Salvin's albatross breeding dates and productivity: nest-camera analysis

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Final report to Department of Conservation, Marine Species Team

June 2021

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Summary

Salvin's albatross *Thalassarche salvini* (Nationally Critical) are one of the New Zealand seabirds most at risk from fisheries bycatch. The status of the main population, at the Bounty Islands, is poorly known because the islands are particularly remote and difficult to access. Here the timing of key breeding events for Salvin's albatrosses is assessed and breeding success estimated. From time-lapse images taken at the Bounty Islands over a year, we estimate laying and hatching dates, determine failure dates and when chicks fledge, and document how long the colony is empty during the non-breeding wintering period. Nest-level failure and success records are used to model daily survival rates and estimate breeding success overall. We also explore whether tracking data can be used to get similar phenology and breeding outcome data, using migration dates.

The colony was empty for almost three months until adult Salvin's albatrosses started to return early- to mid-July. Estimated lay was 21 Aug–5 Sep and estimated hatch was 2–17 Nov, based on brood-guard which ended on 6 Dec (range 29 Nov–14 Dec). Mean fledging was 7 April but was detected as late as 20 April. Tracking data showed clear timings for adult migrations away from the islands, but migration dates proved not to be useful for inferring fail/fledge dates or rates since breeding outcomes for tracked birds remained unclear. Nest cameras provided clear data on breeding outcome, giving an overall breeding success estimate of 0.276 (95% CI: 0.129–0.442) based on modelled daily survival rates. Nest survival rates were modelled separately for incubation and chick-rearing periods, showing that the low breeding success was driven by particularly low daily nest survival rates in November, during hatching and brood-guard periods.

Introduction

Salvin's albatross *Thalassarche salvini* are a Nationally Critical seabird endemic to New Zealand. They breed predominantly at the Bounty Islands (Sagar *et al.* 2015), and are one of the New Zealand seabird species most at risk from fisheries bycatch (Abraham & Thompson 2015; Richard & Abraham 2015).

The population status at the Bounty Islands is poorly known due to logistical difficulties in conducting research at this remote location, and differences and inherent uncertainties in methods previously used to assess population status (Taylor 2000; Baker *et al.* 2014; Sagar *et al.* 2015; Parker & Rexer-Huber 2020). Even basic breeding chronology—laying, hatching, and fledging dates, colony return dates—and metrics like productivity or breeding success remain poorly defined because of access difficulties. Only hatching dates have been recorded directly (i.e. observers being present), with laying date estimates all calculated back from hatching dates using incubation periods from other species (Robertson & van Tets 1982; Clark *et al.* 1998; Sagar *et al.* 2015).

The primary objective of this report is to describe aspects of Salvin's albatross phenology. From time-lapse images taken over a year, we determine the following dates: when chicks fledge; when adults depart the colony at the end of the breeding season; and when adults return to the colony. We also record nest-level reproductive success from the time-lapse cameras and use these to model daily survival rates and estimate breeding success overall. A secondary objective is to evaluate whether similar phenology and breeding outcome data can be obtained from tracking data, using migration dates. Here we examine phenology and productivity findings, and make recommendations for future deployments of nest cameras to assess similar questions at other sites and/or other species.

Methods

Field methods

Six trail cameras were deployed at Proclamation Island, Bounty Islands (Fig. 1 upper), to follow Salvin's albatross breeding activity. Cameras (Bushnell Enduro) were deployed on 21 October 2018 with overview into various parts of the study colony (Fig. 1 lower). We used 1.5 V Varta alkaline batteries and 32 gb SanDisk SD cards. Cameras were programmed to take images hourly during daylight. Each camera was mounted on customised aluminium mounts fixed to a small vertical section of rock using rock bolts, high enough to be out of the way of wildlife traffic. For extra waterproofing, Tesa tape was overlain with a layer of self-amalgamating tape to seal the join in the waterproof case. All six cameras were retrieved on 24 October 2019 and the mounts removed.

Tracking devices were deployed on breeding Salvin's albatrosses in the study colony in October 2018 (GLS and satellite trackers) and October 2019 (satellite trackers) (Thompson *et al.* 2020). In brief, the 2018 deployment involved 54 GLS tags (Intigeo C330s by Migrate Technology and Biotrack) and 14 transmitting GPS devices (Rainier-S20 solar-powered by Wildlife Computers, and Lotek PinPoint Argos). All satellite-tracker birds also carried a GLS. In October 2019 a further 16 satellite trackers were deployed (Geotrak GT-12GS-GPS solar-powered tags, and 12 Telonics TAV-2630 PTT tags). Satellite trackers were attached to a precut UV-stable PVC baseplate with tape, glue and cable ties, first attaching the base plate to back feathers with Tesa tape. All devices were pre-programmed for maximum daily location transmission while maximising the operating lifespan of the device (battery-powered devices), or for solar-powered devices, accounting for power required to transmit the locations (solar-powered devices).

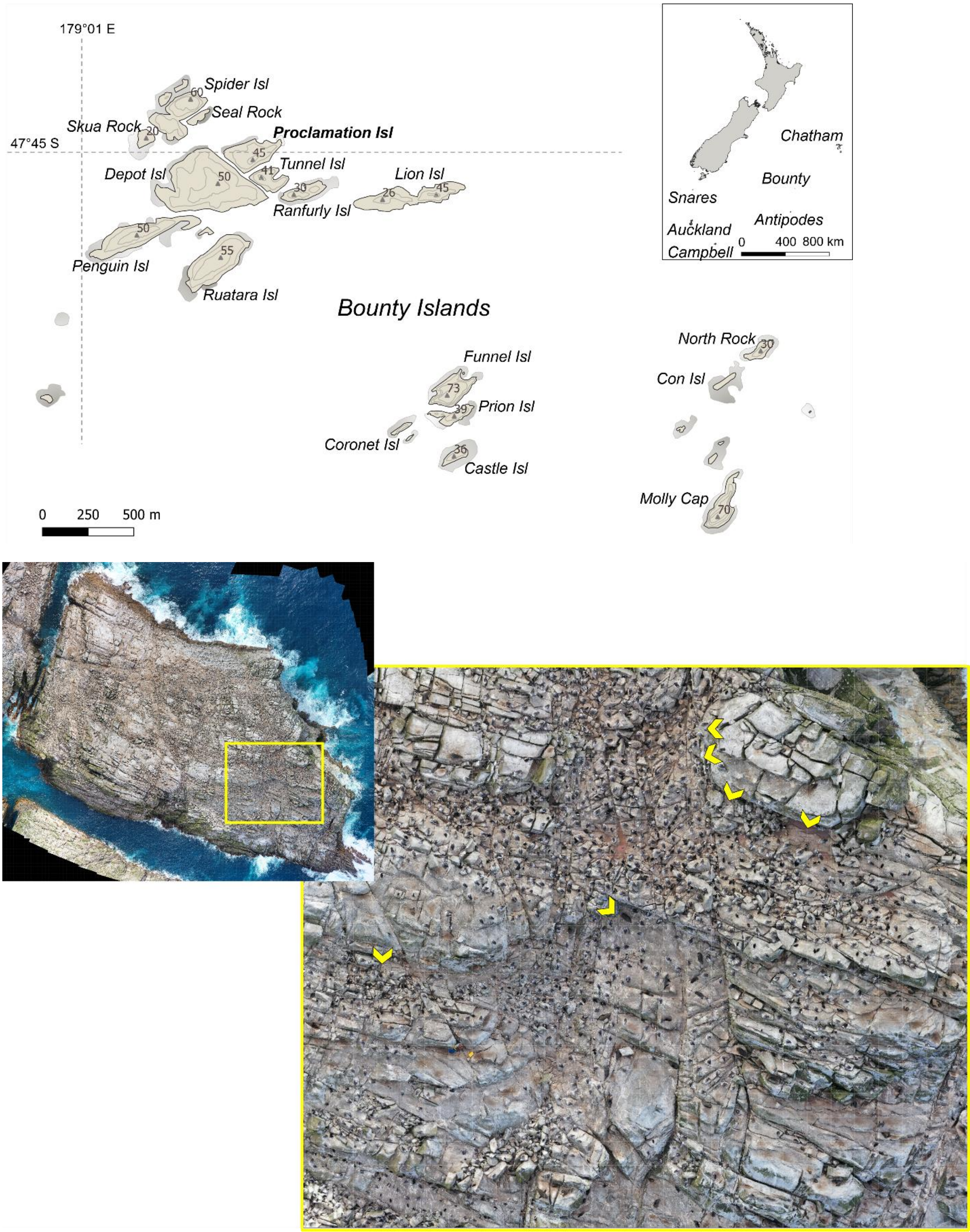

Figure 1. Bounty Islands (upper) and Salvin's albatross study area at Proclamation Island (lower). The yellow box in the whole-island picture marks the extent of the study area shown lower right. Arrowheads mark the location and viewing direction of nest cameras in the study area.

Data preparation, analysis

Nest cameras

Data were extracted from nest camera images on recovery. Three of the six nest cameras recorded Salvin's albatross breeding activity for the full year, and two yielded images for part of the nesting period (Table 1). The sixth camera malfunctioned due to water ingress.

Images were reviewed systematically to mark every nest visible (Fig. 2) and identify for each nest the end of brood-guard (date chick first left unattended), fledging (date chick departed nest), or failure. Nests from before the wintering period (2018–19 breeding season, mid-incubation to fledge) were separated from the post-winter new nests (2019–20 season, lay to mid-incubation). In each camera view, we also identified the last colony departure (date last adult and/or fledgling visible at the end of the season), the first colony return (date first bird seen back in colony), and the colony reoccupied (date adults starting nest building and staying in colony).

Figure 2. Example of nests followed to identify key dates and outcomes (camera 2A, 2018–19 season).

Because brood-end date can be detected with confidence, unlike hatching or laying, we used brood-end date to estimate hatching and laying dates. Incubation and brood-guard duration are not available for Salvin's albatross but there are published data for the closely-related shy albatross *Thalassarche cauta*: mean 73 days incubation and mean 27 d brood-guard (Hedd & Gales 2005). Therefore, to estimate hatching dates in Salvin's albatross we subtracted 27 d from brood-end dates. Then to estimate laying dates a further 73 d was subtracted from estimated hatch dates.

Apparent nesting success was calculated for the part-seasons that nest cameras documented. Cameras were deployed two-thirds of the way into incubation in the 2018–19 breeding season, then also followed the first two-thirds of the 2019–20 season's incubation (Fig. 4). From this we calculated apparent chick success (from last third of incubation to fledging), and also apparent incubation success (from lay for the first two-thirds of incubation). Because apparent success rates suggested worryingly low productivity, particularly for the chick stage, we modelled daily nest survival rates to better understand overall breeding success. Daily survival rate (DSR) models were implemented in the software MARK via the R package RMark (White & Burnham 1999; Laake 2013; Laake & Rexstad 2019; R Core Team 2019). DSR was estimated independently for the chick stage (DSR_{chick}) and egg stage (DSR_{egg}) using 2018/19 nests and the 2019/20 nests, respectively. A basic model of DSR_{chick}, constant across all nests and all dates in the sample (S(~1)), was tested against other models to check for seasonal variation (linear trend S(~Time) or quadratic trend S(~Time + I(Time²)), or whether survival varied by nest age (S(~NestAge)). For incubation DSR_{egg} we tested constant survival (S(~1)) against models assessing seasonal variation (linear trend S(~Time) or quadratic trend S(~Time + I(Time²)). Nest age could not be assessed for 2019/20 nests since lay dates cannot be determined with confidence, and data collection ended before 2019/20 season brood-end. Breeding success is calculated by raising estimated DSR to the number of days laying to fledging (e.g. Fischer *et al.* 2021). Estimated nest survival during the egg (S_{egg}) and chick (S_{chick}) stage is:

$$S_{egg} = DSR_{egg}^{T_{inc}}$$
$$S_{chick} = DSR_{chick}^{T_{chick}}$$

in which DSR is the constant DSR for each stage, T_{inc} is the estimated mean duration of the incubation stage (73 d) (Hedd & Gales 2005), and T_{chick} the duration of the chick-rearing stage (150 d from estimated mean hatch to observed mean fledge, this study). Finally, we estimate overall nest survival (S) as:

$$S = S_{egg}\ x\ S_{chick}$$

Tracking data

Satellite tracking data from 29 birds were downloaded from the Albatross Tracker interface (DOC & MPI; https://docnewzealand.shinyapps.io/albatrosstracker). Daily location data were groomed to remove any anomalous positions by Samhita Bose of DOC's marine science unit before upload, so no further processing or filtering was required. GLS data from 33 birds were processed by Dana Briscoe (Thompson *et al.* 2020).

To determine migration dates from satellite tracker and GLS data, positions were projected and mapped in qGIS and inspected for departures by stepping through dates (Fig. 3). Migration departure was identified as the date directed movements eastward began. Satellite trackers recorded positions more frequently, so we could generally distinguish colony departure (date bird left island and did not return before migrating) from migration start. GLS data are less spatially precise than satellite data, so we estimate that dates from GLS are approx. ±2 to 3 d, and satellite ±1 d.

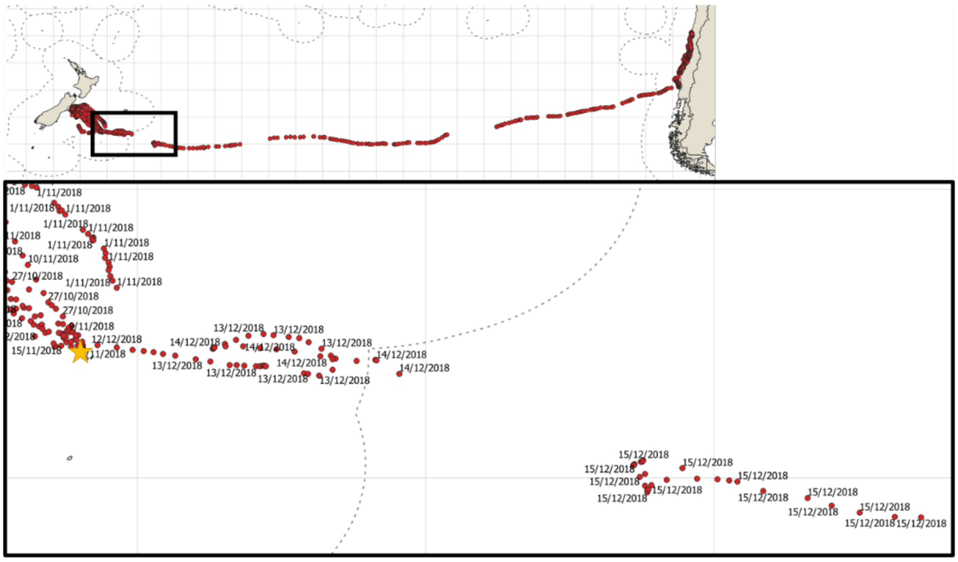

Figure 3. Example of satellite tracking data from Salvin's albatross red-007, illustrating GIS-based step-through assessment of migration date. Star shows Bounty Islands location.

Results

Nest cameras

Cameras recorded up to 368 d (12.3 months) of images (Fig. 4). Camera performance was excellent, with all but one recording for the entire deployment (Fig. 4). Three cameras continued recording even after having been knocked into a mud slurry, recording for up to 10 months longer (grey bars, Fig. 4). Despite mounting cameras on vertical sections of rock > 1.5 m high, it appears that fur seals did slide down these rock faces. One camera's mounting bracket was bent downward changing the view from 16 nests to four nests (camera 2A). Only one camera had waterproofing failure; it was found with water sloshing inside, but with 91 d of images recorded (cam 3B; Fig. 4).

Cameras recorded 18,291 images useful for review of Salvin's albatross breeding. At camera deployment 74 nests from the 2018–19 breeding season were visible (Table 1). Despite displacement of three cameras, 40 nests from three cameras could be followed through to the end of the breeding season to determine fledging dates (Fig. 4). A further 50 new 2019–20 nests were visible when birds returned after the winter non-breeding period (~3 months; Fig. 4).

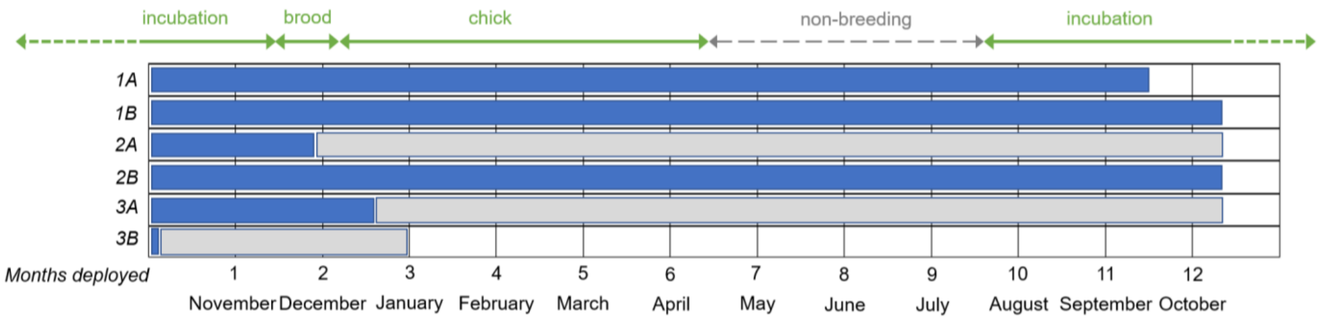

Figure 4. Salvin's albatross nest camera recording duration, Proclamation Island, Bounty Islands. Blue bars show the duration of albatross records, with grey showing camera longevity (if different from albatross duration). Breeding stages are along the top of the figure. Cameras were deployed 21 October 2018 and recovered 24 October 2019.

The colony was empty for almost three months until adults started to return early- to mid-July (Table 1). Just over a month (32–40 d) after adults started returning to the colonies, eggs were laid; estimated lay was 28 Aug (21 Aug–5 Sep). Estimated mean hatch was 9 Nov (2–17 Nov), based on brood-guard which ended on 6 Dec (range 29 Nov–14 Dec) (Table 1). Mean fledging was 7 April, or 162 d after estimated hatching. Fledging was detected as late as 20 April.

Nest cameras followed only parts of the breeding season, so apparent success rates can be calculated just for these part-seasons (chick and egg stages). Apparent chick success (from last third of incubation to fledging) was 0.45, with mean failure date 23 d after estimated hatch during the brood-guard stage. As expected, apparent incubation success was much higher than chick success at 0.80 , spanning from lay through the first two-thirds of incubation with cameras removed ~16 d before mean hatch (Table 1).

These apparent success rates are worryingly low, particularly for the chick stage, so we modelled daily nest survival rates to robustly estimate overall breeding success. The best supported model for the chick-rearing period (2018/19 nests) showed daily survival rates vary seasonally by date, following a linear trend through time (linear trend on the logit scale) (Table 2, Fig. 5). Incubation (2019/20 nests) was best represented by constant daily survival rates across all nests and dates in the sample (Table 2), estimated as 0.995 (95% CI: 0.991–0.997) (horizontal line, Fig. 5). Breeding success overall was estimated as 0.276 (95% CI: 0.129–0.442), comprising estimated egg survival of 0.705 (0.523–0.829) and chick survival of 0.391 (0.246–0.533).

Table 1. General results from Salvin's albatross nest cameras at the Bounty Isl. Three cameras failed before fledging (italicised columns) so were excluded from calculation of fledging success.

Camera ID	**1A**	**1B**	***2A***	**2B**	***3A***	***3B***	**TOTALS all nests**	**TOTALS just cams with whole-season data**
last date camera alive	30/09/2019	27/10/2019	*27/10/2019*	27/10/2019	*26/10/2019*	*20/01/2019*		
camera recording life	344	371	*371*	371	*370*	*91*		
date last albatross image	30/09/2019	24/10/2019	*16/12/2018*	24/10/2019	*5/01/2019*	*22/10/2018*		
days albatrosses recorded	344	368	*56*	368	*76*	*1*	1213	
n images for albatross review	5,165	5,521	*884*	5,559	*1,142*	*20*	18,291	
unique nests viewed at deploy (18/19)	8	24	*16*	8	*18*	*na*	74	40
n fledged/near-fledged	7	7	*na*	4	*na*	*na*	na	18
apparent hatching and chick success	0.88	0.29	*na*	0.50	*na*	*na*	na	0.45
fail dates (average, incub–fledge 18/19)	na	4 Dec	*22 Nov*	19 Nov	*7 Dec*	*na*	25 Nov (n=28)	
nests start 19/20 season	5	38	*na*	7	*na*	*na*	50	
nests with egg at end cam life (19/20)	2	31	*na*	7	*na*	*na*	40	
apparent incubation success	0.4	0.8	*na*	1.0	*na*	*na*	na	0.8
fail dates (average, lay–mid incub 19/20)	10 Sep	3 Oct	*na*	na	*na*	*na*	21 Sep (n=9)	
days wintering, colony empty	90	75	*na*	94	*na*	*na*	86.3	
first ad return (on ground, even if brief)	10 Jul	4 Jul	*na*	14 Jul	*na*	*na*	4 Jul	
colony return dates (>2 full-time)	25 Jul	19 Jul	*na*	23 Jul	*na*	*na*	19 Jul	
estimated lay (mean 73 d incubation)	26 Aug	28 Aug	*na*	30 Aug	*26 Aug*	*na*	28 Aug	
estimated hatch (mean 27 d brood)	7 Nov	9 Nov	*na*	11 Nov	*7 Nov*	*na*	9 Nov	
brood end date average	4 Dec	6 Dec	*na*	8 Dec	*4 Dec*	*na*	6 Dec (n=25)	
fledging dates average	5 Apr	10 Apr	*na*	7 Apr	*na*	*na*	7 Apr (n=16)	
fledging date range	27 Mar–11 Apr	4–16 Apr	*na*	2–11 Apr	*na*	*na*	27 Mar–16 Apr	
last date bird present in colony	11 Apr	20 Apr	*na*	11 Apr	*na*	*na*	20 Apr	

Table 2. Daily survival rate models for Salvin's albatross chick-rearing (2018/19 nests) and incubation (2019/20 nests).

model	N parameters	AICc	deltaAICc	weight	deviance
Chick stage (2018/19 nests)					
S(~Time)	2	242.0781	0.000000	0.42952199	238.0749
S(~NestAge)	2	242.3913	0.313210	0.36725923	238.3881
S(~Time + I(Time^2))	3	243.8407	1.762665	0.17792111	237.8344
S(~1)	1	247.7420	5.663921	0.02529768	245.7409
Egg stage (2019/20 nests					
S(~1)	1	104.6678	0.0000000	0.3953195	102.66585
S(~Time)	2	104.8625	0.1946782	0.3586530	100.85664
S(~Time + I(Time^2))	3	105.6163	0.9485018	0.2460275	99.60463

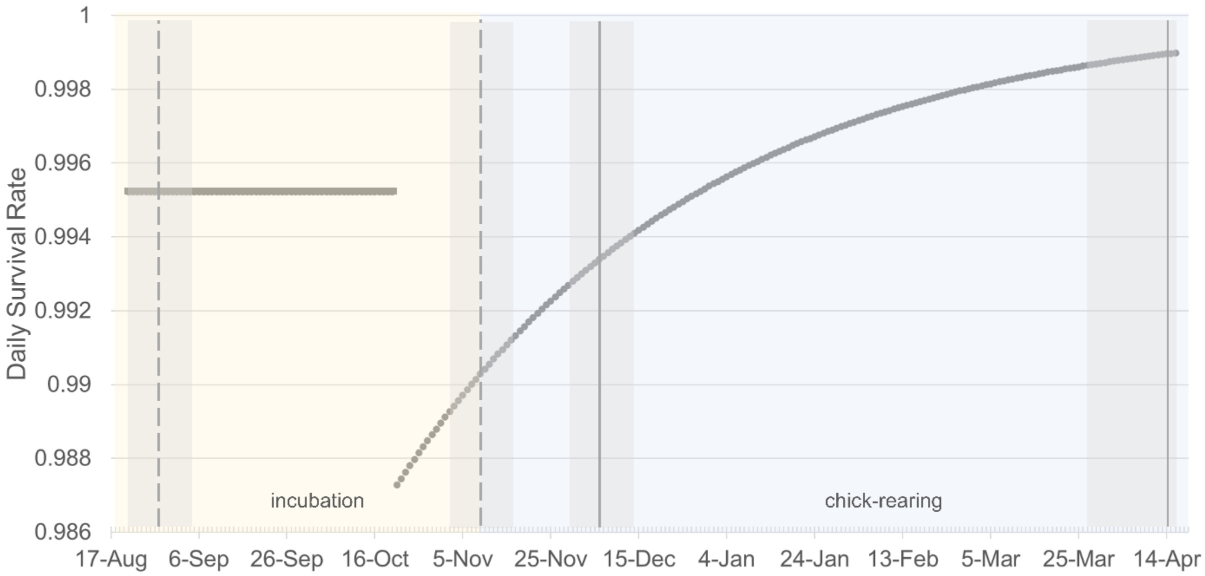

Figure 5. Nest survival rates for Salvin's albatross are constant for much of incubation (bold horizontal line) then vary over time during late incubation and chick-rearing (bold curve). Vertical lines show mean dates of laying, hatching, brood-end and fledging, from left to right respectively, with the date range of each shaded grey.

Tracking data

To evaluate whether phenology and success data can be drawn from tracking datasets, individual tracks were inspected to determine migration dates.

Mean migration was 26 Jan (date departed with no clear return to island), but this average is not very informative considering successful pairs fledge a chick 27 Mar–16 Apr, and mean failure was 25 Nov for hatch-to-fledge. To address this, we separated birds that appear likely to have fledged a chick (departure March onward) from those that probably failed (departure before March) following Hedd & Gales (2005).

Birds that appear to have successfully raised a chick departed 6 Mar (average), a month before estimated mean fledging, while birds whose breeding clearly failed departed 10 Jan, 1½ months after the mean fail date for this period. This is not unreasonable, since we expect the last visit to feed a chick will be well before the date it fledges. It is also not surprising for a failed breeder to stay in NZ waters for a while longer before heading off on its long-distance winter migration. Nest cameras showed that some birds stayed on nest for days to a week after the breeding attempt failed. Tracking data showed birds foraging in the general area after leaving the island (last date detected at island in tracking data).

Discussion

Our deployment of Salvin's albatross cameras at Proclamation Island provided new information about when the birds occupied the breeding colony, allowing estimates of productivity and of key events during breeding. When analysed in conjunction with tracking data they provide new insights into the timing of Salvin's albatross foraging in NZ waters.

The colony was empty of Salvin's albatrosses for less than three months until adults started to return early- to mid-July. Salvin's albatrosses are mostly annual breeders (Sagar *et al.* 2011), so the short period that birds are away is striking; in comparison, the semi-biennial white-capped albatrosses also leave the colony empty for just under three months (Rexer-Huber *et al.* 2019). However, shy albatrosses spend just 1.5 months away from the colony, despite being annual breeders, returning to spend the remainder of non-breeding at the colony (Hedd & Gales 2005). Adult Salvin's albatrosses attended the colony for 32–40 days at the start of the breeding season before the estimated lay date.

Brood-end date can be detected with confidence, unlike hatching or laying, so we calculate back to estimate hatch and lay dates. Salvin's albatross laying was estimated as 28 Aug, in line with 24 Aug–14 Sept estimated from hatching nest checks in 1997 (Sagar *et al.* 2015). Hatching from 2–17 Nov, calculated back from brood-end date, was earlier but still in line with the 15 Nov determined directly from nest monitoring over the pipping-hatching period in 1997 (Sagar *et al.* 2015). It seems the breeding season has been getting earlier over the last four decades: in 1978 the breeding season was ~4 days later than in 1997 (Robertson & van Tets 1982; Sagar *et al.* 2015), and the 1997 dates are ~3 days later than presently. Salvin's albatross fledging was around 7 April, but chicks fledged as late as 20 April. This suggests a chick-rearing period of 162 days (estimated hatching to fledge), longer than the 125 days for shy albatrosses (Hedd & Gales 2005).

Breeding success for Salvin's albatrosses was strikingly low at 0.28. Relatively low egg survival during the first two-thirds of incubation (0.71) was followed by very low chick survival (0.39). Overall breeding success of 0.28 is very low, considering that for Buller's albatross *Thalassarche bulleri* overall breeding success was 0.64–0.86 (whole period from eggs laid to chicks fledged) in the seasons 1992–2004 (P. Sagar unpubl. data). For white-capped albatrosses apparent chick success was 0.29 over the late incubation to fledge period (same as the chick period here), although based on only a third of the nest number followed here for Salvin's albatrosses (Rexer-Huber *et al.* 2019). Daily survival rates for Salvin's albatross chicks varied over time, showing that the low Salvin's albatrosses breeding success is driven by low daily survival rates during November: daily survival was steady before November and then progressively increased afterwards from December to reach maximal daily survival rates in April. In other words, hatching appears to be the most vulnerable breeding stage for Salvin's albatrosses, with failures mostly in November in the weeks just after chicks had hatched. Similarly, fieldwork in 1997 showed 34% failure of Salvin's nests checked daily during pipping/hatching (31 Oct–17 Nov) at the Bounties (Sagar *et al.* 2015), while at the Snares Salvin's albatrosses lost about half of eggs during Oct–Nov (Clark 1996). In contrast, most shy albatross nest failures occurred late in chick rearing (Hedd & Gales 2005).

It is not clear why breeding success should be so much lower for Salvin's albatross than other *Thalassarche* like Buller's albatross. Although Buller's albatross breeding success was generally high, success was much lower (0.30–0.40) in a rapidly growing colony than in two established colonies (P. Sagar upubl. data), presumably a result of a larger proportion of inexperienced birds breeding in the growing colony. However, we think it unlikely that breeder inexperience in a fast-growing colony is the driver of low part-season breeding success in Salvin's albatross here, since inexperienced breeders typically fail soon after laying, yet Salvin's nest failure rates were highest after hatching. Further, the Proclamation colony is well-established, not new, suggesting that rapid colony growth is unlikely, although colony decline / growth data are unavailable. A possible explanation for low breeding success is nest disturbance in the dense mixed-species colonies that Salvin's albatross occupy, although it is not clear why nest disturbance should be higher in November than at other times of year at both the Snares population of Salvin's albatrosses

(Clark 1996) and the Bounties population (this study). It may be worth noting that fur seals fight for harems just prior to their November breeding season, but it is unclear whether this causes Salvin's nest failures. Nest cameras recorded only one case where the failure was likely caused by a fur seal (egg knocked out of nest), but with hourly intervals between photos it was not possible to tell whether fur seals were involved in more failures.

Migration dates can be identified in tracking data, with fast directed movement eastward clear and nothing like movements during chick-rearing. However, we do not think migration dates usefully contribute to accurate estimates of fail / fledge dates or rates. Because the breeding outcome of tracked birds is unknown, outcome is assessed based on departure date. However, departure appeared to differ by more than a month from actual fail or fledge dates, so outcome is necessarily a guesstimate producing less-accurate figures. To illustrate: using the breeding outcome threshold here (successful if departed March or later), 16 out of 50 birds tracked were flagged as successful, implying a success rate of 0.32. This contrasts with the 0.28 actual breeding success estimated from nest camera data. In other words, successful breeders seem to have been overestimated per this method to identify breeding outcome in tracked birds. The majority of Salvin's albatrosses are annual breeders, as documented at the Snares (Sagar *et al.* 2011), so we do not think that there has been a bias toward failed breeders as would have been expected for biennial breeders given trackers were collected the year after deployment. We think it more likely that the outcome threshold chosen overestimates successful breeding outcomes, compounded by the relatively small sample size where mis-assigned 'failure' of just one to three extra birds makes a large difference to estimated breeding success. Until it is possible to determine the breeding outcome of tracked Salvin's albatrosses, we suggest that it is not helpful to infer failure rates and fledging rates from tracking data. Rather, tracking data are best used to their strengths; that is, for assessment of spatial habitat use.

Recommendations

For direct data on breeding success, cameras need to view the full breeding season, following the same nests from lay to fledge. This would require deployment in July with cameras left in place until after April. If island visits must occur partway through the breeding season (e.g. October) then two year-long deployments are needed, with batteries and memory changed partway without changing the field of view of cameras.

The camera hardware (Bushnell Enduro) performed well in a challenging wet windy salty environment, so they can be recommended for other studies requiring hardy time-lapse cameras. The cameras' waterproofing was such that cameras kept recording even after landing in mud slurries, and battery longevity was excellent at cool maritime temperatures (-2 to 25°C recorded).

Disturbance by fur seals is the main issue limiting recording performance at the Bounty Isl. Ideally cameras should be mounted under overhanging rock, to prevent seals sliding down and bending or breaking the mounting bracket. Mount should be >2 ft high to prevent animals disturbing the camera while transiting past. If cameras cannot be protected from above by overhangs, then more cameras should be deployed to counter expected data loss.

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