Mollymawk Chick Numbers and Survival on Campbell Island, November 2019–March 2020

Peter G.H. Frost [1] and Claudia Mischler [2]

[1] Science Support Service,
87 Ikitara Road, Whanganui 4500
pghfrost@xtra.co.nz

[2] Department of Conservation,
15 Wairepo Road, Twizel 7901
cmischler@doc.govt.nz

Summary

An aerial photographic survey of the mixed Campbell Mollymawk, *Thalassarche impavida*, and Grey-headed Mollymawk, *Thalassarche chrysostoma*, colonies along the north-east coast of Campbell Island was carried out on 17 March 2020. At this time, most of the birds present at these colonies would have been chicks. The aim of the study was therefore to establish the number of chicks in these colonies and relate this to the number of nesting adults estimated from a combined aerial and ground-level photographic survey carried out earlier in the nesting season, 18–24 November 2019. Campbell Mollymawks made 90 % of these nesting birds, with Grey-headed Mollymawks the remainder.

Counts were made independently by two analysts and the results averaged. A total of 7890 chicks of both species combined were recorded across four colony groups: Bull Rock South (containing 54.6 % of the total); Bull Rock North (24.8 %); the Eastern colonies (19.1 %); and Sorensen Tarn (1.5 %). Assessed against the number of apparently active nests in November 2019 (i.e. ones assumed to contain an egg, taken to be 82 % of the apparently occupied nests counted at that time), the survival rate from November to March at these colonies was: Bull Rock South, 60.6 %; Bull Rock North, 62.6 %; the Eastern colonies, 70.4 %; and Sorensen Tarn, 99.1 %.

These nest survival estimates cover only the last third of the incubation period and the first 60–70 % of the fledging period and so are not really comparable with the more conventional measures of nesting success. To put them into this broader context, two assumptions were made. First, that the number of active nests at the start of the breeding season in early October could be reasonably estimated using published regression equations that express the number of nests on a given date as a percentage of that initial number. In the case of these four colony groupings, this was estimated as 94.6 %, giving an initial number of nests of 13,215 (both species combined). Second, that the survival of the chicks subsequent to 17 March to fledging, approximately 41 days later, can be estimated from a study of chick survival during the nestling period carried out in the late-1980s for both species separately. This showed shallow linear declines in the number of chicks alive during the latter part of the nestling period, following steeper reductions in chick numbers earlier in that period. Taken together, these figures gave an average daily survival rate of 0.99919 day^{-1}, weighted by the proportion of the two species in the study colonies earlier in the season. Extrapolated through to the end of fledging, this suggests that around 7632 mollymawk chicks could have fledged by the end of the season, an estimate of nesting success of 57.8 %. The upper bound on this nesting success is 59.7 %, set by assuming no more chick mortality after 17 March (i.e. 7890 chicks fledged). The corresponding lower bound is 50.7% (6696 chicks fledged), determined by assuming that the calculated daily survival rate between November 2019 and March 2020 (0.99597 day^{-1}) continues through the rest of the nestling period.

With these assumptions as a caveat, overall nesting success at the mixed mollymawk colonies along the north-east coast of Campbell Island during the 2019–20 breeding season was 50–60 %, with a best estimate of around 58 %. This is broadly in line with the level of nesting success measured for Campbell Mollymawk during 1984–96, the predominant species present in these colonies.

Introduction

Measures of nesting success and breeding productivity are challenging to obtain for long-lived, slow reproducing seabirds, especially those breeding on New Zealand's sub-Antarctic islands. The remoteness of these sites, difficulties of access and, currently, few extended stays by researchers during a species' prolonged breeding season, all compound the difficulty. Yet, good measures of success are essential to complement other demographic parameters needed to model a species' population dynamics, such as age and stage survival, age at first breeding and breeding frequency. This is especially so for vulnerable or threatened species, ones either breeding only on a single island group or which are declining.

Two such species within New Zealand's jurisdiction are the Campbell Mollymawk, *Thalassarche impavida*, which breeds only on Campbell Island, the southernmost of New Zealand's sub-Antarctic islands, and the Grey-headed Mollymawk, *Thalassarche chrysostoma*, a biennial-breeding species with a wide circumpolar distribution centred on South Georgia but which is declining globally (ACAP 2012a, b). Campbell Mollymawk numbers have varied since the 1940s, declining by -2.6 % per year from the mid-1940s to mid-1980s, and even more at some colonies (up to -5.9% per year at the Bull Rock North colony during 1967–82), then staging a recovery, increasing at 1.1 % per year during 1985–97 (Waugh et al. 1999). The Grey-headed Mollymawk population on Campbell I. has also declined sharply, by 82–88 % over a 55-year period from the early 1940s to late-1990s, but without any sign of recovery (Moore 2004). The modelled rate of change during the 1990s, was -2.8% per year (Waugh et al. 1999).

The aim of this study was to count the number of Campbell and Grey-headed Mollymawk chicks from aerial photographs taken in mid-March 2020 of the mixed mollymawk colonies lying along the north-east coast of Campbell I. These would complement counts of the number of apparently occupied nests made from aerial and ground-level photographs taken earlier in the breeding season. In November 2019, these north-east colonies together supported an estimated 15,238 pairs of nesting mollymawks, 90 % of which were Campbell Mollymawks. Overall, the colonies held 60.4 % of nesting Campbell Mollymawks and 25.7 % of the nesting Grey-headed Mollymawk population on Campbell I. (Frost 2020).

Methods

Images of the mixed mollymawk colonies lying along the northeast coast of Campbell I. were taken between 1310 h and 1314 h on 17 March 2020 from a New Zealand Navy helicopter flying from the HMNZS Canterbury. The flight path covered the numerous, mostly small, Eastern colonies; the large Bull Rock South and Bull Rock North colonies; and the small group of Campbell Mollymawks nesting around Sorensen Tarn, above Bull Rock South.

Photographs were taken with a Nikon D5 camera fitted with a 24.0-70.0 mm f/2.8 lens. Shutter speed (1/400s), aperture (F8.0) and ISO number (800) were fixed throughout but focal length varied. Two-thirds of the photographs were taken at focal lengths <30 mm (35 mm equivalent), 70 % of which were at the shortest focal length, 24 mm. The longest focal length, 70 mm, was used only when taking three scenic photographs (waterfalls and sea caves).

Photographs were taken from 90–190 m offshore (mean distance 123±31 m, N=13), based on calculations using focal length, sensor dimensions, and horizontal ground distances estimated from Google Earth on those images where the coast was approximately parallel to the plane of the image. Total flight time, from the Northeast Harbour entrance to North Cape, a distance of approximately 5.2 km, took 3.7 min, an average speed of 45 knots. The distance flown offshore together with the short duration of the flight is likely to have kept disturbance to a minimum. Few adult birds were seen in the air, greatly reducing any risk of collision.

The images were assessed by two analysts working independently. PGHF processed the images using Photoshop Elements 2020 (v18.0) to enhance lighting, contrast and colour. Some images were further processed using Topaz Sharpen AI (v2.1.7), to stabilize, sharpen or focus them depending on which process best enhanced the details, to make it easier to distinguish individual birds and differentiate chicks from adults and their surroundings. Both analysts used the counting software DotDotGoose (Ersts 2020).

The boundaries of these colonies and subsets within them were digitally drawn on the images, following the lines depicted by Moore (1999). The same boundaries were used on images taken in November 2019 to determine the numbers of apparently nesting birds in these colonies (Frost 2020), thus making the two data sets broadly comparable. The exception was the Bull Rock North colony where PGHF used Moore's (1999) boundaries, while CM used borders drawn up during an initial attempt to count nesting birds on the November 2019 images. The fine-scale demarcation of the sub-colonies, when aggregated, produced a similar layout to the coarse-scale delineation used by CM, thereby making the two groupings largely equivalent.

Two images covered the small Sorensen Tarn colony, each from a different angle. Because the tarn is situated in steep-sided, 1–3 m, water-filled depression, several chicks were situated under the vegetated overhangs, rendering them invisible in one image but apparent in the other. Consequently, the tarn was partitioned into five areas, identical in both images, and the numbers of chicks counted in both sets. The highest number in each of the five parallel sets was chosen and their sum used to give the total number of chicks present on the tarn. Calculated this way, this is a minimum number.

Two adjustments had to be made for the analysis of the 30 Eastern colonies and sub-colonies. First, for comparative purposes, the number of chicks counted in colonies 1–6 was compared with the number of apparently occupied nests recorded on 18 November 2019 because the marginally better-quality aerial photographs taken on 24 November did not cover these 6 colonies adequately. This 6-day difference in timing was considered in any subsequent calculations involving time intervals.

Second, the aerial photograph taken of sub-colony 23c in March 2020 only covered the southern half. Consequently, the apparently occupied nests visible in this sub-colony in November 2019 were counted again, omitting the area not covered in the March 2020 photograph. The area photographed in March 2020 contained 89 nests in November 2019, 72 % of the whole for this sub-colony.

In most of the images the birds were small, often distinguishable only as discrete white or grey dots. This made it difficult to identify them as anything other than just

mollymawks, either chicks or adults. Given the late stage in the breeding season, we assumed that most of the birds were chicks. This meant that where we could not reasonably clearly identify a bird as an adult, it was marked as a chick. This gives an upper bound for the number of chicks in these colonies. Where possible, however, chicks and adults were differentiated on the following criteria.

Chicks

Birds were classed as chicks if they were sitting horizontally or, if sitting upright on their tarsi, their rears were on the ground. Standing birds were classed as chicks if their heads and necks were stretch more-or-less horizontally. Where an adult was nearby, birds either adopted this posture, which we interpreted as begging, or assumed a submissive posture (head down).

Adults

Birds were classed as adults if they were positioned close to a chick, with the usually smaller bird facing the adult, occasionally with head and neck outstretched, apparently begging. Other features of birds taken to be adult included standing upright with head held high and the body horizontal to the ground; having a noticeably dark back, scapulars and wing feathers; having distinctly pale legs and feet (chicks of both species have grey legs and feet); and, occasionally, showing a yellow/orange bill (even if only 1 pixel wide), a feature of adult Campbell Mollymawks (chicks of both species have grey bills; the bill of an adult Grey-headed Mollymawk would appear the same, given the small size of the birds on the images).

Several birds had greyish heads. These were not automatically classed as adult Grey-headed Mollymawks because near-fledging Grey-headed Mollymawks also have greyish heads. Most chicks of this species would have had less fully developed plumage than Campbell Mollymawk chicks at this time in the season, however, given the Grey-headed Mollymawk's longer fledging period (G. A. Taylor pers. comm.), so the possibility of these birds being adults was always considered first.

On many occasions, such as in well-vegetated areas around the smaller Eastern colonies, only a presumed head of a chick, or a greyish/whitish chick-sized smudge partly screened by vegetation, was visible. In such cases, the corresponding area in the November 2019 images was checked. If there was an adult present at this position in 2019, the small spot or smudge was counted as a chick.

The most problematic areas were in the Bull Rock South colony (and to a much lesser extent in Bull Rock North) where chicks were standing or sitting among similar-sized and coloured rocks. These images were re-processed to bring out as much detail as possible, but this was often only partly successful, even when studied alongside the November 2019 images. In such cases, personal judgement was used conservatively.

The counts made by the two analysts were averaged. Although there was sometimes considerable disparity in the numbers of chicks counted in individual sections of these colonies, which may be due to slightly differing alignments of the section boundaries and to differences in interpretation as to which were chicks and which were adults, the overall differences were slight. They ranged from 0.9 % (nett difference 17 chicks) at Bull Rock North, 2.6 % (3 chicks) at Sorensen Tarn, to 3.2 % (140 chicks) and 3.3 % (51 chicks) at Bull Rock South and the Eastern Colonies, respectively.

To calculate nest survival, account was taken of the observation by Rexer-Huber et al. (2020) that only 82 % of a sample of 311 occupied nests (both species combined), surveyed in the Bull Rock South colony on 20 November 2019, contained eggs. The remainder were empty, occupied either by non-breeders or birds that had already failed. Assuming that this figure applies more widely, the number of apparently occupied nests counted during the combined aerial and ground survey in November 2019 was reduced proportionately, to give an estimate of the number of apparently active nests. This is a reasonable assumption, given that from wider surveys carried out in mid-October 1995–97, the percentage of Campbell and Grey-headed Mollymawk nests with eggs was 85.2 % and 79.5 %, respectively (Moore 2004).

To estimate overall nesting success, from egg laying through to fledging, we made various assumptions. First, that the number of nests at the start of the 2019–20 breeding season (N_{t0}) can be reasonably estimated using the equations published by Moore (2004) to calculate the percentage (y) of the mid-October number of apparently active nests present on the date in question (18-24 November in this case, when the aerial and ground surveys of nesting birds were carried out). The equation used here, for all colonies except Bull Rock North, was:

$$y = 133.31\text{-}0.1185x \text{ (where } x \text{ is the Julian day of the year)}$$

For Bull Rock North (Moore, 2003), the equation used was:

$$y = 144.47\text{-}0.1522x$$

From these values for y, the number of active nests in mid-October (N_{t0}) was calculated as:

$$N_{t0} = 100\, N_{t1}/y$$

where N_{t1} was the estimated number of active nests present in November 2019.

Second, to estimate the number of chicks likely to have fledged in April–May (N_f) we formed three models. To estimate an upper bound to fledging survival, we assumed no further mortality of chicks from mid-March through to fledging:

$$N_f = N_{t2}$$

where N_{t2} is the number of chicks estimated in the second survey.

This is not an entirely unreasonable assumption given the sharp decline in chick mortality due to predation by Subantarctic Skua, *Catharcta antarctica*, from early February onwards. Skuas take many unattended small, downy chicks during the early post-guard period, but the nestlings soon become more daunting prey as they grow up to twice the size of a skua and can regurgitate large quantities of stomach oil defensively. Skua predation is therefore biased towards the first half of the mollymawk nestling period, when they are rearing their own chicks. By early February, however, around six weeks into the mollymawk nestling period, most skua chicks have fledged and have left the island along with most adults, so skua predation declines (G.A. Taylor pers. comm.).

Nevertheless, underweight mollymawk chicks are still vulnerable to mortality during cold, wet conditions, even at this late stage (Moore & Moffat 1990), so some mortality should be expected. The only available data on chick survival during the late fledging period comes from Campbell I. in the late-1980s (Moore & Moffat 1990). This showed greatly increased survival among Campbell Mollymawk chicks after the first third of the on-average 130-day nestling period. The pattern was different for the smaller sample of Grey-headed Mollymawk nests, with three-quarters of the chicks being lost during the 27-day guard-phase. Chick survival improved substantially after this, but these was still some mortality (Figure 1).

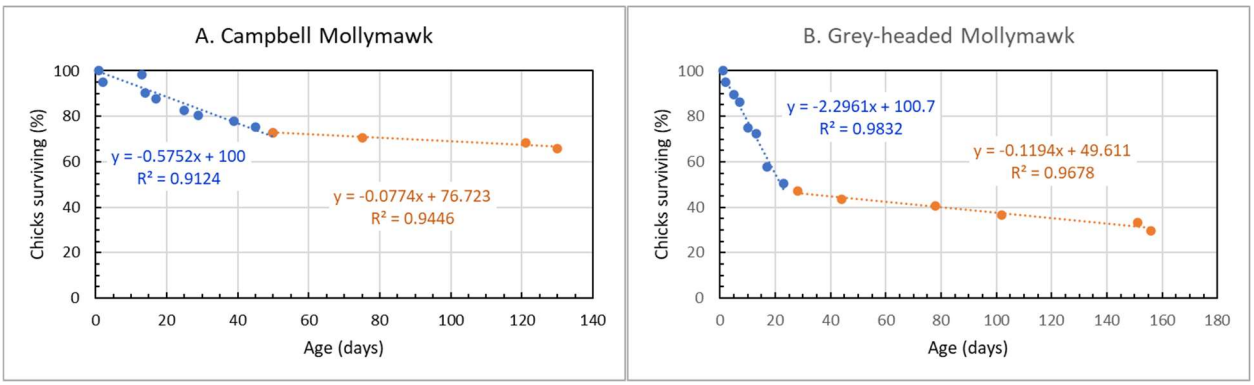

Figure 1. Survival of A. Campbell and B. Grey-headed Mollymawk nestlings with age, derived from Moore & Moffat (1990: Fig. 4), based on data collected during the 1987–88 breeding season, and used in this study to estimate daily survival rates during the latter part of the nestling period.

Overall, for the latter part of the fledging period the relationship, *percent chicks alive (y) vs age (x, days)*, was strongly and significantly linear for both species (Figure 1):

$y = -0.0774\,x + 76.723$ ($r = 0.9719$, $p < 0.01$) for Campbell Mollymawk, and

$y = -0.1194\,x + 49.611$ ($r = 0.9848$, $p < 0.001$) for Grey-headed Mollymawk

Daily survival rates ($\hat{s}$) determined from the slope of these regressions (b) are 0.99923 day^{-1} for Campbell Mollymawk, and 0.99881 day^{-1} for Grey-headed Mollymawk, calculated as:

$$\hat{s} = (1+(b/100))$$

These gave a weighted average ($\hat{s}_w$) of 0.99919 day^{-1}, assuming that the 9:1 ratio of Campbell to Grey-headed Mollymawks in these colonies when surveyed in November 2019 broadly still held. The remaining nestling period was estimated to be 41 days, based on the weighted average of the projected remaining period to fledging of Campbell Mollymawks (c.39 days assuming a 198-day nesting period: ACAP 2012a) and Grey-headed Mollymawks (c.60 days, assuming a 218-day nesting periods: ACAP 2012b), given 10 October as the end of egg laying.

Therefore, the second model of chick survival was to apply this daily survival rate ($\hat{s}_w$) to the estimated number of chicks present in March 2020 (N_{t2}) that could have survived to fledge 41 days later on average (N_f) as:

$$N_f = N_{t2}.\hat{s}_w^{41}$$

The third model was designed to set a lower bound to nesting success. It assumed that the survival of chicks from 17 March to fledging continued at the same daily rate as calculated for the period November 2019–March 2020. Following Johnson & Klett (1985), we estimated of daily survival rate ($\hat{s}_x$) over this period as:

$$\hat{s}_x = \sqrt[(t2-t1)]{(S_{(t1-t2)})} = (S_{(t1-t2)})^{1/(t2-t1)}$$

where S = proportion of nests that survived between 24 November 2019 (t_1) and 17 March 2020 (t_2), a period of 114 days (120 days in the case of Eastern colonies E1-E6). The number of chicks present in March 2020 (N_{t2}) that could have survived to fledge 41 days later on average (N_f) was then calculated as:

$$N_f = N_{t2}.\hat{s}_x^{41}$$

In all cases, overall nesting success was calculated as the number chicks estimated to have fledged (N_f) expressed as a percentage of the number of active nests estimated to have been present in mid-October (N_{t0}).

Results

A total of 7890 chicks were counted across all four sites, just under 55 % of which occurred in the large Bull Rock South colony (Table 1). This represents an overall survival of 63.1 % for the 12,496 estimated active nests during the intervening 114-day period (120 days in the case of Eastern colonies E1-E6). Adults comprised just 3.6 % of the birds present at these colonies.

Table 1. Number of mollymawk chicks counted on the north-eastern coastline of Campbell Island, 17 March 2020, relative to the number of nests with eggs, assumed to be 82% of all apparently occupied nests counted from aerial and ground-level photographs of these colonies taken between 18–24 November 2019 (see text for details). The number of chicks in each region is the mean value obtained by two independent analysts.

Region	Occupied nests Nov 19	Estimated active nests Nov 19	Number of chicks Mar 2020	% survival Nov-Mar
Eastern colonies	2613	2144	1510	70.4
Bull Rock South	8677	7115	4310	60.6
Bull Rock North	3807	3121	1955	62.6
Sorensen Tarn	141	116	115	99.1
Total	15,238	12,496	7890	63.1

Survival varied greatly both within and between colonies in a region (Annex tables A1–A3). At some of the Eastern colonies (E10a, E19-20), Bull Rock North (BRN17-18) and Sorensen Tarn almost all chicks apparently survived from November to March (Annex tables A1-3). For some of these, this may be a result of underestimating the number of active nests in November, calculated overall as 82 % of the number of apparently occupied nests counted then. This may also explain the apparent anomaly at Eastern Colony E13b/14, where survival seemingly exceeded 100%. For Sorensen Tarn, however, it could indicate the difficulties Subantarctic Skua probably face in preying on eggs and chicks, given the lack of almost anywhere suitable to land in the water-filled tarn from which to launch an attack (G.A. Taylor pers. comm.).

The causes of nest failure or chick loss are not known. Skua predation is undoubtedly a major factor (Moore & Moffat 1990), although we have no data on this. The small Eastern colony, E1, appeared to have been struck by a landslip that took out some nests and probably disrupted others (Figure 2). Minor slips were apparent at some other colonies (e.g. Eastern colonies E4 and E8a, and BRN17), while at Bull Rock North, several bare areas on steep slopes, on which many birds were nesting in November 2019, appear to have been swept clean (Figure 3). This suggests that one or more storms may have been a factor affecting nest/chick survival.

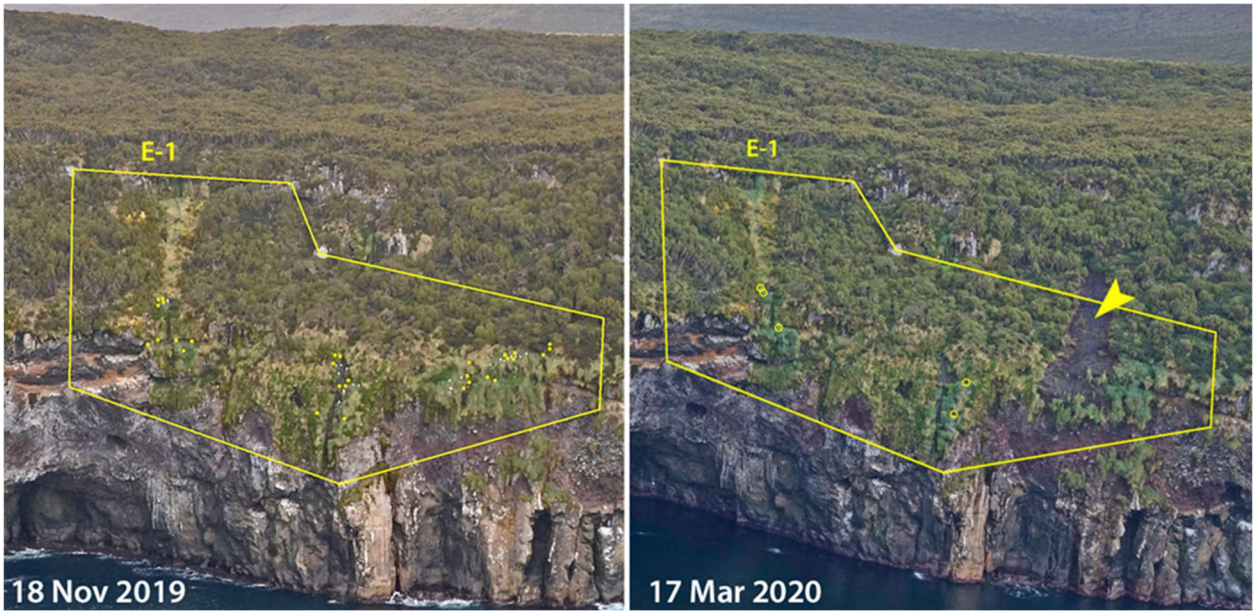

Figure 2. View of Eastern colony E-1 in November 2019, showing the positions of apparently nesting birds (yellow dots), and in March 2020, showing the locations of the six surviving chicks (yellow circles). A major landslip, which may have disrupted nesting on the right-hand side of the colony, is arrowed.

Figure 3. Bull Rock North sub-colonies 5 and 10a (part), both arrowed, showing bare areas that had nesting mollymawks in November 2019, but which appear to have been swept clean of nests by March 2020.

With 61.3 % of nests active in November 2019 surviving to mid-March 2020, 114–120 days later, overall daily survival rate was calculated to be 0.99597 day^{-1}. If this rate remained constant during the remaining average 41 days to fledging, then around 6696 chicks could have fledged from these colonies by the end of the 2019–20 breeding season (Table 2). Expressed as a percentage of nests likely to have been present in early October, the start of the breeding season, this gives a minimum overall estimate for nesting success of 50.7 %. Conversely, if no more nests failed from mid-March to fledging in late-April, 7890 chicks would have fledged, giving an overall maximum estimate for nesting success of 59.7 % (Table 2).

Table 2. Estimated overall nesting success in the mixed Campbell and Grey-headed Mollymawks colonies along the north-eastern coast of Campbell Island (see text for details of how the number of mollymawk nests in early October, and the maximum and minimum number of chicks fledging, were estimated)

Region	Estimated no. nests mid-Oct 2019	Estimated active nests mid-Nov 2019	Estimated number of chicks fledging (minimum)	Estimated number of chicks fledging (maximum)	Upper and lower bounds to overall nesting success (%)
Eastern colonies	2267	2144	1331	1510	58.7–66.6
Bull Rock South	7524	7115	3599	4310	44.5–57.3
Bull Rock North	3301	3122	1652	1955	46.6–59.2
Sorensen Tarn	123	116	115	115	94.3
Total	13,215	12,497	6696	7890	50.7–59.7

Accepting that some chicks may still die from malnutrition or other incidental factors, a more realistic estimate of nesting success would be to assume a higher daily survival rate during the latter part of the nestling period but one that is still < 1. Using a combined daily survival rate 0.99919 day^{-1}, calculated using Moore & Moffat's (1990) data for chick survival during the latter part of the 1987-88 nesting season, and applying this to the estimated number of chicks alive in March 2020, suggests around 7632 mollymawk chicks could have survived to fledging, giving an estimated nesting success of 57.8 %.

Discussion

During the 2019–20 breeding season on Campbell I., a total of 7890 active Campbell and Grey-headed Mollymawks nests survived through the last third of the incubation period up to the first 60–70 % of the nestling period. Conventionally, nesting success is calculated for two discrete periods, incubation and nestling. It is measured as the product of hatching success (the proportion of eggs that hatch to produce a chick) and fledging success (the proportion of hatched chicks that fledge successfully). Studies at Bull Rock South, carried out in the 1980s and 1990s, have shown substantially higher nesting success in Campbell Mollymawk (52 %, Moore & Moffat 1990; 66 ± 12 % [±s.d., N = 6 years], Waugh et al., 1999) than Grey-headed Mollymawk (16 %, Moore & Moffat 1990; 40 ± 20% [N = 6 years], Waugh et al., 1999). In both species, hatching success was higher than fledging success: 80–86% vs 65–79% in Campbell Mollymawk; 56–80% vs 29–51% in Grey-headed Mollymawk (Moore & Moffat 1990, Waugh et al. 1999).

The crude measure of success in this study (0.613 or 63.1%) cuts across both these periods, but only partly so for each. It is not strictly comparable therefore with these earlier findings. This complicates efforts to interpret the contemporary significance of the 2019–20 measure. The only broadly comparable statistic comes from work by P.J. Moore and colleagues who surveyed sections of the Bull Rock South and Bull Rock North colonies at least four times during each of the 1993–94 and 1994-95 breeding seasons: in mid-October, late-December, mid-March and late-April (Moore 2002, 2008). From these data, daily survival rate of nests of both species combined can be calculated. For the nearest comparable period to the data for 2019–20, late-December to mid-March, the daily survival rates for nests in both colonies taken together were 0.99291 day^{-1} and 0.99279 day^{-1}, in 1993–94 and 1994–95, respectively. The equivalent figure for 2019–20 was higher, 0.99597 day^{-1}, suggesting that at this mid-stage of the breeding season, 2019–20 was at least as good as, if not better than in these earlier years.

Using Moore's (2004) regression equations applied to the number of nests assumed to be active in November 2019, some 13,215 active nests could have been present at the start of the breeding season. If no more nests failed after 17 March, 7890 chicks would have fledged in late-April/early-May, giving an upper bound to nesting success for 2019–20 of 59.7 %, within the range of earlier measures.

Conversely, by extrapolating the mean daily survival rate during November 2019–March 2020 through to fledging, a lower bound to nesting success was calculated. By this measure, at least 6696 chicks would have fledged, giving a minimum nesting success for the 2019–20 breeding season of around 50.7 % for both species combined, slightly below that found in earlier studies for Campbell Mollymawk but above that for Grey-headed Mollymawk (Moore & Moffat 1990, Waugh et al. 1999).

A more realistic estimate of nesting success, accepting that some chicks would die during the latter part of the nestling period, assumed a daily survival rate of 0.99919 day^{-1}, based Moore & Moffat's (1990) data for chick survival during the latter part of the 1987-88 nesting season. This suggests around 7632 mollymawk chicks fledging by the end of the season, a nesting success around 57.8 %. This is within the range of the 1984–96 estimates for Campbell Mollymawk (66% [95% CL 56.4–75.6], Waugh et al. 1999), the predominant species in the colonies surveyed in March 2020.

Broadly speaking therefore, overall nesting success in these colonies in 2019–20 was 50–60 %, with a best estimate of around 58 %. This conclusion is based on several assumptions and extrapolations, however, and so should be judged accordingly.

Acknowledgments

We are grateful to Leading Aircraftsman Dillon Anderson who took the aerial photographs at the request of CM. Peter Moore gave valuable information and insights for which we are also most grateful. Igor Debski (Department of Conservation) kindly made available the unpublished spreadsheets originally compiled by Peter Moore. Graeme Taylor (Department of Conservation) provided the stimulus and funding for this study, as well as much useful feedback. The November 2019 ground and aerial survey, on which this study builds, was organised and carried out by Kalinka Rexer-Huber and Kevin Parker.

References

ACAP (Agreement on the Conservation of Albatrosses and Petrels). 2012. Species assessment: Campbell Albatross *Thalassarche impavida*. Online at https://www.acap.aq/resources/acap-species/293-campbell-albatross/file (downloaded 20 July 2018)

ACAP (Agreement on the Conservation of Albatrosses and Petrels). 2010. ACAP Species assessment: Grey-headed Albatross *Thalassarche chrysostoma*. Online at https://www.acap.aq/resources/acap-species/248-grey-headed-albatross/file (downloaded 20 July 2018).

Ersts, P.J. 2019. DotDotGoose (version 1.5.0). American Museum of Natural History, Center for Biodiversity and Conservation. New York, NY. Available from http://biodiversityinformatics.amnh.org/open_source/dotdotgoose [accessed 17 April 2020].

Frost, P. 2020. Status of Campbell Island and Grey-headed mollymawks on the northern coasts of Campbell Island, 2019. Final report for project BCBC2019-03. Department of Conservation. 24 pp. Online at https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/final-reports/bcbc2019-03-campbell-island-seabird-project-final-report-frost.pdf

Moore, P.J. 2002. Counting mollymawks on Campbell Island – data supplements. Science & Research Internal Report, 192. Department of Conservation, Wellington, New Zealand.

Moore, P.J. 2003. DOCDM-453700 [unpublished spreadsheet]. Department of Conservation, Wellington, New Zealand.

Moore, P. 2004. Abundance and population trends of mollymawks on Campbell Island. Science for Conservation, 242. Department of Conservation, Wellington, New Zealand.

Moore, P.J. 2008. DOCDM-453701 [unpublished spreadsheet]. Department of Conservation, Wellington, New Zealand.

Moore, P.J.; Moffat, R.D. 1990. Mollymawks on Campbell Island. Science and Internal Report Series 59, Department of Conservation, Wellington, New Zealand. Online at https://www.doc.govt.nz/documents/science-and-technical/SRIR59.pdf.

Rexer-Huber, K.; Parker, K.A.; Parker, G.C. 2020. Campbell Island seabirds: Operation Endurance November 2019. Final report to Marine Species and Threats, Department of Conservation, Wellington, New Zealand. Parker Conservation, Dunedin. 23 p. Online at https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/final-reports/bcbc2019-03-campbell-island-seabird-project-report.pdf

Waugh, S.M., Weimerskirch, H., Moore, P.J., and Sagar, P.M. 1999. Population dynamics of Black-browed and Grey-headed Albatrosses *Diomedea melanophrys* and *D. chrysostoma* at Campbell Island, New Zealand, 1942-96. Ibis 141: 216-225.

Annex

Table A1. Average count of mollymawk chicks in mid-March 2020 relative to the number of mollymawks estimated to be sitting on eggs in the Eastern colonies in November 2019 (see text for details), and the estimated number of Campbell and Grey-headed Mollymawks among these. The given number of chicks recorded in March 2020 is the average of the counts by two observers. The difference in these counts across all areas was 3.3 %.

		Estimated number of nests Nov 2019		Both species	
Area	Mollymawks nests with eggs Nov 2019	Campbell mollymawk	Grey-headed mollymawk	Number of chicks Mar 2020	% survival Nov 2019-Mar 2020
E-1	25	20	5	5	20.0
E-2	16	12	3	12	75.0
E-3	36	30	7	20	55.6
E-4	16	13	3	7	43.8
E-5a	63	51	12	38	60.3
E-5b	25	20	5	20	80.0
E-6a	57	46	11	27	47.4
E-6b	35	29	7	24	68.6
E-7	67	54	13	60	89.6
E-8a	51	41	10	39	76.5
E-8b	18	15	3	16	88.9
E-9	16	13	3	13	81.3
E-10a	3	2	1	3	100.0
E-10b	21	16	4	14	66.7
E-11a	9	7	2	7	77.8
E-11b	29	23	6	15	51.7
E-12	33	26	7	25	75.8
E-13a	73	59	14	43	58.9
E-13b/14	21	17	4	25	119.0
E-15 upper	863	698	165	594	68.8
E-15 lower	275	222	52	210	76.4
E-16/17	64	52	12	55	85.9
E-18	4	3	1	3	75.0
E-19	13	11	2	13	100.0
E-20	39	32	7	39	100.0
E-23a	81	65	16	68	84.0
E-23b	50	40	10	32	64.0
E-23c [S part]	73	59	14	43	58.9
E-24	68	55	13	47	69.1
Total	2144	1731	412	1510	70.4

Table A2. Number of mollymawk chicks counted in mid-March 2020 relative to the number of mollymawks estimated to be sitting on eggs in the Bull Rock South colony (A) and Sorensen Tarn (B) in November 2019 (see text for details), together with the estimated number of Campbell and Grey-headed Mollymawks in each area. The number of chicks recorded in March 2020 is the average of the counts by two observers. The differences in these counts across all areas in Bull Rock South and at Sorensen Tarn were 3.2 % and 2.6 %, respectively.

A		Estimated number of nests Nov 2019		Both species	
Area	Mollymawks nests with eggs Nov 2019	Campbell mollymawk	Grey-headed mollymawk	Number of chicks Mar 2020	% survival Nov 2019-Mar 2020
BRS-1	11	10	1	7	63.6
BRS-1a	29	29	0	4	13.8
BRS-2	68	41	27	43	63.2
BRS-3	486	437	49	273	56.2
BRS-4	104	93	11	47	45.2
BRS-5a	293	245	48	148	50.5
BRS-5b	518	518	0	318	61.4
BRS-6	213	208	5	104	48.8
BRS-7	17	16	1	8	47.1
BRS-9	216	216	0	97	44.9
BRS-10	198	182	16	108	54.5
BRS-11	240	236	4	116	48.3
BRS-12	207	205	2	157	75.8
BRS-13	145	143	2	98	67.6
BRS-14	252	249	3	134	53.2
BRS-15	287	287	0	190	66.2
BRS-16	168	163	5	113	67.3
BRS-17	462	448	14	284	61.5
BRS-18	111	111	0	57	51.4
BRS-19	194	187	6	104	53.6
BRS-20	149	143	6	119	79.9
BRS-21a	578	552	26	379	65.6
BRS-21b	441	421	20	265	60.1
BRS-22	244	166	80	192	78.7
BRS-bbt	1117	1092	25	683	61.1
BRS-SS, a-c	207	207	0	156	75.4
BRS-d	105	94	11	68	64.8
BRS-GH2	54	35	19	44	81.5
Total	7115	6734	381	4310	60.6

B		Estimated number of nests Nov 2019		Both species	
Area	Mollymawks sitting Nov 2019	Campbell mollymawk	Grey-headed mollymawk	Number of chicks Mar 2020	% survival Nov 2019-Mar 2020
Sorensen Tarn	116	116	0	115	99.1

Table A3. Number of mollymawk chicks counted in mid-March 2020 relative to the number of mollymawks estimated to be sitting on eggs in the Bull Rock North colony in November 2019, together with the estimated number of Campbell and Grey-headed Mollymawks among these (see text for details). A. Counts made by PGHF, who analysed the images by section boundaries given in Moore (1999). B. Average counts of chicks by both assessors across four aggregated sections of the Bull Rock Colony, following the divisions used by CM. The difference in these counts across all areas was 0.9 %.

A.		Estimated number of nests Nov 2019		Both species	
Area	Mollymawk nests with eggs Nov 2019	Campbell mollymawk	Grey-headed mollymawk	Number of chicks Mar 2020[1]	% survival Nov 2019-Mar 2020
BRN-1	51	26	25	24	47.1
BRN-2	51	39	12	30	58.8
BRN-3	115	114	1	73	63.5
BRN-4	165	163	2	132	80.0
BRN-5	264	262	2	130	49.2
BRN-5a	41	41	0	28	68.3
BRN-6	177	136	41	112	63.3
BRN-7	262	262	0	171	65.3
BRN-8	215	177	38	140	65.1
BRN-9	60	60	0	50	83.3
BRN-10a	62	62	0	33	53.2
BRN-10b	74	74	0	54	73.0
BRN-11	224	208	16	137	61.2
BRN-12	572	453	119	388	67.8
BRN-13	474	398	76	275	58.0
BRN-13a	39	37	2	15	38.5
BRN-14	72	56	16	31	43.1
BRN-15	122	48	74	77	63.1
BRN-16	52	35	17	32	61.5
BRN-17	21	13	8	21	100.0
BRN-18	9	2	7	9	100.0
Total	3122	2666	456	1962	62.8

B.		Estimated number of nests Nov 2019		Both species	
Section	Mollymawk nests with eggs Nov 2019	Campbell mollymawk	Grey-headed mollymawk	Number of chicks Mar 2020[2]	% survival Nov 2019-Mar 2020
N1 (Areas 5-15)	2658	2274	384	1636	61.6
N2 (Areas 1-4)	381	342	39	264	69.3
N2 ext (Area 16)	52	35	17	29	55.8
N3 (Areas 17-18)	30	15	16	26	86.7
Totals	3122	2666	456	1955	62.6

[1] The counts at this scale were made by one analyst only

[2] Average of the counts made by both analysts