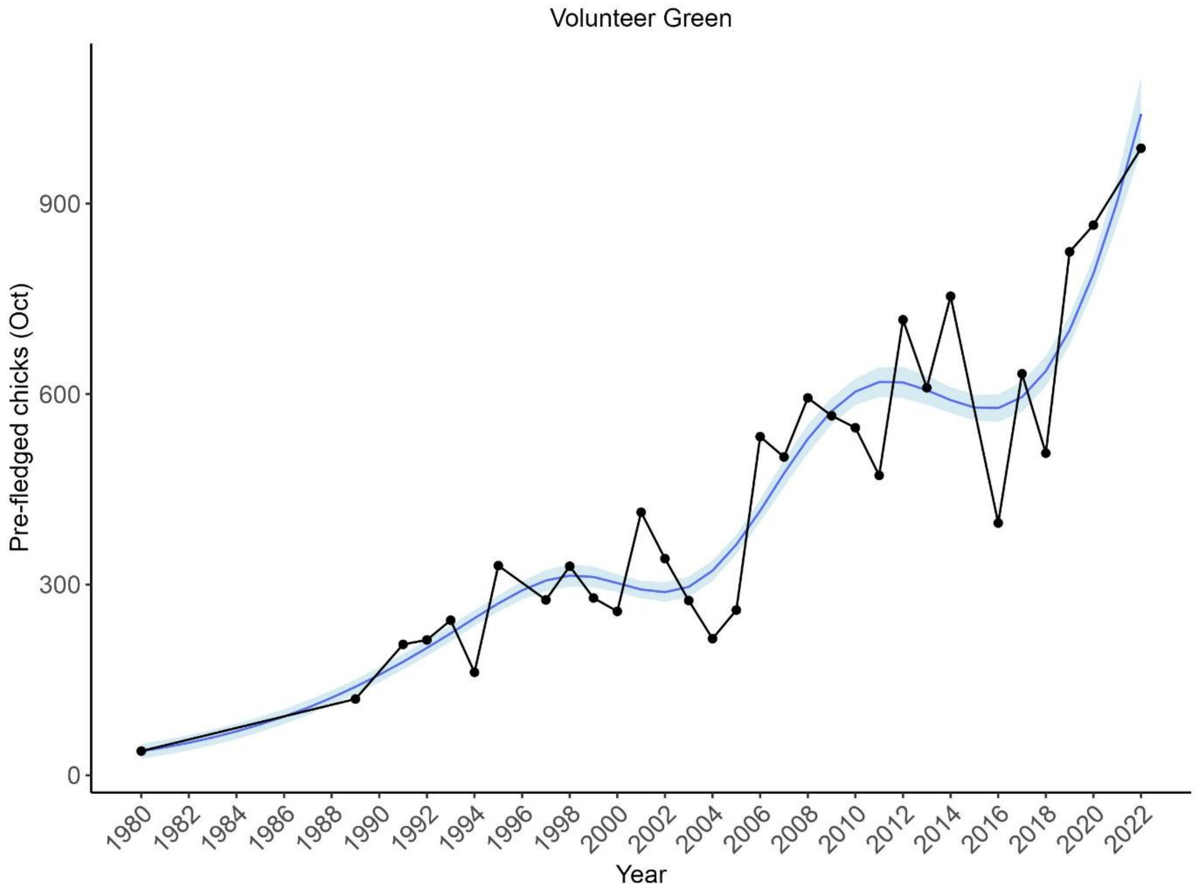

Figure 12 GAM-based trend (mean ± 95% confidence interval) of king penguin pre-fledged chicks in October at Volunteer Green.

Magellanic penguin

Thirty-two transects were carried out between Engineer Point and the Car Park at Yorke Bay, of which half (n = 16) contained occupied Magellanic penguin burrows (**Figure 13**). Taking all burrows for which there was certainty over occupancy status (n = 236), gave an occupancy rate of 22.4% – an improvement from last year (18.7%). The modelled long-term trend shows a decline since 2014/2015 following an initial increase, although the overall trend appears stable (**Figure 14**). Some caution is warranted given the relatively large confidence intervals associated with this model. Where burrows occurred, estimated densities varied substantially from 2,683–76,804 burrows/km², with an average of 22,560 ± 24,025 burrows /km². This compares with an estimated density of 8179 ± 2572 /km² last year.

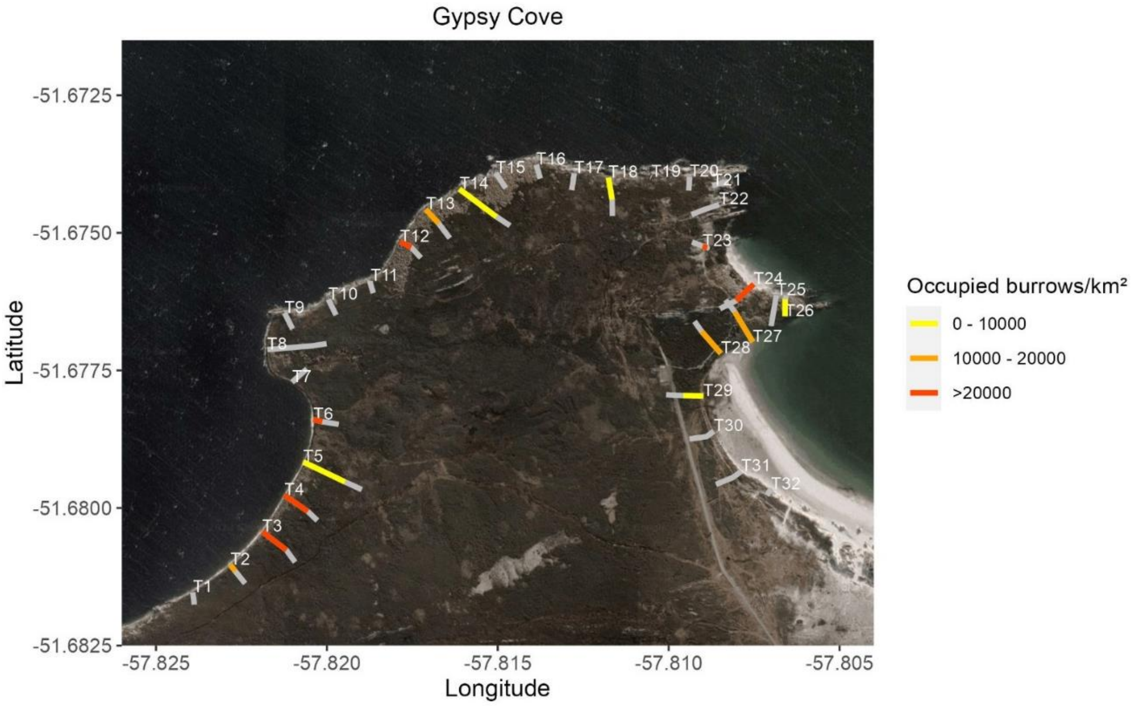

Figure 13 Transect locations for the Magellanic penguin survey at Gypsy Cove, 2022. Grey lines represent the section of transects where no burrows were found.

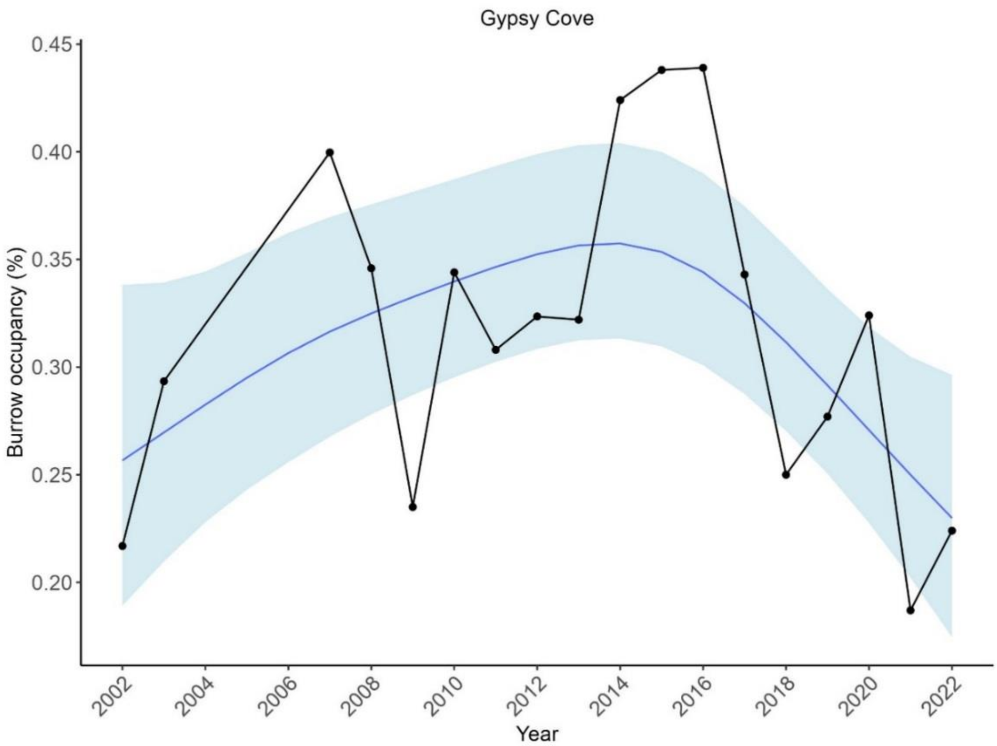

Figure 14 GAM-based trend (mean ± 95% confidence interval) of Magellanic penguin burrow occupancy at Gypsy Cove, 2002–2022.

Southern giant petrel

This season on Steeple Jason, the colony at NW/S Ridge/W continued its decline to almost zero breeding pairs (n = 3) (**Figure 15**), with no chicks raised for the second season in a row (**Figure 16**; Stanworth & Crofts 2022). On the contrary, colonies at the Neck and the House (House Track_House) saw above average breeding pair numbers (+ 8% and +10%, respectively), and above annual average breeding success (Neck: +26%; House Track_House: +150% increase) (**Figure 16**). At Bleaker Island, chick counts were 22% lower than the annual average (**Figure 17**).

Overall, the number of breeding pairs decreased compared to the previous season, whilst breeding success remained stable (**Figure 18**). Results from the GAMM continue to indicate an overall increasing/stable trend in the breeding pair index of Steeple Jason colonies (**Figure 18 A**). The estimated trend for breeding success at Steeple Jason may be stabilising, after having increased since 2014–2015 (**Figure 18 B**).

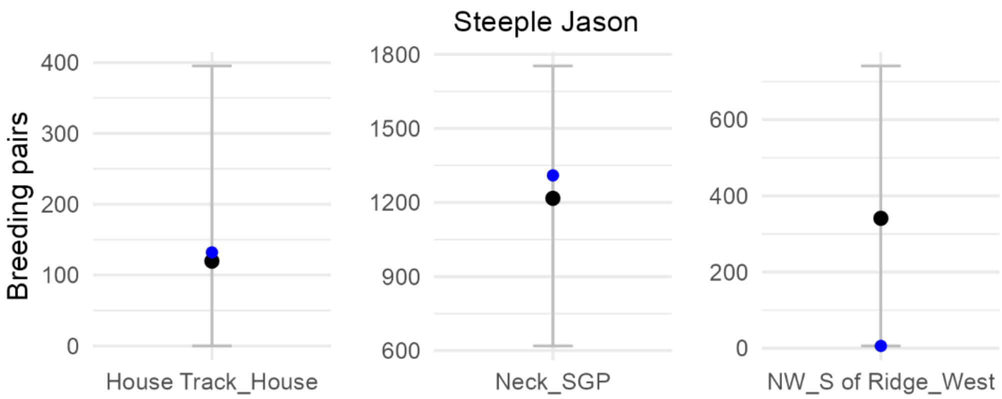

Figure 15 Southern giant petrel estimated breeding pairs at FIMSP sites, Steeple Jason. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding pair counts (blue dot).

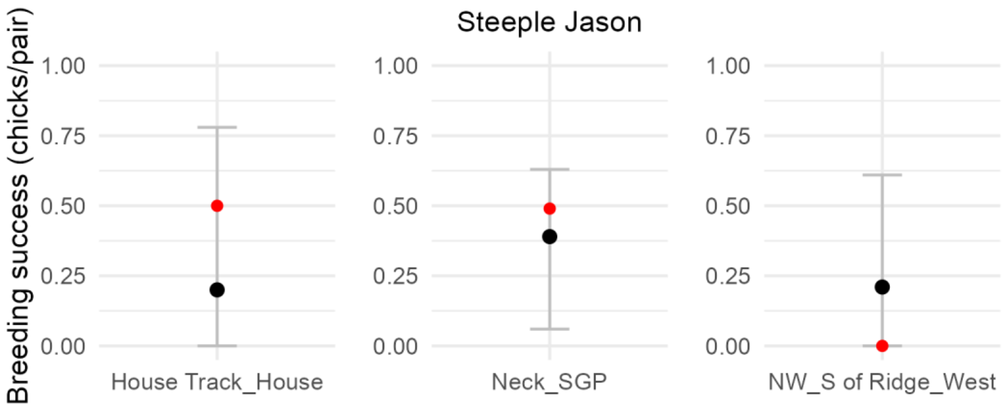

Figure 16 Southern giant petrel estimated breeding success at FIMSP sites, Steeple Jason. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding success (red dot).

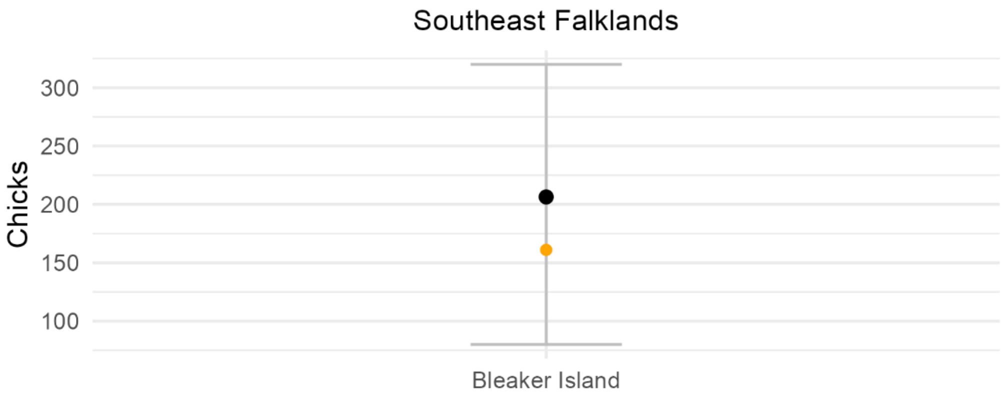

Figure 17 Southern giant petrel chicks counted at Bleaker Island, Southeast Falklands. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's chick counts (orange dot). Data provided by Bleaker Island landowners.

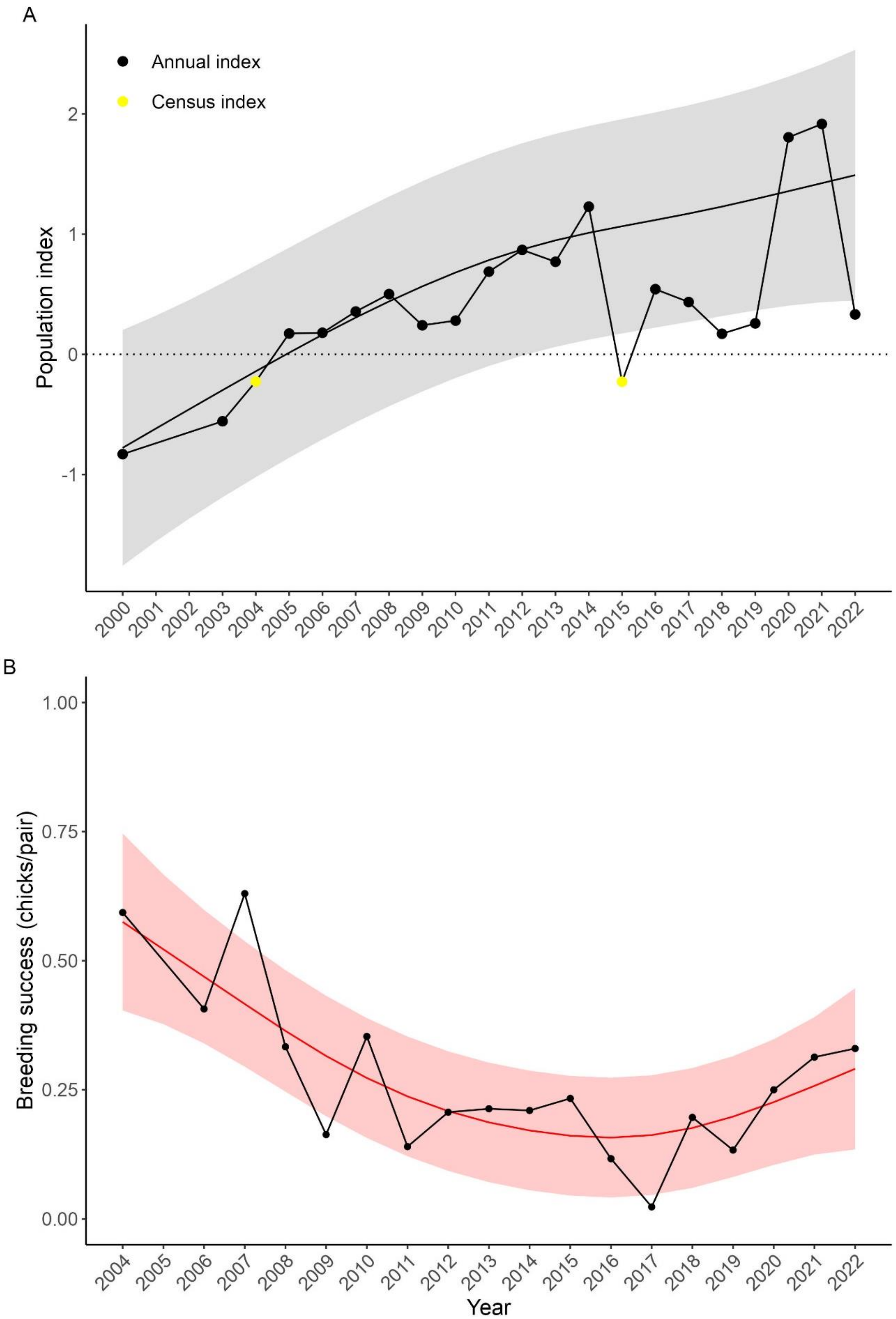

Figure 18 GAMM-based trends (mean ± 95% confidence interval) of southern giant petrel breeding population index (**A**) and breeding success (**B**), using data from FIMSP sites at Steeple Jason.

Southern rockhopper penguin

Breeding pair numbers for southern rockhopper penguins were below their annual average at all monitored sites, except Bleaker Island (+16%) (**Figure 19**). Greatest reductions, relative to their annual averages, were seen in southwest Falklands (Stephen's Peak: -54%) and at Falklands Sound colonies (Fanning Head total: -33%) (**Figure 19**).

In terms of breeding success, colonies generally performed above their annual averages, except at Sea Lion Island (-18%) and at Fanning Head total -10%) (**Figure 20**).

Overall, breeding pairs were lower compared to the previous year, although breeding success increased (**Figure 21**). The fitted trend for the breeding pair index of southern rockhoppers shows a continuing decline over the last 7–9 years; however, the long-term population index data support a fluctuating stable trend (**Figure 21 A**). The fitted trend for southern rockhopper breeding success shows a long-term continuous decline in breeding success over the last 29 years, since monitoring began, although data from recent years suggest that breeding success may be stabilising (**Figure 21 B**).

Using data from Steeple Jason alone indicates a more notable decline in the breeding pair index since 2011, with this year's value having reached a historic low (**Figure 22 A**). The fitted trend for breeding success at Steeple Jason is fluctuating stable (**Figure 22 B**).

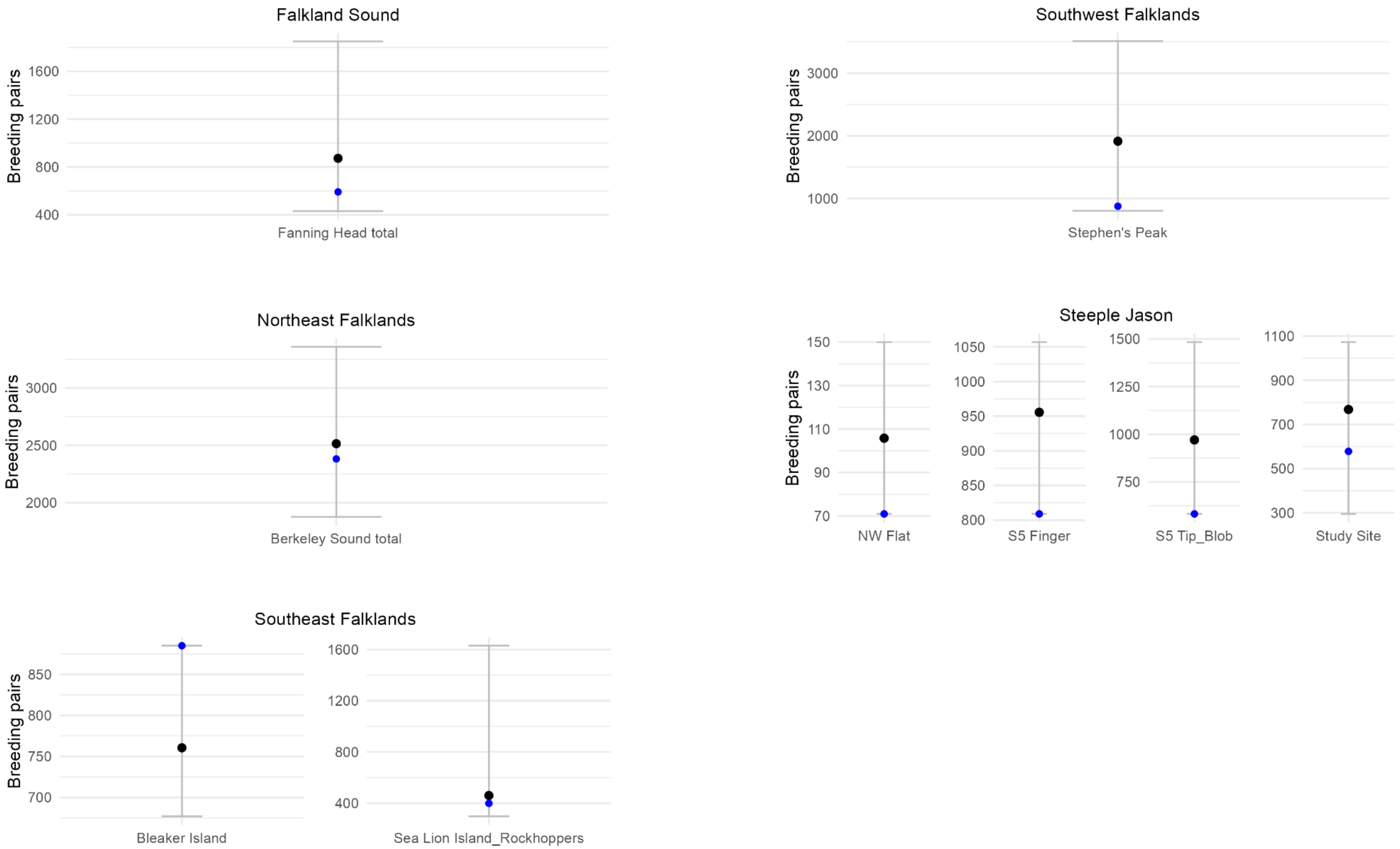

Figure 19 Southern rockhopper penguin estimated breeding pairs at FIMSP sites. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding pair counts (blue dot).

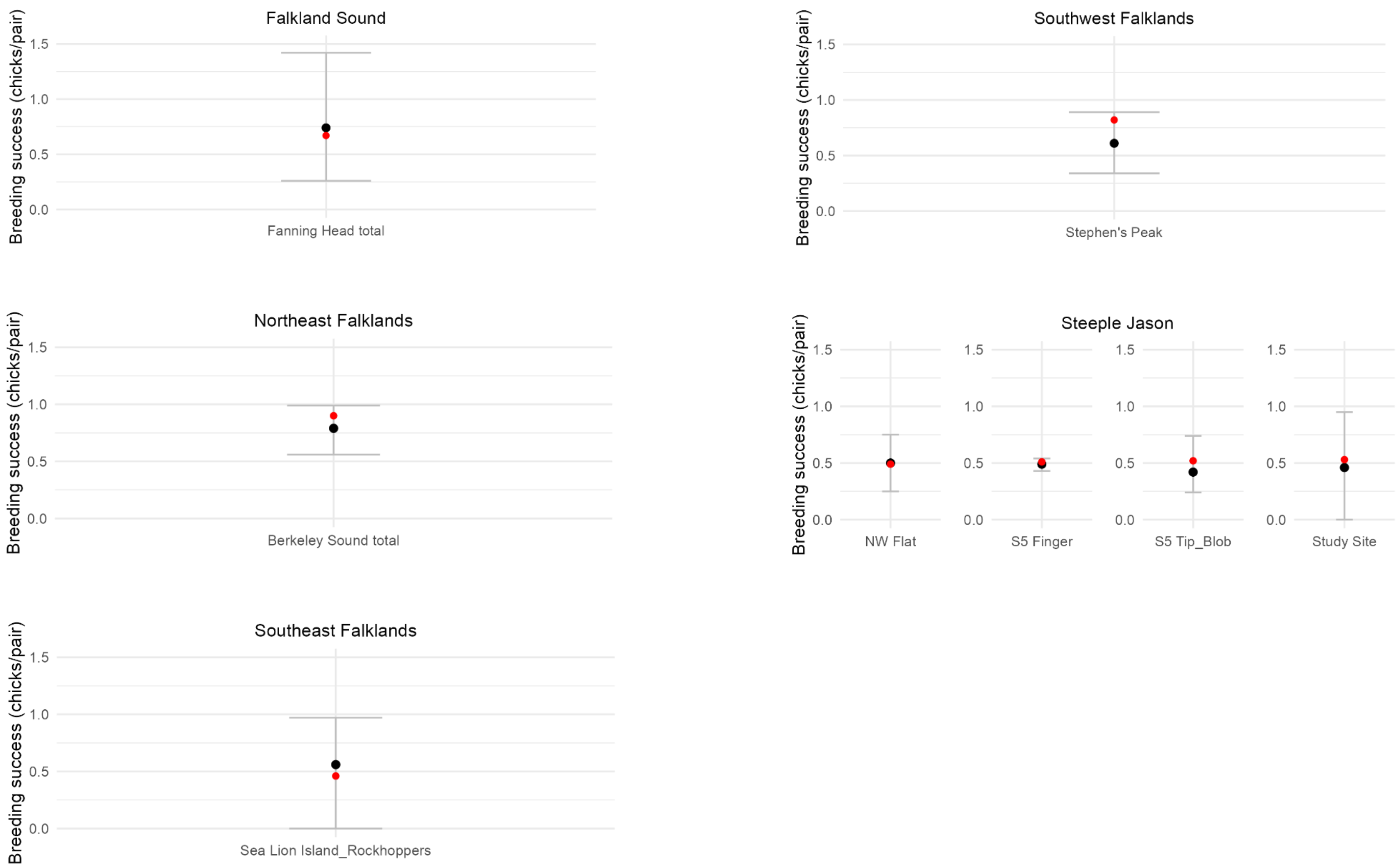

Figure 20 Southern rockhopper penguin estimated breeding success at FIMSP sites. Bars indicate the minimum, maximum, annual mean (black dot) and the current season's breeding success (red dot).

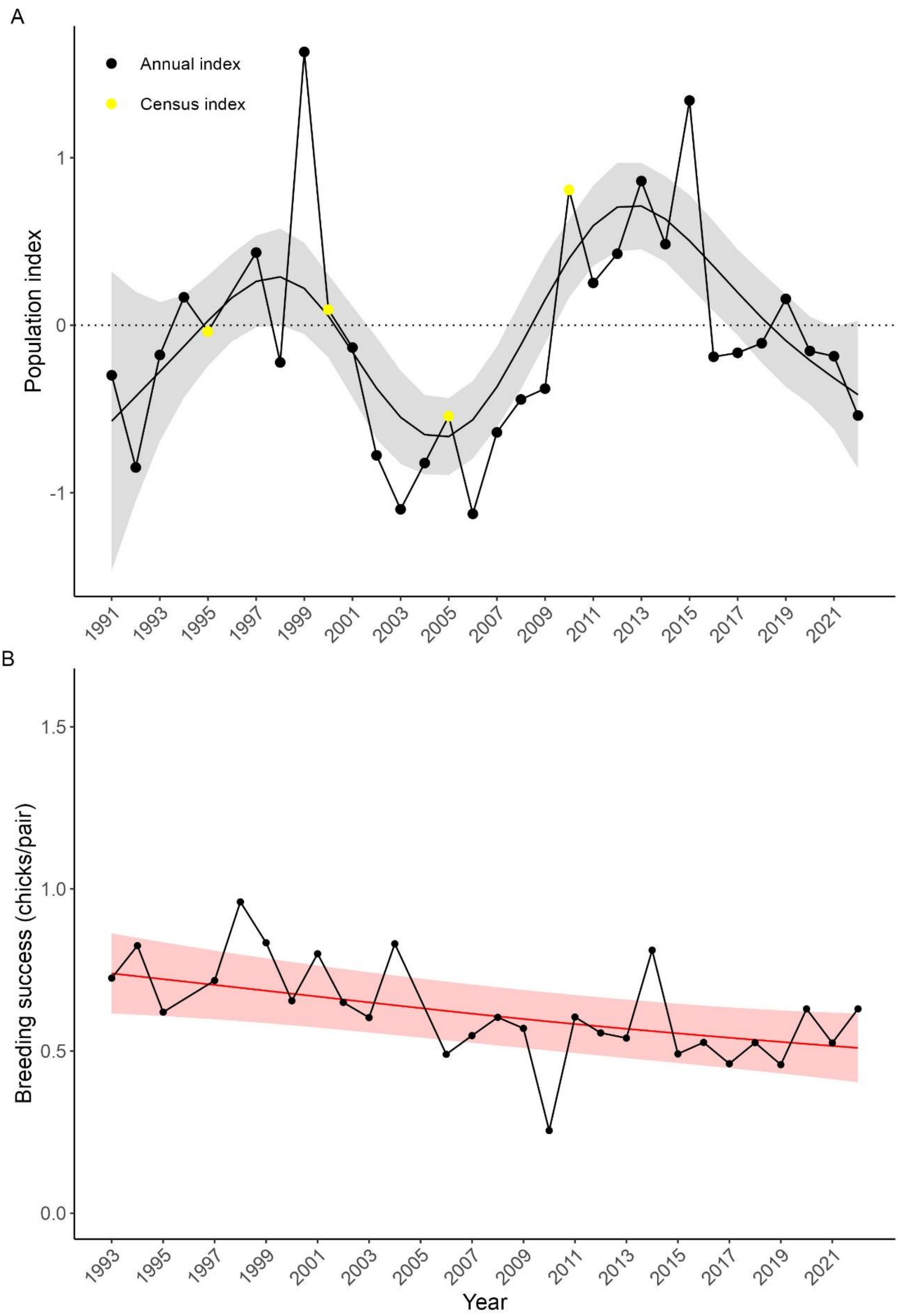

Figure 21 GAMM-based trends (mean ± 95% confidence interval) of southern rockhopper penguin breeding population index (**A**) and breeding success (**B**), using data from sites across the Falklands (n = 37).

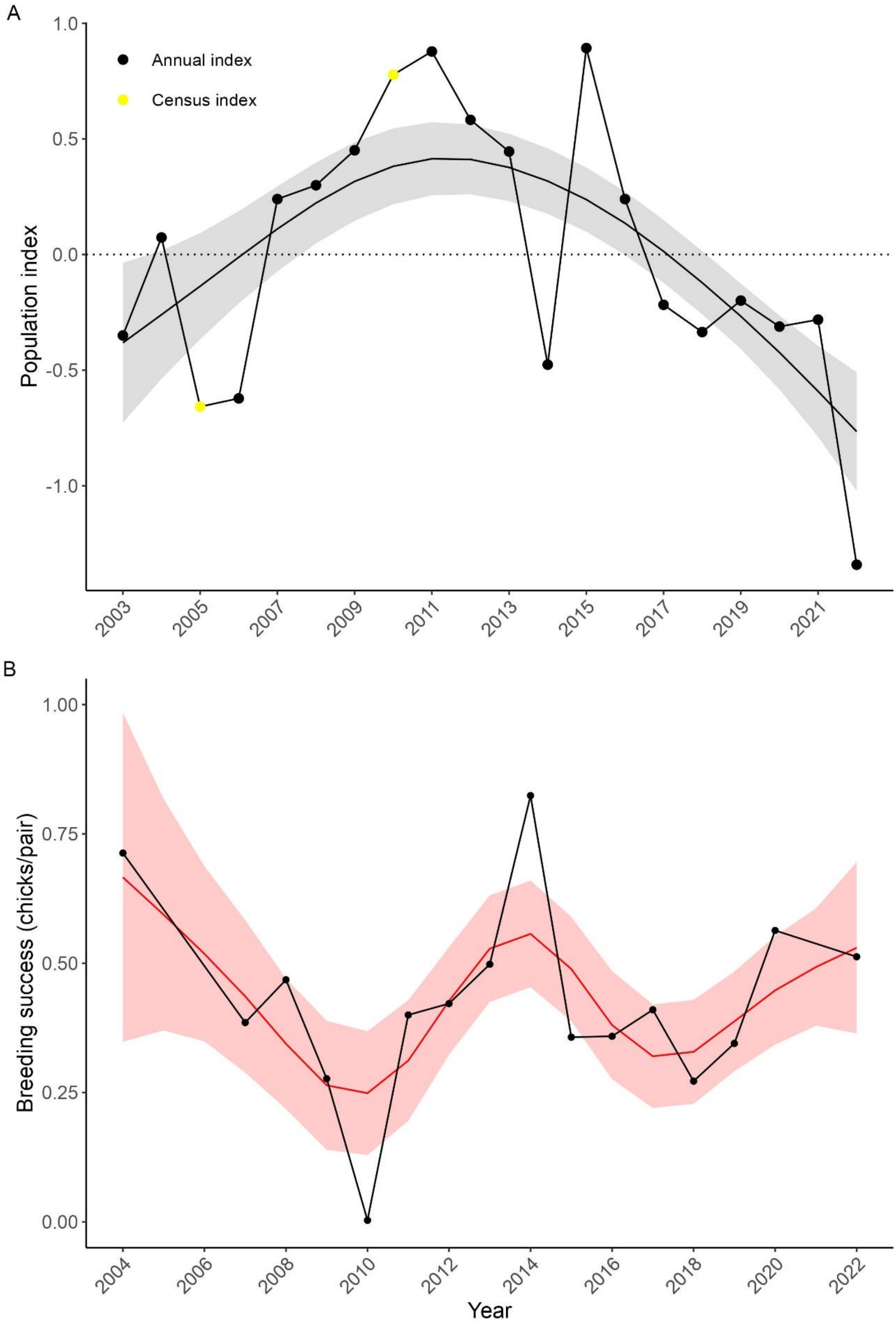

Figure 22 GAMM-based trends (mean ± 95% confidence interval) of southern rockhopper penguin breeding population index (**A**) and breeding success (**B**), using data from Steeple Jason colonies only.

Environmental data

MEI values were similar to the previous season over the period of October through to January, and indicative of strong La Niña conditions (**Figure 23**). However, February marked a turning point with values progressively increasing towards a more neutral MEI. A storm in early January likely affected the breeding success at Cow Bay and Volunteer Green (D. Patterson, pers. comm.).

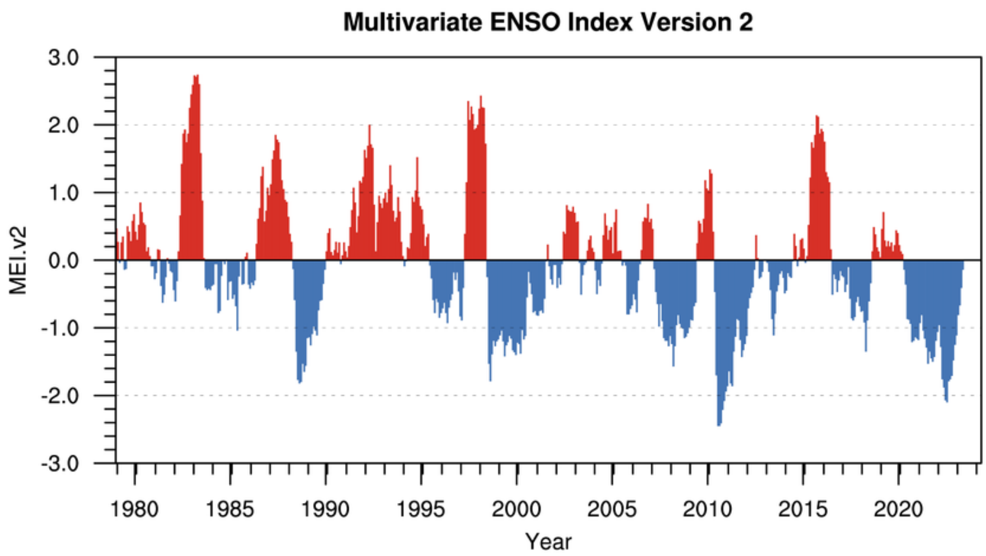

Figure 23 Bi-monthly Multivariate El Niño/Southern Oscillation (ENSO) Index (MEI.v2). Source: https://psl.noaa.gov/enso/mei/. Positive red values indicate warmer El Niño conditions; blue negative values indicate cooler La Niña conditions.

Anthropogenic and other impacts at colonies

Marine plastics

Few pieces of marine debris were noted during the 2022 FISMP fieldwork. Multiple pieces of plastics of unknown origin were found at the Port Stephen's gentoo colony and a single gentoo chick at Lagoon Sands was found entangled in marine plastics commonly used by the fishing industry (**Figure 24**).

Oiling

No oiled birds were observed at FISMP sites in 2022.

Diseases

No signs of diseases were directly observed at monitoring sites during 2022. However, multiple colonies, notably at Fitzroy and elsewhere, chicks suffered fatalities from avian pox in March (after PFC counts were made).

Figure 24 Gentoo chick entangled in marine plastics at Lagoon Sands.

Discussion

The FISMP serves to collect long-term data on seabird population breeding pairs and breeding success in the Falkland Islands. Long-term datasets are essential for assessing the health of a population, and serve as the foundation for comprehensive investigations into impacts of climatic and anthropogenic drivers on seabirds and the wider marine ecosystems (Jenouvrier et al. 2005, Ventura et al. 2021c, 2023).

Overview

During the breeding season of 2022/23, black-browed albatross, gentoo penguin, southern giant petrel, and southern rockhopper penguin all showed overall lower numbers of breeding pairs compared to the previous season, but higher rates of breeding success. Meanwhile, relative to last season, brown skua, imperial shag, king penguin and Magellanic penguin showed improved values in respective breeding units collected.

No atypical short-term environmental conditions were identified during this season that may have affected individual or multiple species. However, processes that regulate seabird population dynamics are complex, and occur on land where they breed, and at sea where they forage.

Annual fluctuations in demographic parameters can provide useful indications of shorter-term drivers, such as disease, weather events or foraging conditions. For example, many species showed a 10-year low in breeding pairs during the El Niño years of 2014/2015/2016; at Steeple Jason, a severe storm in 2010 reduced breeding success of black-browed albatross to a record low since monitoring started. However, assessing longer-term trends enables detection of both multi-annual fluctuations and gradual changes. This is particularly important as many seabirds are long-lived, and therefore long-term data series are required to detect changes in abundance (Grémillet & Boulinier 2009). The El Niño in 2014/2015/2016 resulted in an overall trend inflexion for most FISMP species (either in their breeding numbers, breeding success, or both), suggesting that the event had a more long-term effect on species. The long-term trends of each FISMP species are discussed below in the context of their global conservation status and threats.

Species-specific

Black-browed albatross

Globally, the conservation status of black-browed albatross is favourable (*Least Concern*), with the global population considered to be increasing (BirdLife International 2018a). In the Falkland Islands, where >72% of this species breeds, breeding pair data from the FISMP continue to support this trend. Reasons behind the continued increase remain speculative. Improved fishing mitigation in some fisheries, and a reduction in longline fishing effort across some of their range may explain part of the increase (McInnes et al. 2017, Kuepfer et al. 2022b, Kuepfer 2023). In addition, while discards from fisheries appear insufficient to offset poor foraging conditions during breeding, they may artificially be influencing survival rates of immatures, or body conditions of adult birds (Kuepfer et al. 2022b, Kuepfer 2023).

Unlike breeding pairs, breeding success has been on a downward trajectory since 2014/2015. Breeding success in seabirds is influenced by a wide array of extrinsic and intrinsic factors, including environmental conditions before and during breeding, as well as breeding experience of parents (Ollason & Dunnet 1978, Goutte et al. 2010, Ventura et al. 2021a). While in long-lived, late-maturing, animals like albatrosses, adult survival is predicted to be the key driver of population dynamics (Ventura et al. 2021c), sustained low productivity can eventually result in proportionally lower numbers of immature birds being recruited back into the breeding population. At this stage, it is unclear what is driving the declining trend in breeding success, and the extent to which this trend is genuine cause for concern or simply part of a natural, more long-term, oscillation.

Historically, key threats identified for the species have been dominated by fisheries bycatch mortality (Sullivan et al. 2006, Dias et al. 2019, Kuepfer et al. 2022a); however, climate change is increasingly known to pose a significant and additive threat to the species broadly (Sydeman et al. 2012, Jenouvrier et al. 2018) and in the Falklands. Climate change is resulting in higher sea surface temperatures, which negatively impact black-browed albatross breeding behaviour and breeding success (Ventura et al. 2021a c), and may restrict availability of natural prey (Quillfeldt et al. 2010, Kuepfer et al. 2022b). Extreme weather events, which are predicted to become more frequent and severe (Solomon et al. 2007), pose a further threat to the species, with a predicted ~2% annual population decline under simulated scenarios of increased storm frequencies (Ventura et al. 2023). Young albatross chicks also regularly die of an unidentified infectious disease across the Falklands (Ventura et al. 2021b). Diseases have become more prevalent globally with increased temperatures (Cohen et al. 2020).

Brown skua

Globally, the population trend for brown skua is considered decreasing, but does not approach thresholds for higher threatened status (*Least Concern,* BirdLife International 2018b). At Steeple Jason, Apparently Occupied Territories of skuas have increased by 25% since the beginning of monitoring in 2016. This increase is particularly significant given the lack of observed pairs in key colony areas at Steeple Jason in 2012 (A. Stanworth pers. obs.). However, this trend opposes trends reported from other sites within the Falkland Islands. On New Island, which likely represented the largest skua population in the Falklands, the species sharply decreased by 47% between 2004 and 2009 (Catry et al. 2011). Potential declines in breeding success have also been reported from Sea Lion Island (Galimberti & Sanvito 2020).

Causes for declines may be multi-fold and site-specific. New Island has seen an increase in the population of striated caracara (*Phalcoboenus australis*), which represents both a predator and a competitor of skuas (Catry et al. 2008, 2011). At Sea Lion, where the caracara population has remained stable, skua declines may be linked to unfavourable foraging conditions (Galimberti & Sanvito 2020).

The skua in the Falklands represents a sub-species *C. antarctica antarctica* of the brown skua *C. antarctica*. Despite the near-endemic status of this sub-species, it remains severely understudied. Additional resources would be required to improve our understanding of the population patterns and trends associated with this species.

Gentoo penguin

The global population of gentoo penguin is considered stable (*Least Concern,* BirdLife International 2020c). The FISMP data suggests that the Falkland Islands population is consistent with this trend, inferring a stable breeding population with stable/increasing breeding success.

Local gentoo breeding pairs and breeding success are both exhibiting oscillating patterns across years. The inverse relationship between the two breeding parameters suggests potential density-dependent regulatory factors at play. Fluctuations in seabird populations have been linked to climate oscillations (Irons et al. 2008). As climate effects can be density dependent (Searle et al. 2022), it is important to account for both density dependence and climate variation when predicting the impact of climate change on this population (see e.g. Jaatinen et al. 2021).

Environmental changes driven by regional or global processes such as El Niño and wider climate change are a threat to this species (BirdLife International 2020c, this report). Changes influencing local oceanography, such as frontal positions can effect food availability and in turn influence breeding pair numbers (Baylis et al. 2012, Handley et al. 2016). Harmful algal blooms (HAB) were attributed as the cause of the paralytic shellfish poisoning incident that resulted in a major gentoo penguin mortality event in the Falkland Islands in 2002 (Pistorius et al. 2010), and incidents of HAB are predicted to increase in a warming climate (Gobler 2020). A significant population down-turn in 2016 was linked to both disease incidence and food availability aligning with a strong El Niño event in the preceding season (Crofts & Stanworth 2017).

Industry interactions may also pose localised threats to this species, specifically oil spills (Lynch 2013) and disturbance from tourism resulting in decreased breeding productivity (Trathan et al. 2008, Dunn et al. 2019). Gentoo penguins also appear to be the most susceptible species to fisheries bycatch in the Falkland Islands fishery, although overall penguin bycatch in the Falklands is rare (reviewed in Crawford et al. 2017, Kuepfer et al. 2018). Egg harvesting also takes place under licence in the Falkland Islands.

Imperial shag

Globally, this species has a very large range, and the population is not believed to be decreasing sufficiently rapidly or be of small enough size to be evaluated as anything other than *Least Concern* (BirdLife International 2018c, see also Yorio et al. 2020). However, the taxonomy of imperial shag is complex, and the global assessment combines numerous sub-species (BirdLife International 2018c). Therefore, a splitting of the taxonomy could affect the future conservation status of the imperial shag in the Falkland Islands, where monitored sites continue to suggest a general decreasing trend. However, the currently monitored sites are likely to be extremely limited in their ability to indicate national trends, and therefore information on the Falklands Island population of this species is limited.

Monitoring is made difficult by colony locations, but also by the bird's breeding ecology (see also Yorio et al. 2020). The species' breeding pattern exhibits two distinct peaks within a single season, with birds laying in both spring and summer. Furthermore, assessing reproductive success is unpractical because birds often nest in large colonies, either individually or alongside other species, and accessing nests would cause significant disturbance. The species also sees regular establishment and extinction of individual colonies, thus adding further challenges to tracking population dynamics through time.

Being largely dependent on coastal marine environments, the species is subject to increasing pressures from human activities and climate-mediated changes (Yorio et al. 2020). Amongst others, increasing frequency and severity of extreme weather, disease outbreaks, competition for food, or predation pressure on eggs and chicks from predatory birds like brown skua and southern giant petrel are all threats likely to increase in a changing climate (see e.g. Sherley & Ludynia 2012, BirdLife International 2015, Yorio et al. 2020). Accessible colonies can also be affected by human disturbance resulting from unregulated visitation (Yorio et al. 2001).

King penguin

Globally, this species is thought to be increasing with an estimated 1.1 million pairs breeding annually (*Least Concern,* BirdLife International 2020a). The relatively small Falklands' population occupies the northern limits of the global range for this species, but the continued increase in the population at Volunteer Green is consistent with the global trend.

Increases in the Falkland Islands' population may be related to immigration from the much larger population at South Georgia, improved feeding conditions (Pistorius et al. 2012), or other factors increasing survival or productivity such as suitable feeding conditions. While threats, particularly natural predators, are present at this colony, they are currently insufficient to impede the population's growth.

Volunteer Green represents the Falklands largest colony, although much smaller colonies typically consisting of <5 birds exist elsewhere in the Falkland Islands, usually in association with gentoo penguins. During an archipelago-wide census (2005/06), eight king penguin fledglings were observed at six other localities (Pistorius et al. 2012). In the majority of instances, however, breeding at these sites is unsuccessful. The reasons for this remain unclear; however, elevated (natural) predation pressure in the absence of the protection of a larger colony may be a factor.

Magellanic penguin

Globally, this species is considered stable or slowly declining, with the IUCN Red List assessment noting population fluctuations in the species (*Least Concern,* BirdLife International 2020d). The Falkland Islands represents the south-eastern limit of the Magellanic penguin's breeding range (Woods & Woods 1997). At Gypsy Cove, the burrow occupancy rate has also been fluctuating, with the estimated trend initially increasing and subsequently (since 2017) more sharply decreasing. The overall trend currently still suggests a mostly stable situation, with no clear evidence of long-term declines. Historic data at other sites in the Falklands show higher occupancy rates around 2000 with a subsequent decline in occupancy over a 7–8 year period before a recovery period (Stanworth & Crofts 2022). It is therefore possible that the trend observed at Gypsy Cove represents part of a more long-term oscillation pattern.

In Argentina, Magellanic penguins have been shown to be threatened by climate change, including as a result of increased reproductive failure in the face of more frequent and intense storms (Boersma & Rebstock 2014). Further, the species may also be susceptible to loss of suitable habitat as a result of flooding or grazing. Vegetation cover contributes positively to Magellanic breeding, because it reduces adults from exposure during incubation, and provides eggs and chicks with cover from predation (Stokes & Boersma 1998). In the Falkland Islands, Tussac grass (*Poa fabellata*) habitats is a favoured habitat for Magellanic penguins. Exclusion of grazing in colony areas at Gypsy Cove has allowed recovery of tussac, thus reducing the identified threat of habitat loss. Finally, although the issue of fishery bycatch seems negligible for the species in the Falkland Islands fisheries (Kuepfer et al. 2018), it has been identified as a threat elsewhere across their non-breeding range (González-Zevallos & Yorio 2006, Crawford et al. 2017).

Southern giant petrel

Globally, southern giant petrels were downgraded to *Least Concern* in 2009, and recent data indicate the global trend is still increasing (BirdLife International 2018d). The Falkland Islands hold over 40% of the world's breeding southern giant petrel, of which 8% breed on Steeple Jason (Stanworth & Crofts 2017). Breeding pair data from the FISMP are consistent with the global trend. Breeding success, on the other hand, has been declining since 2014/15, although this seems to now be stabilising.

Until recently, an increasing breeding population and decreasing breeding success suggested a limiting factor on productivity, such as for example through resource limitations (see also black-browed albatross). Like most seabirds, southern giant petrels are central place foragers during the breeding season, and therefore are more susceptible to inter- and intra-specific competition for local resources during this period. Opportunities to assess breeding performance at a broader scale for the Falklands' population would be beneficial, as this may be a site-specific issue.

Historically, key threats of southern giant petrel included hunting (Williams 1984), and fisheries bycatch (Sullivan et al. 2006, BirdLife International 2018d). However, improved protective laws on land and mitigation measures in fisheries means that these threats have been virtually eliminated (BirdLife International 2018d). Other threats include ingestion of marine plastic debris and oil spills at sea (BirdLife International 2018d). On land, feral cats and rats, as well as habitat degradation from introduced rabbits and sheep have historically shown to pose a threat to this species elsewhere (Elliott 1957).

Southern rockhopper penguin

The southern rockhopper penguin is categorised as *Vulnerable* on the IUCN Red List, making it the only FISMP species to hold an unfavourable conservation status (BirdLife International

2020b). Southern rockhopper penguin populations have declined rapidly from large abundance in the first half of the 20th century, and the global population is suspected to continue to decline at a rapid rate (BirdLife International 2020d).

In the Falkland Islands, the breeding population appears to be stable across the islands, but showing signs of declines at Steeple Jason, which held an estimated 38% of the national breeding population in 2010. This season, the Steeple Jason population index showed a historic low (since the start of monitoring), which is cause for concern, should this pattern continue. Breeding success appears stable at Steeple; across the Falklands, the trend has been declining, although data from more recent years are indicative that the trend may be stabilising.

A key driver behind the long-term declines of rockhopper, globally, is believed to be reduced food availability linked to warming sea temperatures (Crawford et al. 2008, Dehnhard et al. 2013, BirdLife International 2020b, although see e.g. Raya Rey et al. 2014). Specifically in the Falklands, warming temperatures have been related to delayed breeding, lighter eggs and likely reduced breeding success (Dehnhard et al. 2015a b). Other key threats faced by the local southern rockhopper population as a result of the climate crisis and anthropogenic activities include climate-mediated increases in severe weather events (Demongin et al. 2010), diseases and HABs (Gobler 2020), fishery-mediated changes to food-webs (Hilton et al. 2006), and oil pollution (Falklands Conservation 2012).

Implications for management

Outlook

Whilst a number of threats manifest at specific seabird colony locations in the Falklands, the most significant and urgent overarching threat to seabirds in the Islands is the continuing climate crisis. Under a continuing climate crisis scenario, studies support the prospect of elevated existing pressures on land and at sea such as through increased severe weather events; alterations to prey availability as a consequence of warming seas and changes to ocean circulations; increase in infectious diseases; and loss of suitable breeding habitat as a result of drought, erosion or flooding (Crawford et al. 2008, Cohen et al. 2014, 2020, Ventura et al. 2021a, 2023). El Niño events, which appear to negatively affect breeding seabirds in the Falklands, are predicted to increase with climate change (e.g. Wang et al. 2019). Even relatively small changes in the occurrence and severity of threats could have significant and national-scale effects on seabird populations in the Falklands such as predicted by Ventura et al. (2023), and such as has been experienced during the recent Avian Influenza epidemic, which has not yet reached the Islands.

Conservation

Concerningly, few of the climate crisis threats to seabirds can simply be avoided. Resilience of populations can, and is, being increased at colonies by predator removal, disturbance reduction, habitat improvement and biosecurity measures. Changes in the marine environment which are most likely to impact populations are difficult to mitigate; however, long-term prospects for seabird populations in the Islands are likely best served by measures to mitigate the climate crisis. By protecting carbon- and species- rich habitats, carbon release can be actively reduced (Bax et al. 2022). Avoidance of impacts on inshore areas, and prioritising an ecosystem-based approach to fisheries management in offshore areas, would reduce additive effects from anthropogenic pressures on fragile ecosystems. A national commitment to decarbonisation would tackle at its source the greatest threat to the valuable seabird populations in the Islands and globally.

Acknowledgements

The continuation of the FISMP is dependent on access to seabird colonies. Falklands Conservation would like to thank the many landowners/managers who have allowed us to conduct fieldwork on their land, including the Wildlife Conservation Society, Falkland Islands Government, Sea Lion Island, Port Stephens, Fitzroy, Race Point, Johnson's Harbour, Goose Green, Walker Creek and North Arm. We thank Derek and Trudi Patterson, Rob McGill, Mike Pole-Evans, Alec Hazell, and Mike Clarke for logistical support, and the many volunteers who participated in data collection, particularly Mike Morrison for his long-standing support. We would also like to thank Derek Patterson and landowners at Dunbar (Hugues and Marie-Paul Delignieres) and Bleaker Island (Mike, Phyl and Nick Rendell) for providing their survey data and allowing it to be included within the report. Thanks to Brontee Evans, Glenn Welch, Janna Biesiot, Peter Hoyer, Hamish McKee, Olli Lawson and Brendon Lee for helping to count seabirds from drone images. Thanks to Francesco Ventura for sharing R code for analysis. The FISMP is made possible with financial support of the Falkland Islands Government through the Environmental Studies Budget.

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Appendix

Appendix 1: Count information

Site	AON Dates	AON Counters	PFC Dates	PFC Counters
Bertha's Beach	05/11/2022	Morrison M	06/01/2023	Morrison M
Bull Point	10/11/2022	Kuepfer A, Munro G, Hoyer P, Stanworth N, Jackson F, Lawson O	06/01/2023	Kuepfer A, Lee B, Lawson O, Evans B
Bull Roads	10/11/2022	Welch G, Kuepfer A	06/01/2023	Evans B, Kuepfer A
Cow Bay	09/11/2022	Harte E, Kuepfer A	14/01/2023	Kuepfer A, Lawson O
Diamond Cove	08/11/2022	Kuepfer A, Hoyer P	14/01/2023	Kuepfer A, Lee B, Evans B
Eagle Hill Centre	08/11/2022	Kuepfer A, Hoyer P	13/01/2023	Kuepfer A, Lee B
Eagle Hill East	08/11/2022	Kuepfer A, Hoyer P	13/01/2023	Kuepfer A, Lee B, Evans B
Eagle Hill West	08/11/22, 09/11/22	Hoyer P, Kuepfer A, Welch G	13/01/2023	Kuepfer A, Lee B, Evans B
Fanning Harbour	07/11/2022	Harte E, Kuepfer A, Hoyer P	10/01/2023	Kuepfer A, Lawson O
Fanning Head North	07/11/2022	Kuepfer A, Hoyer P	10/01/2023	Kuepfer A, Evans B
Fanning Head South	07/11/22, 10/11/22	Kuepfer A, Lee B, Biesiot J	10/01/2023	Kuepfer A, Evans B
Fox Point Fitzroy	15/11/2022	Morrison M	06/01/2023	Morrison M
House Track_House	18/11/2022	Lawson O, Kuepfer A	11/03/2023	Lawson O, Kuepfer A
House_Gentoos	18/11/2022	Lawson O, Kuepfer A	20/01/2023	Evans B, Kuepfer A
Lagoon Sands	09/11/2022	Harte E, Kuepfer A	15/01/2023	Kuepfer A, Evans B, Lee B
Low Bay	12/11/2022	Kuepfer A, Stanworth N, Lawson O	08/01/2023	Kuepfer A, Lawson O
Motley Point	11/11/2022	Kuepfer A, Lawson O, Stanworth N, Welch G	07/01/2023	Kuepfer A, Lawson O, Welch G
Neck_Gentoos	18/11/2022	Lawson O, Kuepfer A	20/01/2023	Evans B, Kuepfer A
Neck_SGP	19/11/22, 21/11/22	Kuepfer A, Lawson O, Sanchez N	11/03/2023	Riaz J, Lawson O, Kuepfer A
New Haven	12/11/2022	Kuepfer A, Hoyer P	08/01/2023	Evans B, Kuepfer A, Lawson O, Lee B
NW Flat	18/11/2022	Lawson O, Kuepfer A	22/01/23, 12/03/23	Lawson O, Kuepfer A, Biesiot J
NW_S of Ridge_West	18/11/2022	Sanchez N, Lawson O	12/03/2023	Kuepfer A, Morris Z
Penthouse	18/11/2022	Kuepfer A, Harte E, Sanchez N	13/03/2023	Kuepfer A, Biesiot J
Pleasant Road	01/11/2022	Morrison M	03/01/2023	Morrison M
Rookery Sands	07/11/22, 15/11/22	Jones J, Harte E, Kuepfer A	10/01/2023	Kuepfer A, Lawson O, McKay H, Evans B
Rugged Hill Centre	08/11/2022	Kuepfer A, Hoyer P	14/01/2023	Kuepfer A, Welch G
Rugged Hill East	08/11/2022	Kuepfer A, Lawson O	14/01/2023	Kuepfer A, Lee B, Evans B
Rugged Hill West	08/11/2022	Kuepfer A, Hoyer P	14/01/2023	Kuepfer A, Biesiot J, Welch G
S5 Finger	18/11/2022	Kuepfer A, Lawson O	22/01/23, 11/03/23	Lawson O, Stanworth A, Morrison M, Kuepfer A
S5 Tip_Blob	18/11/2022	Lawson O, Kuepfer A	22/01/23, 11/03/23	Lawson O, Stanworth A, Kuepfer A, Morrison M
Sea Lion Island_Gentoos	11/11/2022	Morrison M	08/01/2023	Morrison M
Sea Lion Island_Rockhoppers	10/11/2022	Morrison M	09/01/2023	Morrison M

Stephen's Peak	15/11/2022	Kuepfer A, Welch G, Stanworth N, Pompert-Robertson S, Lawson O	19/01/23, 20/01/23	Kuepfer A, Lawson O, Lee B, Welch G, Biesiot J
Study Site	19/11/22, 20/11/22	Kuepfer A, Harte E	21/01/23, 13/03/23	Kuepfer A, Stanworth A, Morris Z, Morrison M
Volunteer Green	09/11/2022	Harte E, Kuepfer A	14/01/2023	Evans B, Lee B
Yorke Bay	15/11/2022	Kuepfer A, Biesiot J	25/01/2023	Kuepfer A, Munro G, Welch G

AON – Apparently Occupied Nests (breeding pairs); PFC – Pre-fledged chicks

Appendix 2: Black-browed albatross count data

Location	Colony	Grid ref	AON		PFC	
			mean ± sd	**Count type**	**mean ± sd**	**Count type**
Steeple Jason	NW Flat	-51.012 -61.252	392 ± 5.2	D	220 ± 0.5	D
Steeple Jason	Penthouse	-51.031 -61.228	64 ± 10.3	TR	7 ± 0	TA
Steeple Jason	S5 Finger	-51.031 -61.231	2199 ± 3.7	D	956 ± 1.4	D
Steeple Jason	S5 Tip_Blob	-51.037 -61.22	456 ± 1.1	D	110 ± 0.7	D
Steeple Jason	Study Site	-51.046 -61.207	1650 ± 3.5	TA, TR	922 ± 0	TA

AON – Apparently Occupied Nests (breeding pairs); PFC – Pre-fledged chicks; TR – Tally Repeated; TA – Tally Agreed; GP – Go Pro image count; D – Drone image count.

Appendix 3: Southern giant petrel count data

Location	Colony	Grid ref	AON		PFC	
			mean ± sd	**Count type**	**mean ± sd**	**Count type**
Steeple Jason	House Track_House	-51.017 -61.241	132 ± 1.6	D	66 ± 0.2	D
Steeple Jason	Neck_SGP	-51.042 -61.206	1310 ± 1.8	TR, D, TA	646 ± 1	TA, TR, D
Steeple Jason	NW_S of Ridge_West	-51.024 -61.248	3 ± 0	TA	0 ± 0	TA

AON – Apparently Occupied Nests (breeding pairs); PFC – Pre-fledged chicks; TR – Tally Repeated; TA – Tally Agreed; GP – Go Pro image count; D – Drone image count.

Appendix 4: Gentoo penguin count data

Location	Colony	Grid ref	AON		PFC	
			mean ± sd	**Count type**	**mean ± sd**	**Count type**
Fitzroy	Bertha's Beach	-51.882233 -58.358916	462 ± 2.4	TR	435 ± 1.8	TR
Fitzroy	Fox Point Fitzroy	-51.92 -58.45	291 ± 6.2	TR	423 ± 10.2	TR
Fitzroy	Pleasant Road	-51.83 -58.24	216 ± 1	TR	206 ± 3.1	TR
New Haven	New Haven	-51.742073 -59.222044	572 ± 4	D	792 ± 2.1	D, TA, TR

North Arm	Bull Point	-52.309364 -59.398188	1052 ± 2.6	TA, TR, D	1539 ± 1.8	TR, D, TA
North Arm	Bull Roads	-52.342591 -59.321461	512 ± 9.1	D	795 ± 4.7	D
Port Stephens	Stephen's Peak	-52.127660 -60.853720	2151 ± 3.8	D	3044 ± 28.8	D, TR, TA
Race Point	Fanning Harbour	-51.464667 -59.087958	162 ± 4.9	D	198 ± 5.7	D
Race Point	Rookery Sands	-51.434122 -59.106928	740 ± 2	TR, D	1017 ± 2.3	D, TR
Sea Lion Island	Sea Lion Island_Gentoos	-52.426578 -59.072513	2339 ± 4.5	TR	4290 ± 9.5	TR
Stanley	Yorke Bay	-51.676316 -57.782917	169 ± 7	D	195 ± 2.1	TR
Steeple Jason	House_Gentoos	-51.02065 -61.22673	2127 ± 11.4	D	1556 ± 7.5	D
Steeple Jason	Neck_Gentoos	-51.034787 -61.214888	982 ± 3.7	D	1944 ± 4.6	D
Volunteer	Cow Bay	-51.434127 -57.878783	1620 ± 47	D	1542 ± 4	D
Volunteer	Lagoon Sands	-51.512773 -57.780580	646 ± 9.3	D	675 ± 14.5	TR, TA
Volunteer	Volunteer Green	-51.478494 -57.837858	1274 ± 12.1	GP	1231 ± 12.8	TR
Walker Creek	Low Bay	-52.07662 -58.87963	262 ± 8.3	D	340 ± 2.6	D
Walker Creek	Motley Point	-52.112811 -58.649976	1022 ± 4.1	D	1097 ± 2.8	D

AON – Apparently Occupied Nests (breeding pairs); PFC – Pre-fledged chicks; TR – Tally Repeated; TA – Tally Agreed; GP – Go Pro image count; D – Drone image count.

Appendix 5: Southern rockhopper penguin count data

Location	**Colony**	**Grid ref**	**AON**		**PFC**	
			mean ± sd	**Count type**	**mean ± sd**	**Count type**
Berkeley Sound	Diamond Cove	-51.538059 -57.923512	108 ± 8.3	D	83 ± 0	TA
Berkeley Sound	Eagle Hill Centre	-51.544476 -57.802756	545 ± 14.1	D	570 ± 9.6	TR
Berkeley Sound	Eagle Hill East	-51.544064 -57.785118	115 ± 8.6	D	107 ± 0	TR
Berkeley Sound	Eagle Hill West	-51.545082 -57.810499	656 ± 12.8	D	654 ± 24.4	GP, TR
Berkeley Sound	Rugged Hill Centre	-51.54320 -57.85185	353 ± 14.9	D	176 ± 3.9	D
Berkeley Sound	Rugged Hill East	-51.543674 -57.845031	358 ± 4.6	D	310 ± 3.1	TR
Berkeley Sound	Rugged Hill West	-51.54314 -57.85783	247 ± 38.1	D	271 ± 9.4	D
Port Stephens	Stephen's Peak	-52.133250 -60.861010	875 ± 24.5	D	714 ± 61.6	D
Race Point	Fanning Head North	-51.460831 -59.141540	240 ± 5.7	D	191 ± 2.2	TR
Race Point	Fanning Head South	-51.469284 -59.137749	352 ± 9.2	D	204 ± 2.9	TR
Sea Lion Island	Sea Lion Island_Rockhoppers	-52.446670 -59.115083	399 ± 9.2	TR	185 ± 3.1	TR

Steeple Jason	NW Flat	-51.012810 -61.252682	71 ± 7.3	D	35 ± 4.3	D
Steeple Jason	S5 Finger	-51.031884 -61.231434	809 ± 14.4	D	416 ± 16.6	TR
Steeple Jason	S5 Tip_Blob	-51.037932 -61.220460	582 ± 12.8	D	301 ± 4.2	TR
Steeple Jason	Study Site	-51.046215 -61.206635	578 ± 0	TA	307 ± 0	TA

AON – Apparently Occupied Nests (breeding pairs); PFC – Pre-fledged chicks; TR – Tally Repeated; TA – Tally Agreed; GP – Go Pro image count; D – Drone image count.