



Photograph by Kalinka Rexer-Huber (©), Parker Conservation

Status of Campbell Island and Grey-headed Mollymawks on the Northern Coasts of Campbell Island, November 2019

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Summary

This report assesses the current breeding populations of Campbell Island Mollymawk (*Thalassarche impavida*) and Grey-headed Mollymawk (*Thalassarche chrysostoma*) in colonies along the north-east and northern coast of Campbell Island. It is based on analyses of both aerial and ground-level photographs of the colonies. Aerial photographs were taken during two Navy helicopter flights along the coast, 6 days apart in mid-to-late November 2019. Ground-level photographs were taken from 14 fixed vantage points overlooking the eight sites where mollymawks breed. Information on overall numbers were derived for the larger colonies from the aerial photographs, supplemented by more detailed information on species composition and what proportion of the birds were sitting on nests or standing (occasionally sitting) around, either as partners of nesting birds, or as courting pre-breeders, or simply just loafing.

Overall, an estimated 23,612 Campbell Mollymawks and 5311 Grey-headed Mollymawks appeared to be occupying nests ('apparently occupied nests'), although not all of these necessarily involved a bird sitting on an egg. In a contemporaneous survey at the Bull Rock South colony, 18% of occupied nests were empty. If this figure applies more widely, the actual number of breeding pairs could be lower: 19,362 and 4355 pairs of Campbell and Grey-headed mollymawks, respectively. A further 4582 Campbell Mollymawk individuals (16 % of the species' total) and 1210 Grey-headed Mollymawks (just under 19 % of that species' total) were recorded loafing.

These figures, compared with those covering the past 25 years, suggest that the Campbell Mollymawk population may be relatively stable, whereas the Grey-headed Mollymawk population has probably declined, perhaps by as much as 1.7–4.7 % per annum over this period.

DRAFT

Introduction

The north-east and north coasts of Campbell Island support several mixed colonies of the Campbell Island Mollymawk (*Thalassarche impavida*)—hereafter Campbell Mollymawk—and Grey-headed Mollymawk (*Thalassarche chrysostoma*). The Campbell Mollymawk is endemic to the Campbell Island archipelago, breeding only on these northern coasts and on the offshore island, Isle de Jeanette Marie (Gill *et al.* 2010; ACAP 2012a; Sagar 2014; BirdLife International 2018b). The most recent estimates, 2006–2012, put the breeding population along the northern coast at 21,648 breeding pairs (Sagar 2014). The only detailed estimate for Isle de Jeanette Marie, from an aerial survey in 1990, is a breeding population of 193 Campbell Mollymawk (Moore & Blezard 1999).

These northern colonies are also the only breeding site for Grey-headed Mollymawk in New Zealand. This is a biennial, circumpolar breeding species with strongholds in South Georgia (supporting around 50 % of the global breeding population of 96,000 pairs) and two island groups off southern Chile, Diego Ramirez and Ildefonso (just under 19 % of the global population: ACAP 2010b; BirdLife International 2018a). The population on Campbell Island, most recently estimated to be 8,611 breeding pairs annually (Sagar 2014), makes up just under 9% of the global total (ACAP 2010b)

These colonies have been surveyed intermittently since the 1940s, other than a period of more detailed study during the period 1984–1997 (Moore & Moffat, 1990; Moore 1999, 2004; Moore & Blezard 1999a, b; Waugh *et al.* 1999). These studies pointed to long-term declines in both species. Moore (2004) suggested environmental change affecting food supply as perhaps the most likely cause of this decline but also noted that the large decrease recorded between the late 1960s and early 1980s coincided with a peak in long-line fishing for southern bluefin tuna. Neither species has figured prominently in bycatch statistics from some pelagic fisheries, e.g. Grey-Headed Mollymawk making up <1% of the total bycatch in two Patagonian toothfish *Dissostichus eleginoides* fisheries around the Prince Edward, Crozet and Kerguelen island groups (Nel, Ryan & Watkins 2002; Delord *et al.* 2005), but how representative or reliable such figures are across the whole of the Southern Ocean's pelagic fishery is an open question. Richard & Abraham (2015) place the Campbell Mollymawk in the 'High Risk' category, whereas Grey-headed Mollymawk was assessed as 'Low Risk'. These assessments were based on a risk assessment that compared estimates of fishing-related mortality to potential biological removal, a measure of maximum level of human-induced mortality that a population can sustain, while still remaining above half its carrying capacity over the long term (Richard & Abraham 2015). Until the demography of these species is better understood, both should be considered vulnerable to fishing-related mortality, if not as breeding adults then at least during the extended juvenile (pre-breeding) stage of life. Being long-lived, slow-reproducing species with delayed maturity, mollymawks, albatrosses and larger petrels may be particularly susceptible to even small changes in their vital demographic rates.

An essential element of any population analysis is to have a reasonably accurate assessment of the size of the breeding population and its changes through time. To this end, this project aimed to compile, process, and analyse images taken during Operation Endurance, November 2019 (Rexer-Huber, Parker & Parker 2020), part of a planned survey of seabirds on Campbell Island. The key components of this work were to determine colony size and species composition and, where possible, estimate the numbers of active breeding birds of each species present. Full details of how and where the images were obtained are given in Rexer-Huber *et al.* (2020).

Methods

The colonies situated along the coast from North-east Harbour north to Bull Rock, and from there westwards to the end of the Courrejolles Peninsula, were photographed in November 2019 from various platforms. Aerial images were taken during two helicopter flights and one from a drone (Courrejolles Peninsula only). The two photographic series were taken a week apart from helicopters flying some distance offshore from North-east Harbour to Hooker's Peninsula (one extended with intermittent coverage to the Courrejolles Peninsula). They comprised 77 images (548 MB) taken with a Nikon D7000 camera, and 42 images (281 MB) taken with a Nikon Coolpix P1000 camera. The Courrejolles Peninsula was also photographed with a Hasselblad L1D-20c camera mounted on a DJI Mavic 2 Pro drone (66 images and 7 videos).

High-resolution, ground-level images were taken from 14 marked vantage points overlooking all colonies from Bull Rock South in the east to the Courrejolles Peninsula in the west, a total of 540 images in 16 sets (two back-up sets taken from slightly different angles). Details of the geographic locations of vantage-point and drone photographs are given in Rexer-Huber *et al.* (2020). Most were taken with a Canon EOS 7D Mark II camera and an EF-S60mm f/2.8 Macro USM lens from cliffs overlooking the South and North Bull Rock colonies, Hooker's Peninsula, Hooker's Finger, and the Courrejolles Isthmus. The inaccessible Courrejolles Peninsula was photographed from two distant vantage points, C1 and C2, 2.4–1.2 km and 149–169° south of the peninsula, using an EF75-300mm f/4-5.6 lens on a Canon EOS 7D Mark II camera. Details of the locations, dates, times, cameras and lenses used, along with the camera settings, are given in Tables 1 and 2.

Image processing and analysis

Around 50 % of the 793 images received were in JPG file format, making them immediately compatible with the image processing and counting software used in this project: Adobe Photoshop Elements 14; ImageJ 1.52p (National Institutes of Health, USA); Image Composite Editor 2.0.3.0 64-bit (ICE, Microsoft Research); and DotDotGoose 1.5.0 (Centre for Biodiversity and Conservation, AMNH; Ertz 2019). The remaining 395 images were in Canon's CR2 RAW image format. None required initial processing as RAW files and so were converted directly to JPG files using Digital Photo Professional 4 (Canon). Key image data—camera make and model; lens focal length and 35-mm equivalent; f-stop; shutter speed; ISO setting; and, for the drone images, GPS reading—were extracted with Picmeta Systems' Picture Information Extractor 7.12.11.29 and compiled by image set. The GPS data were originally recorded as DMS latitude/longitude, and so were converted to decimal degrees (DD) with an Excel VBA macro.

For the multiple overlapping images of the Bull Rock and other northern mollymawk colonies taken from on-ground fixed vantage points, other than the Courrejolles Peninsula, analysis could only usefully be carried out on multi-image panoramas. These panoramas were created using Microsoft's Image Composite Editor (ICE). The resulting images are huge (the biggest, a 22-image composite covering the middle section of the Bull Rock South colony, measures 25,362 x 20,197 pixels, 54 Mb). These composites were not always used in the analyses, especially those covering the more densely packed colonies, because of the risk of distortion and loss of individuals along the boundaries of the composited images. Where this was a risk, individual images were used, with subsections being demarcated along common lines visible in adjacent images, to ensure that there was no overlap or gaps in the areas analysed. Where possible, these lines were drawn between prominent features—rocks, fissures, erosion scars, drainage lines, distinctive grass tussocks, etc.—visible in adjacent images. Otherwise, for example where a line had to go through a colony of birds, particular care was taken to ensure that the lines were drawn compatibly in the two images.

Table 1. Operational details of the various aerial and ground-level photographic surveys of the mixed Campbell Island and Grey-headed Mollymawk colonies on the north and north-east coasts of Campbell Island, 18–24 November 2019.

Area	Platform/position	Date	Time	Camera	Lens
North-east coast	NH90 Helicopter (aerial)	18/11/2019	11:02-11:07	NIKON D7000	18-105mm f/3.5-5.6 G VR
Sorensen Tarn	Ground-level photo from NNE edge	20/11/2019	09:09	Olympus TG-5	Olympus 4.5-18 mm f/2.0-4.9
Bull Rock North	Ground-level fixed points MP11, MP11a	20/11/2019	09:16-10:27 ⁴	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Bull Rock South	Ground-level fixed points MP10, MP10a	20/11/2019	09:56-10:37 ³	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Bull Rock South	Ground-level fixed point MP12	20/11/2019	14:24-14:28	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Hooker's Finger	Ground-level fixed points MP2-MP6	21/11/2019	13:25-16:48 ¹	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Hooker's Peninsula	Ground-level fixed points MP7-MP9	21/11/2019	19:22-20:06 ²	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Courrejolles Isthmus	Ground-level fixed point MP1	23/11/2019	13:18-13:20	Canon EOS 7D Mark II	EF-S60mm f/2.8 Macro USM
Courrejolles Peninsula	Ground-level fixed points C1, C2	23/11/2019	08:54-09:02	Canon EOS 7D Mark II	EF75-300mm f/4-5.6
Courrejolles Peninsula	DJI Mavic Pro Drone (aerial)	23/11/2019	10:39-11:21	Hasselblad L1D-20c	Hasselblad 28mm f/2.8-11
North-east and north coast	Sea Sprite Helicopter (aerial)	24/11/2019	09:30-09:35	COOLPIX P1000	4.3-539mm f/2.8-8 NIKKOR
Sorensen Tarn	Sea Sprite Helicopter (aerial)	24/11/2019	09:33	COOLPIX P1000	4.3-539mm f/2.8-8 NIKKOR

Table 2. Camera settings for aerial and ground-level photographs taken of the mixed Campbell Island and Grey-headed Mollymawk colonies in November 2019. Most cameras were set on Automatic Exposure mode except for the Olympus TG-5 camera, which was set on Aperture Priority.

Area	Platform/position	Shutter	Aperture	ISO	Focal Length (actual)	Focal Length (35mm equiv.)
North-east coast	NH90 Helicopter (aerial)	1/400 s	F10.0	250	18 mm	27 mm
Sorensen Tarn	Ground-level photo from NNE edge	1/60 s	F8.0	100	4.5 mm	25 mm
Bull Rock North	Ground-level fixed points MP11, MP11a	1/395-1/644 s	F5.6-14.0	250	60 mm	60 mm
Bull Rock South	Ground-level fixed points MP10, MP10a	1/395-1/1328 s	F5.6-10.0	250	60 mm	60 mm
Bull Rock South	Ground-level fixed point MP12	1/395-1/1328 s	F5.6-10.0	250	60 mm	60 mm
Hooker's Finger	Ground-level fixed points MP2-MP6	1/256-1/790 s	F5.0-10.0	250	60 mm	60 mm
Hooker's Peninsula	Ground-level fixed points MP7-MP9	1/166-256 s	F4.0-5.6	250	60 mm	60 mm
Courrejolles Peninsula	Ground-level fixed points C1, C2	1/256-1/395 s	F5.6-7.1	250	75-300 mm	75-300 mm
Courrejolles Peninsula	DJI Mavic Pro Drone (aerial)	1/200 s	F6.3-8.0	100	10.3 mm	28 mm
Courrejolles Isthmus	Ground-level fixed point MP1	1/664 s	F8.0	250	60 mm	60 mm
North-east and north coast	Sea Sprite Helicopter (aerial)	1/160 s	F2.8	100	6.3 mm	35 mm
Sorensen Tarn	Sea Sprite Helicopter (aerial)	1/200 s	F3.2	100	6.3 mm	35 mm

The marked sections followed those used by Moore (1999). In most cases, the dividing line between sections was reasonably obvious, but minor problems arose when the images, although taken from the vantage points established by Moore (1999), only partly matched those shown in that report or where the positions of the earlier dividing lines was not clear from the published images. Most of the delineations marked on the present set of images, however, probably correspond reasonably closely those used in earlier surveys. Figure 1 illustrates this for the middle section of Bull Rock South. Incomplete sections were covered in the adjacent images on each side.

All birds seen on the images were counted and catalogued using DotDotGoose [v 1.5.0] (<http://cbc.amnh.org>; Erts 2019). Individuals were classed as follows: Campbell Mollymawk; or Grey-headed Mollymawk; or Mollymawk unspecified (species not determinable). Individuals in each of these classes were in turn classified by activity (sitting, loafing, flying or undetermined). Obviously, it was not possible to determine consistently the identity of individuals seen on all the aerial images and most telephoto ones taken of the Courrejolles Peninsula colonies, so data from these sources simply comprised a count of the number of mollymawks, distinguished where possible by activity. In contrast, species identity and activity could be more easily determined during analysis of the ground-level photographs, although there were still some birds where either identity or activity or both were uncertain. Such birds were classed simply as mollymawks, with or without being partitioned by activity. Birds in flight were recorded simply for completeness and were not used in any of the analyses.



Figure 1. Delineated sections for the mixed-mollymawk colony at Bull Rock South. Incomplete sections were covered in the adjacent image on either side. The numbering of each section corresponds to that used by Moore (1999). For comparison, see Figures A2a-d in that report.

Calculations

The general approach was to allocate any indeterminate individuals in a colony, first by activity, based on the proportions of sitting and loafing birds observed in that colony, then to species, using the observed proportions of each species observed within an activity class. The calculations were slightly more involved in extrapolating from incomplete (sample) ground-level counts to, it was assumed, more complete counts from aerial photographs, when generally only the numbers of individuals and their activity could be determined. Again, indeterminate individuals were first assigned proportionately to an activity, then to a species. For the Eastern colonies, where there were no corresponding ground-level counts of species and activity, I applied average species' proportions for each activity, as measured at Bull Rock South, the nearest colony. Other site-specific details of the calculations involved in arriving at population estimates are given below in the accounts for each relevant area.

Results and Discussion

Overall estimates of the numbers of Campbell and Grey-headed mollymawks present at the each of the main nesting areas on the north and north-east coasts of Campbell Island are shown in Table 3. An estimated 23,254 Campbell Mollymawks and 5623 Grey-headed Mollymawks were apparently sitting on nests, although not all nests necessarily contained an egg. Rexer-Huber *et al.* (2020) estimated from contemporaneous transect counts at the Bull Rock South colony that 18 % of nests, both species combined, were empty, despite the presence of a sitting bird, and therefore deemed to be 'tryers'. No adjustments have been made to the figures in Table 3 to account for this, so the true number of nesting pairs is almost certainly lower than those given in the table, perhaps as few as 19,068 and 4611 pairs of Campbell and Grey-headed mollymawks respectively. At the same time, the survey was carried out in late November, by which time some of the initial nests in the season will have failed. Using the formulae given in Moore (2004), approximately 13 % of Campbell I Mollymawk nests and 7 % of Grey-headed Mollymawk nests might be expected to have failed by late November when the survey was carried out.

In addition to the apparently nesting birds, considerable numbers of loafing birds were counted (Table 3). From observations of such birds seen in the images, these comprised birds sitting or standing next to incubating birds, presumably their partners; pairs of non-nesting birds displaying or preening each other, probably pre-breeders looking for or setting up nest sites; individuals standing on or next to empty nests, which could be potential breeders or recently failed breeders standing next to their nest sites; and other birds simply loafing around individually or in small, 2-4 bird, groups. Overall, of all birds counted on land, 16 % of Campbell Mollymawks and 20 % of Grey-headed Mollymawks were loafers. Details for each colony in these areas are given in the following subsections.

Courrejolles Peninsula

The Courrejolles Peninsula supported just under 31 % of all Campbell and 58 % Grey-headed mollymawks nesting along the north and north-east coasts of Campbell Island, re-emphasizing the importance of this peninsula as the stronghold for Grey-headed Mollymawk on the island (Moore 2004; Sagar 2014). The peninsula is inaccessible, so surveys are carried out from two vantage points, C1 and C2 (Moore 1999), 2.1 to 2.4 km away, overlooking the southern slopes of the peninsula on which the colonies are situated. Surveys from the air or sea have been done less often. (There are no colonies on the northern side, something confirmed by examining a short video taken during one of the helicopter flights.)

Table 3. Overall population estimates for Campbell and Grey-headed Mollymawk along the north and north-eastern coasts of Campbell Island. Sitting birds are those apparently occupying nest sites, although some nests may be empty (see text for details).

Area	Methods ¹	Campbell Mollymawk		Grey-headed Mollymawk	
		Sitting	Loafing	Sitting	Loafing
Courrejolles Peninsula	AC, GC	7303	1435	3085	744
Courrejolles Isthmus	GC	133	44	130	88
Hooker's Finger	GC	1201	162	815	130
Hooker's Peninsula	AA, GC	459	94	342	99
Bull Rock North	AA, GC	3596	398	407	49
Bull Rock South	AA, GC	8261	1920	416	80
Sorensen Tarn	GC	140	42	0	0
Eastern Colonies	AA	2519	487	126	20
Total		23,612	4582	5311	1210

1. AC = ground-level photo count, adjusted using ground-level measures of species and activity
AA = aerial photo count, adjusted using ground-level measures of species and activity
GC = count from ground-level photographs, adjusted to account for indeterminate individuals

In this survey, counts were made from telephoto images taken from the two vantage points, C1 and C2 (Moore 1999). Aerial images from a Hasselblad L1D-20c camera mounted on a DJI Mavic 2 Pro drone and flown from C2 to within 0.14 km of the peninsula at the closest point, were examined. Despite the proximity to the colonies, the 10.3 mm focal length of the camera (equal to 28 mm on a 35 mm camera), meant that the birds were no better resolved than those taken using a 300 mm telephoto lens from the two vantage points, so these images were not analysed further. Nevertheless, they remain a useful back-up to those images that were analysed.

No clear differentiation among the species could be made in Areas 1–3, those furthest from the vantage points, but it was often possible to distinguish between standing loafing birds and those sitting on nests. Some birds, sitting on grass tussocks, usually on the edges of colonies, were also judged to be loafing, as were one of two birds sitting close to each other when one was judged to be on a nest. Across the three areas, 82% of birds were judged to be sitting, just under 16% classed as loafing, and the balance (just over 2%) were indeterminate. After accounting for the birds in this last group, which were allocated proportionately to the other two classes, 'sitting' and 'loafing', they were then further allocated to species based on the proportion of Campbell and Grey-headed Mollymawks observed in Area 4.

Area 4 was situated 1.2–1.5 km from vantage point C2. Photographs taken with a 300 mm telephoto lens were sufficiently resolved to determine the identity of 71 % of the 3871 individuals counted in this area. The balance (29 %) were indeterminate although, as with the identified individuals, it was generally possible to classify them by whether they were sitting or loafing. Overall, around 77% of all birds were judged to be sitting, just under 19% to be loafing, and the balance (under 4%) were indeterminate (Table 4).

Table 4. Composition, numbers and activity of mollymawks in the large mixed-species colony on the Courrejolles Peninsula: A. as counted from telephoto images of the colony; B. as estimated based on extrapolation from the species' proportions and activities determined from detailed counts and assignment of individuals in Area 4 (see A.).

A. Counted	Campbell Mollymawk		Grey-headed Mollymawk		Mollymawk spp.			Total
	sitting	loafing	sitting	loafing	sitting	loafing	undefined	
Area 1	0	0	0	0	1009	174	84	1267
Area 2	0	0	0	0	2433	559	24	3016
Area 3a	0	0	0	0	2578	413	39	3030
Area 3b	0	0	0	0	1100	247	36	1383
Area 4	1545	363	652	188	802	181	140	3871
B. Calculated								
Area 1	760	123	321	63				1267
Area 2	1724	371	729	192				3016
Area 3a	1836	275	776	143				3030
Area 3b	794	167	335	87				1383
Area 4	2189	499	924	259				3871
Total	7303	1435	3085	744				12,567

Courrejolles Isthmus

The Courrejolles Isthmus supports one major colony that descends a series of terraces below fixed-point photo point MP1, and a smaller secondary colony (JDK), that lies west of the main colony and appears not to be visible from MP1. The latter was not surveyed or photographed in 2019.

Overall, 133 Campbell Mollymawks and 130 Grey-headed Mollymawks were estimated to be sitting on nests in Colony 1 in November 2019 (Table 3). A further 44 Campbell Mollymawks and 88 Grey-headed Mollymawks were assessed as loafing. There were no aerial images covering this colony to show its full extent, so the counts are presented as is, adjusted only by a proportional allocation of individuals of each species whose initial status (sitting, loafing) could not be determined. These unallocated individuals comprised just over 4 % of Campbell Mollymawks and just under 9 % of Grey-headed Mollymawks, so the adjustments are unlikely to have introduced much error.

Hooker's Finger

Four main colonies occur on Hooker's Finger, overlooked by 5 vantage points (MP2-6). Colony 2 is spread over about 0.4 ha with 17 identified sub-colonies (Moore 1999: Figure A30, A31). Five of these were apparently empty at the time of this survey, but the steep and undulating topography makes it difficult to obtain clear views of all the sub-colonies. Moreover, photographs taken of Colony 2 from vantage points MP2 and MP3, while together encompassing all 17 sub-colonies, do not do so individually. Although there is some overlap, counts and classification of individuals in those sub-colonies visible from both vantage points show that coverage of each is partial. Given the different angles of view, MP2 from diagonally above and MP3 from diagonally below, it is not possible to determine which individuals are common to both image sets, and which are additional to one or the other. Consequently, the highest count of identified individuals for each sub-colony was chosen for analysis. This is not ideal, because some birds will have been omitted, but it is a parsimonious one that minimises the risk of double counting and hence overestimating the size of these sub-colonies.

The problem of incomplete coverage is further illustrated by Colony 3. Actual counts of Campbell and Grey-headed Mollymawks in this colony from MP3 were around 50% lower than those made from MP4. Whereas both sets are presented in Table 5, to underscore the point, only those from MP5 were used when calculating totals for Hooker's Finger. Overall, an estimated 1201 Campbell Mollymawks and 815 Grey-headed Mollymawks were apparently occupying nests on Hooker's Finger, with a further 162 and 130 birds of each species respectively classed as loafers, corresponding to around 12 % and 14 % of the total number of birds of each species counted on land (Table 5). Hooker's Finger is the second-most important area for Grey-headed Mollymawks behind the Courrejolles Peninsula.

Hooker's Peninsula

Five colonies, most comprising several sub-colonies, have previously been identified on the steep slopes of Hooker's Peninsula (Moore 1999). Except for Colony 5, all were photographed during this survey from at least one of three vantage points (MP7–9), as well as from offshore during the two helicopter flights. Colony 5, a small colony shown on Figure A21 but not marked on Figure A19 in Moore (1999), could not be found on the individual or composite images taken from MP8, or on the composite aerial images. It appears to have been abandoned and the area it once occupied now looks overgrown.

Colonies 1–4 and their subdivisions were marked on composite images made up of photographs taken from all three vantage points, MP7–9. Colony 1, the largest on the peninsula, was covered solely from MP7, while colonies 2–4 were covered from the western and eastern ends of the slopes from vantage points MP8 and 9, respectively. Delineation of the colonies and their sub-divisions closely followed those shown in Moore (1999: Figures A20–24), but a comparison with a composite of three images taken from offshore during the 24 November Sea Sprite helicopter flight showed that there were areas in all colonies that were not visible from the vantage points. Moreover, it was not possible to determine reliably which parts of these colonies, and which birds in them, were the same or different when viewed from MP8 and MP9.

Consequently, the number of mollymawks present, and whether they were sitting or loafing (or indeterminate), were counted on the composite image made from photographs taken offshore from the Sea Sprite helicopter, because this gave the best overall view of the extent of the colonies and their inhabitants on the peninsula. Information on species composition and activity was obtained from analyses of the composites of photographs taken from the three vantage points. Although the composite from MP9 was analysed, the results were not used in the overall analysis to eliminate the risk of double counting. A total of 459 Campbell and 342 Grey-headed mollymawks were apparently occupying nests on Hooker's Peninsula, with a further 94 (~17 %) and 99 (~22 %) birds of each species respectively being recorded as loafers (Table 6).

Sorensen Tarn

This small, 0.05 ha, tarn is situated on a narrow plateau above the northern end of the Bull Rock South colony. Despite its proximity to this much larger colony, the tarn is discrete and not covered by photographs taken from either of the two nearby vantage points, MP10 and MP11, located on the ridge separating the two Bull Rock colonies, below the level of the tarn. It was photographed from the air during the second helicopter flight and on the ground with a pocket camera (Olympus TG5). Although more birds were counted in the aerial photographs (229 vs 182), the ground-level photographs were better resolved and showed more birds sitting on nests (108 vs 87 from the aerial photos), and so was preferred as the source for analysis. The photographs taken from the helicopter did not clearly show many of the birds visible in the ground-level photograph that were nesting along the edge of the tarn under overhanging *Chionochoa antarctica* tussocks.

Table 5. Numbers of mollymawks at mixed-species colonies on Hooker’s Finger, as derived from counts of birds visible in images taken from vantage points MP2–6 (A), and as calculated (B), based on proportional allocation of undefined birds and activity to species and activity derived from observed proportions among identified individuals in the respective colonies. The total excludes counts and estimates of Colony 3 as seen from MP3. See text for the details of how the numbers in Colony 2 were calculated.

A. Ground-level counts	Campbell Mollymawk			Grey-headed Mollymawk			Mollymawk spp.			Total
	Colony	sitting	loafing	undefined	sitting	loafing	undefined	sitting	loafing	
2 (from MP2/3)	180	12	13	443	51	20	16	1	31	180
3 (from MP3)	124	8	21	62	12	13	0	0	7	124
3 (from MP4)	210	19	1	115	16	0	0	0	9	210
5 (from MP5)	419	71	66	42	8	8	0	0	5	419
6 (from MP6)	272	43	27	150	48	4	0	0	8	272

B. Calculated	Estimated numbers				Total in area
	Campbell Mollymawk		Grey-headed Mollymawk		
Colony	sitting	loafing	sitting	loafing	
2 (from MP2/3)	205	14	493	55	767
3 (from MP3)	147	10	75	15	247
3 (from MP4)	216	20	118	16	370
5 (from MP5)	480	81	49	9	619
6 (from MP6)	300	47	155	50	552
Total (excluding 3 from MP3)	1201	162	815	130	2308

Table 6. Estimate of Campbell and Grey-headed mollymawk breeding population on Hooker’s Peninsula, Campbell Island, based on assessments of species composition and activity, determined from ground-level photographs of whole or parts of colonies on the peninsula (A), applied to counts of birds overall in each colony from aerial images of the peninsula, in which species were not differentiated (B). The aerial images were taken during the 24 November 2019 Sea Sprite helicopter flight, 3 days after the ground-level survey.

A. Ground-level Colony	Campbell Mollymawk			Grey-headed Mollymawk			Mollymawk spp.			Total
	sitting	loafing	undefined	sitting	loafing	undefined	sitting	loafing	undefined	
1 (from MP7)	241	64	1	82	39	1	0	0	2	430
2a, d (from MP8)	0	0	1	53	32	12	0	0	1	99
2c, d (from MP9)	0	0	0	6	6	3	0	0	0	15
3b-e (from MP8)	33	4	7	52	37	25	0	0	11	169
3a-e (from MP9)	45	28	14	51	33	11	0	0	15	197
4a, c (from MP8)	0	0	0	18	21	1	0	0	0	40
5 (from MP8)	no counts; area not visible on ground-level images									

B. Composite	From aerial photographs Mollymawk spp.				Estimated from aerial and ground-level counts				Total in area
	sitting	loafing	undefined	Total	Campbell Mollymawk sitting	loafing	Grey-headed Mollymawk sitting	loafing	
Colony 1	380	116	21	517	295	75	101	46	517
Colony 2	115	28	11	154	0	0	124	30	154
Colony 3	244	37	26	307	164	19	103	21	307
Colony 4	14	2	0	16	0	0	14	2	16
Colony 5	Not present				-	-	-	-	-
Total	754	183	56	994	459	94	342	99	994

Only Campbell Mollymawk were recorded on Sorensen tarn, including several pairs nesting along its outer rim. When adjusted to take account of initially undefined individuals, an estimated 140 birds were sitting, along with a further 42 loafing birds (Table 3).

Bull Rock North

The Bull Rock North colony is the third largest of the mixed-mollymawk colonies on Campbell Island. The colony was photographed from vantage point MP11. Birds on the slopes below and to the lower left of MP11 are hidden in photographs taken from that point, but are visible on photographs taken during the two helicopter flights (Figure 2).

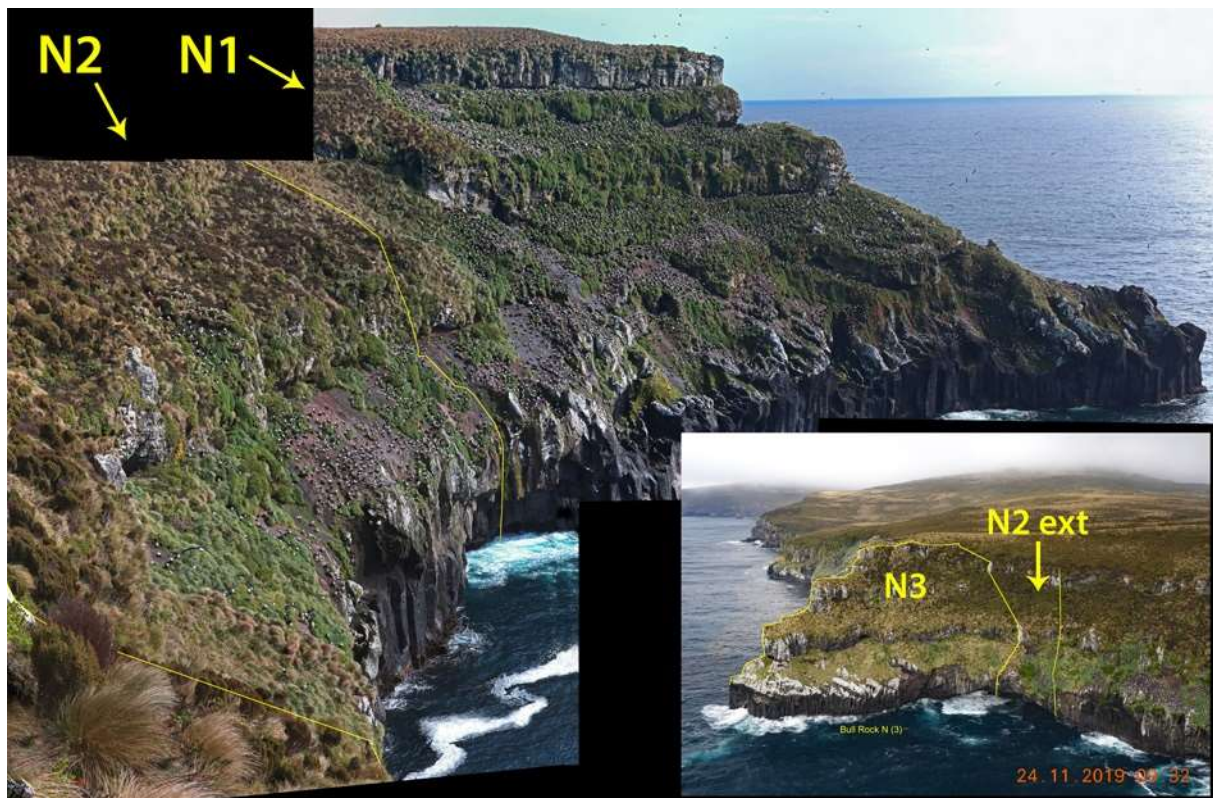


Figure 2. View over the Bull Rock North colony as viewed from vantage point MP11 (main image) showing the core of the colony (count area N1), and the middle section (count area N2). Not all the birds in the colony can be seen from MP11. Areas in which these hidden birds occur are shown in the inset (N3 and N2 ext, that part of N2 in which birds were hidden by the vegetation and topography). Birds in sections N2 ext and N3 were counted on the image shown in the inset taken from Sea Sprite helicopter.

A large 8-image composite was produced and divided into two sections (N1 and N2) along a convenient dividing line. As with other ground-level analyses, individual birds were identified to species and by activity. Individuals with uncertain specific identity or activity were classed separately. Once this initial analysis had been completed, it was clear from an examination of the helicopter images, taken a few days before and after the ground-level photographs, that some birds in N2 were hidden or obscured by topography or intervening vegetation, and birds on the slopes immediately below MP11 had not been covered at all. These areas were identified on an aerial image taken during the second, Sea Sprite, helicopter flight and the birds in them counted. Although these birds could not be reliably identified to species, it was generally possible to tell if a bird was sitting or standing around (loafing). Some birds, sitting on tussocks or isolated on the fringes of nesting groups, were also classed as loafing. Any birds whose activity was uncertain, were classed as such.

As with other colonies where the analysis involved counts from aerial images, in which individuals were only partly differentiated, and from ground-level photographs, where both species identity and activity could be more precisely determined, any unspecified individuals were first allocated proportionately to either sitting or loafing. These were then assigned to species, based on the proportions observed in the ground-level photographs, and added to the number of known individuals, both by species and by activity.

An estimated 4003 nesting mollymawks were calculated from the combined aerial and ground-level images. Just under 90 % of these were Campbell Mollymawks. The rest were Grey-headed Mollymawks (Table 7). In addition, a further 447 birds were estimated to be loafers, in similar proportions of the two species as the nesting birds. Because the counts at this colony were made before the subdivisions used by Moore (1999) were available, only aggregate numbers can be given at this stage.

Bull Rock South

Bull Rock South contains the largest concentration of mollymawks, supporting 30 % of all breeding birds (both species combined). Most are Campbell Mollymawks. Bull Rock South has been the site of a detailed comparative study of the two species (Waugh *et al.* 1999), as well as the focus for long-term monitoring. Moore (1999) delineated around 25 sections (some sub-sectioned) to make it easier to count the colony and track changes. Some of these sections are shown in Figure 1.

Surveys at Bull Rock South have traditionally involved photographing sections of the colony from two vantage points, MP10, located at the northern end on a bluff overlooking the colony to the south, and MP12, on a small elevated terrace about two-thirds of the way along the colony with about a 200° lateral view across the colony from north west to south. From the position of the photographs taken during this survey, compared with those shown in Moore (1999), it seems that the photo point chosen was about 20–30 m east of, and below, the established MP10 vantage point. Whereas this slightly altered the various fields of view, it likely had little effect on the numbers counted. The images from both vantage points were composited into multi-image panoramas covering all sections, at least in part, other than section 20, situated on a slumped ledge below the general elevation of the colony. The sections in each composite image were demarcated, following the boundaries shown in Moore (1999). The middle sections of the colony are shown in Figure 3.

The colony was also photographed during the two helicopter flights. The images from the second flight were better resolved, although the birds were still often little more than white blobs. Individuals of the two species could not be reliably distinguished, although most birds were known to be Campbell Mollymawks. Consequently, individuals counted on the aerial images were classed simply as sitting, loafing or undecided. Each of the sections were counted separately (see Figure 1 for example). The species and their activity could easily be distinguished on the vantage point photographs, at least for a substantial sample of birds in each section (Table 8).

To estimate the total number of nesting birds of each species, information from both the aerial and ground-level images were combined. As at the other sites, undifferentiated individuals counted in the aerial photographs were allocated proportionately in each section to either the sitting or loafing activity classes. These were then matched with the corresponding counts in each section from the ground-level photographs, in which undifferentiated individuals had also been assigned proportionately to one of the two activity classes, by species, and the resulting proportions in each section applied to birds counted in the same sections in the aerial photographs. The only section where this could not be done was section 20, which was not visible from the ground. The average proportions of the neighbouring colonies 17, 18 and 21a were used instead.

Table 7. A. Counts of mollymawks at Bull Rock North, both from ground-level photographs (GC) and from aerial images taken during a helicopter fly-past offshore, covering areas not visible from vantage point MP11. B. Estimated numbers of Campbell and Grey-headed mollymawks apparently occupying nests ('sitting') and loafing around in the Bull Rock North colony, calculated by redistributing the numbers of undefined individuals (including ones not identified to species ['Mollymawk spp.']) proportionately, based on observed proportions of both species and activities in the analysis of ground-level photographs.

A. Counts		Campbell Mollymawk			Grey-headed mollymawk			Mollymawk spp.		
Area	Method	Sitting	Loafing	Undefined	Sitting	Loafing	Undefined	Sitting	Loafing	Undefined
N1	GC	2964	255	26	342	41	6	0	0	63
N2	GC	463	88	18	42	2	3	0	0	5
N2 ext	AC							47	27	7
N3	AC							24	16	11

B. Calculated	Campbell I Mollymawk		Grey-headed Mollymawk		Total
Area	sitting	loafing	sitting	loafing	in area
N1	3040	261	354	42	3697
N2	482	92	45	2	621
N2 ext	46	27	5	3	81
N3	28	18	3	2	51
Total	3596	398	407	49	4450

Table 8. Numbers of Campbell and Grey-headed Mollymawks in different activity classes ('sitting', 'loafing' or 'uncertain') in the various sections the Bull Rock South colony, based counts from photographs taken for vantage points MP10 and MP12. These sections are the same as those described by Moore (1999). Sections 3 and 4 could not be differentiated on the photographs, and so the counts cover both areas. The sections 'ss' and 'a' to 'c' were also not clearly distinguishable. The counts come mostly from section 'c'. Section 20 was not visible from the vantage points.

Section	Campbell Mollymawk			Grey-headed mollymawk			Mollymawk (unspecified)
	Sitting	Loafing	Uncertain	Sitting	Loafing	Uncertain	Uncertain
1	17	20	3	2	2	0	0
1a	43	13	5	0	0	0	0
2	33	8	9	22	3	4	1
3-4	187	36	81	21	4	6	5
5a	137	19	24	27	1	2	2
5b	280	78	65	0	0	0	3
6	124	41	37	3	0	0	0
7	13	1	1	1	0	0	0
9	197	38	27	0	0	0	0
10	130	31	65	11	2	3	2
11	227	50	33	4	0	0	0
12	221	15	49	2	0	0	5
13	108	31	23	1	0	0	0
14	304	45	32	4	0	0	1
15	69	21	64	0	0	0	0
16	174	18	37	5	0	0	0
17	65	15	32	2	0	0	0
18	96	26	36	0	0	0	0
19	98	18	30	4	1	0	2
21a	397	80	14	3	0	2	1
21b	559	108	127	42	10	10	5
22	142	27	52	68	14	9	4
bbt	220	31	176	5	0	0	0
ss, a-c	89	9	23	0	0	0	0
d	103	17	21	12	3	1	2
GH-2	23	0	10	12	0	2	0
Totals	4056	796	1076	251	40	39	33

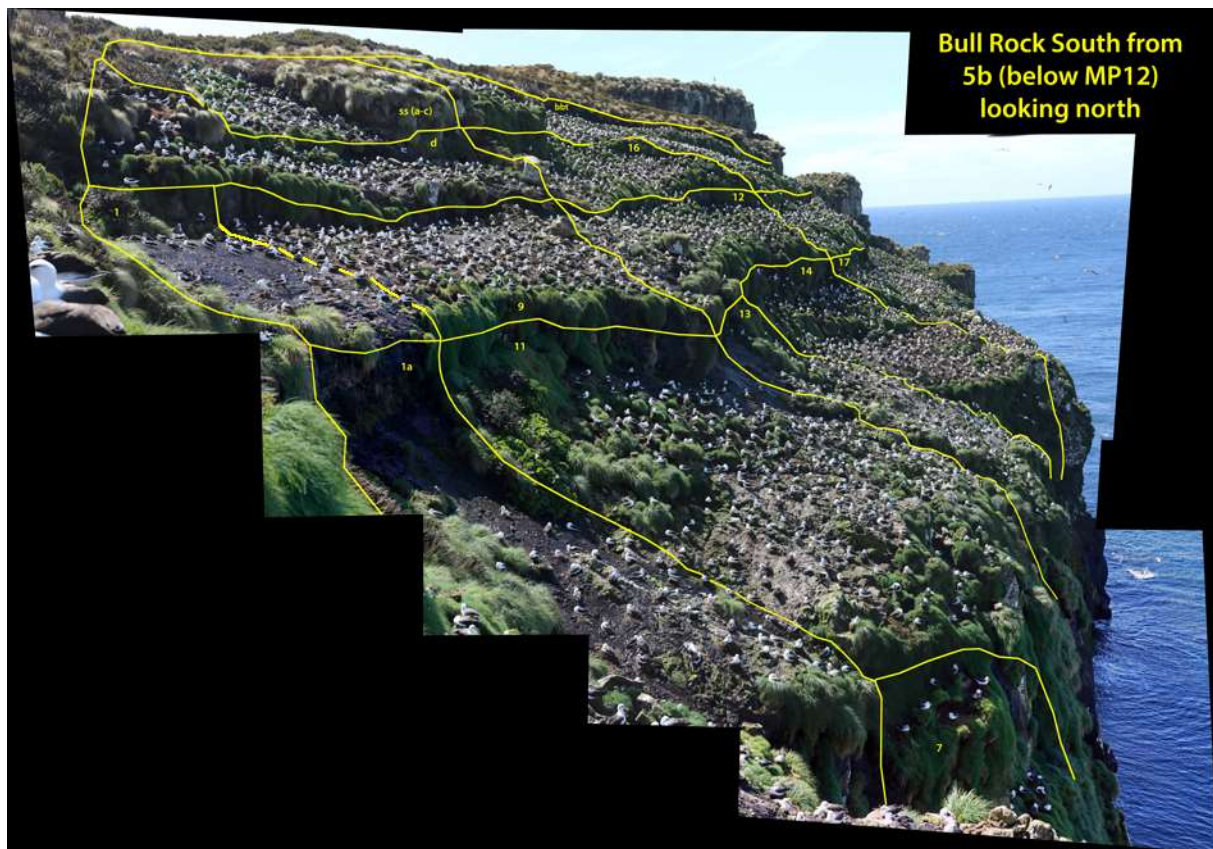


Figure 3. Composite image showing the middle section of the Bull Rock South colony, as viewed from below MP12, with some of the counting sections marked. These follow the boundaries established by Moore (1999) and were consistent with those drawn on aerial photographs of the same area. They served to separate counts in different sections and allowed some comparability between the ground-level and aerial counts.

Overall, 8677 birds were judged to be sitting on nests, around 95 % (8261) being Campbell Mollymawks (Table 8). Not all were necessarily sitting on eggs. Rexer-Huber *et al.* (2020) found 18 % of sitting birds, of both species, had empty nests. The estimated number of nesting Grey-headed Mollymawks (416) is slightly above the 318 nesting birds of this species recorded by Rexer-Huber *et al.* (2020), primarily because the few Grey-headed Mollymawks nesting on the edge of the lower ledges were not covered in the walk-through survey. Loafing birds made up a further 19 % of Campbell Mollymawks and 16 % of Grey-headed Mollymawks (Table 9).

Eastern Colonies

A series of 24 mostly small colonies are spread along 2.9 km of coast from just south of Buchanan Stream to just south of Bull Rock South colony. Because of the steep cliffs and difficulties of access, they are seldom visited on foot. Even then, there are few vantage points from which to photograph the colonies, so only a few surveys have been carried out, including some from aerial photographs taken helicopters flying offshore. The same applied in this survey, with two sets of photographs taken 6 days apart by crew on two naval helicopters. The first, taken on 18 November 2019, covered all the colonies but the focal length used (18 mm [35 mm equivalent = 27 mm]: Table 1) was too small to provide much resolution, but they did provide a useful guide to the locations of these colonies. The second set were taken on 24 November from a Sea Sprite helicopter. The focal length used, 6.3 mm, equivalent to 35 mm on a camera with a 1:1 crop factor, produced slightly better resolved images than those taken on the first flight.

Table 9. Estimated number and activity of Campbell and Grey-headed Mollymawks in the Bull Rock South colony, based on extrapolation from detailed counts, differentiated by species and activity, for each area except Area 20, applied to total counts of birds separated according to activity only on aerial photographs of the colony. For Area 20, which was not covered by ground-level photographs, the average proportions for adjacent colonies (17, 18 and 21a) were applied. See Table 8 for ground level counts.

Area	A. Counted from aerial photographs				B. Estimated from aerial and ground-level counts				
	Mollymawk (unspecified)				Campbell mollymawk		Grey-headed mollymawk		
	Sitting	Loafing	Uncertain	Total	Sitting	Loafing	Sitting	Loafing	Total
1	13	8	0	21	12	7	1	1	21
1a	35	15	0	50	35	15	0	0	50
2	83	21	0	104	51	16	32	5	104
3	589	84	5	678	539	77	54	8	678
4	126	23	1	150	115	21	12	2	150
5a	354	71	4	429	302	69	55	3	429
5b	623	231	13	867	632	235	0	0	867
6	253	56	8	317	255	57	5	0	317
7	21	8	0	29	20	8	1	0	29
9	260	44	3	307	263	44	0	0	307
10	239	81	3	323	224	78	17	4	323
11	291	61	3	355	288	62	5	0	355
12	250	54	2	306	250	54	2	0	306
13	171	48	8	227	176	50	1	0	227
14	304	53	4	361	303	54	4	0	361
15	344	63	7	414	350	64	0	0	414
16	203	42	3	248	200	43	5	0	248
17	559	140	6	705	552	141	12	0	705
18	135	34	0	169	135	34	0	0	169
19	234	42	4	280	230	41	7	2	280
20	180	58	3	241	178	58	4	1	241
21a	701	162	5	868	670	154	35	9	868
21b	528	165	13	706	512	159	26	9	706
22	296	89	3	388	212	62	86	28	388
bbt	1351	222	13	1586	1344	224	18	0	1586
ss+a-c	239	41	16	296	253	43	0	0	296
d	126	28	2	156	116	24	12	4	156
GH-2	66	30	0	96	44	26	22	4	96
Totals	8574	1974	129	10,677	8261	1920	416	80	10,677

Both sets of images were counted without reference to each other a couple of months apart. Despite the differences in image quality, the counts gave surprisingly similar results: 3155 birds counted overall in the first set (NH90 helicopter flight); 3152 in the second (Sea Sprite flight, although the numbers of birds in colonies E1-E6 were taken from the first set because these 6 small colonies were not covered in the second set of images). More reliance was placed on the counts from the second set because it was marginally easier to distinguish the activity (sitting, loafing) of birds in this set (Table 10).

Overall, the Eastern colonies are estimated to support 2519 nesting Campbell Mollymawk and 126 nesting Grey-headed Mollymawk. The ratio of Campbell to Grey-headed Mollymawk (20:1) is higher than that recorded 31 years earlier (6:1), when these colonies were surveyed by Moore & Moffat (1990). The significance of this change, if real, cannot be determined until at least a selection of these colonies is surveyed on the ground, or higher-resolution aerial photographs become available, to check the ratios, derived here from the Bull Rock South colony. A further 487 Campbell Mollymawks (just over 18 % of the species' total), and 20 Grey-headed Mollymawks (nearly 14 % of that species' total) were estimated to be loafing.

Conclusion

At the outset, it needs emphasising that the overall figures given for each area in this report represent the best estimates of birds present. For distant areas, such as the Courrejolles Peninsula, or counts of birds from aerial photographs, the estimates are based on ratios observed in parts of these colonies only (or in adjacent ones as in the cases of Areas 1–3 the Courrejolles Peninsula—estimated from Area 4 counts—or the Eastern colonies, estimated from counts at Bull Rock South). Moreover, even the number of birds on 'nests' are better expressed as the number of 'apparently occupied sites' (AOS), a standard expression used in surveys where the contents of nests were not examined. For example, in a ground survey of the proportion on birds sitting on empty nests carried out on the same date that the vantage-point photographs were taken, 18% of apparently active nests were empty (Rexer-Huber *et al.* 2020). Whereas this problem has previously been highlighted (e.g., Moore 2004), it seems that earlier reported numbers were not adjusted for this.

Moore & Blezard (1999) and Moore (2004) have already discussed the many sources of bias and error in such surveys (e.g., variation in the timing of the survey relative to the start of the breeding season; differences in definition and interpretation; types of counts, whether in the field and therefore how the counts were made and with what optical aids, or from photographs, affected by viewpoint location, field of view, camera, lens and image quality, and the kind and extent of image processing). This survey was undoubtedly affected by these biases and errors, but their extent and how to correct for them is unclear, given the brief nature of the survey.

With these caveats in mind, the following conclusions are drawn. The total number of apparently nesting Campbell Mollymawks recorded in this survey (23,612) is similar to that reported by Moore (2004). The average for the period 1995–97 was 24,600 nests. Both these values are slightly higher than the 21,648 nests estimated by Sagar (2014), but that survey did not include the Eastern colonies. If they are considered (adding either the 1995–97 average—2,257 nests—or the 2504 nests estimated in this survey), the differences across time are minimal. This suggests that, overall, the current Campbell Mollymawk population may be relatively stable.

Table 10. Counts of birds and apparent activity as determined from aerial images taken during two helicopter flights, 18 November 2019 (NH90, colonies E1–E6) and 24 November 2019 (Sea Sprite, colonies E7–E24), extrapolated to species and activity based on the proportions of each measured at the Bull Rock South colony immediately north of the eastern colonies. See text for further details.

Colony	Counted from aerial photos			Estimated from BRS species ratios			
	Mollymawk (unspecified)			Campbell Mollymawk		Grey-headed mollymawk	
	Sitting	Loafing	Unclear	Sitting	Loafing	Sitting	Loafing
<i>Applied ratio from BRS</i>				<i>0.952</i>	<i>0.960</i>	<i>0.048</i>	<i>0.040</i>
E1	26	17	7	29	19	1	1
E2	19	5	0	18	5	1	0
E3	44	9	0	42	9	2	0
E4	19	10	2	19	11	1	0
E5a	64	14	15	72	16	4	1
E5b	24	8	7	28	10	1	0
E6a	59	6	11	66	7	3	0
E6b	39	14	5	41	14	2	1
E7	74	12	9	78	12	4	1
E8a	59	8	3	59	8	3	0
E8b	21	5	2	22	5	1	0
E8c	0	0	0	0	0	0	0
E9	18	5	2	19	5	1	0
E10a	3	0	0	3	0	0	0
E10b	22	4	3	24	4	1	0
E11a	10	2	1	10	2	1	0
E11b	32	3	3	33	3	2	0
E12	33	5	8	38	6	2	0
E13a	87	18	2	85	17	4	1
E13b/14	24	4	2	25	4	1	0
E15 upper	1027	195	29	1001	192	50	8
E15 lower	332	47	3	319	45	16	2
E16/17	76	18	2	74	17	4	1
E18	4	0	1	5	0	0	0
E19	16	3	0	15	3	1	0
E20	48	5	0	46	5	2	0
E23a	93	16	7	94	16	5	1
E23b	52	15	11	58	16	3	1
E23c	113	19	13	118	20	6	1
E24	79	16	4	78	16	4	1
Total	2517	483	152	2519	487	126	20

Conversely, the number of apparently nesting Grey-headed Mollymawk calculated for November 2019 (5311) is considerably lower than the average of around 7800 nesting pairs reported by Moore (2004) for the period 1995–97, and the average of 8611 apparently nesting pairs for the years 2006–2012, estimated by Sagar (2014). These earlier numbers are 47 % and 62 % respectively above the current estimate, suggesting a decline of 32–38 % over the past 25 years or less. This is equivalent to an annual rate of change of -1.7 % to -4.7 %, a substantial rate of decline.

For both species, the actual breeding population could be lower, considering the percentage of empty nests (18 %) found by Rexer-Huber *et al.* (2020). If this percentage of empty nests is more widely applicable, it could mean that the number of active nests in the late incubation period in November 2019 was as low as 19,362 and 4355 for the Campbell and Grey-headed mollymawk populations, respectively.

But these figures, whether adjusted or not for occupied but empty nests, do not take account of nest failures up to the time of the survey. With a nesting season starting early October, as many as 13% of Campbell Mollymawk nests and 7% of Grey-headed Mollymawk nests may have failed by the time of the survey, based on the species-specific formulae for the time course of nest failure developed for these species on Campbell Island by Moore (2004).

With these and other considerations, such as the spread of laying dates among birds in an even a reasonably synchronous breeding population, the possibility of arriving at a single figure for the number of pairs breeding annually is questionable. It is more likely a moving target.

[A section-by-section comparison of recorded numbers in each colony over time remains to be done and will form the basis of a separate report.]

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