



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 22,766 Campbell Mollymawks and 5,937 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 at the time of the survey could be lower: 18,668 and 4868 pairs of Campbell and Grey-headed mollymawks, respectively. A further 4933 Campbell Mollymawk individuals (just under 18 % of the species' total) and 1344 Grey-headed Mollymawks (just over 18 % of that species' total) were recorded loafing.

The November 2019 survey was carried out about three-fifths of the way through the species' incubation period, assuming peak egg laying around 10<sup>th</sup> October. By the time of the survey, some nests would have failed, so the initial number of nests will be higher. Using regression formulae developed during earlier surveys to account for these losses (Moore 2004), the number of nesting Campbell and Grey-headed Mollymawk pairs at the start of the 2019 breeding season was estimated to be 24,338 and 6,429, respectively.

These figures, compared with those covering the past 25 years, suggest that the Campbell Mollymawk population is relatively stable, whereas the Grey-headed Mollymawk population has continued to decline by around 0.84 % per annum since the mid-1990s.

## 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.

<b>Area</b>	<b>Platform/position</b>	<b>Date</b>	<b>Time</b>	<b>Camera</b>	<b>Lens</b>
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 <sup>4</sup>	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 <sup>3</sup>	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 <sup>1</sup>	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 <sup>2</sup>	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.

<b>Area</b>	<b>Platform/position</b>	<b>Shutter</b>	<b>Aperture</b>	<b>ISO</b>	<b>Focal Length (actual)</b>	<b>Focal Length (35mm equiv.)</b>	<b>Number of images</b>
North-east coast	NH90 Helicopter (aerial)	1/400 s	F10.0	250	18 mm	27 mm	77
Sorensen Tarn	Ground-level photo from NNE edge	1/60 s	F8.0	100	4.5 mm	25 mm	2
Bull Rock North	Ground-level fixed points MP11, MP11a	1/395-1/644 s	F5.6-14.0	250	60 mm	60 mm	38
Bull Rock South	Ground-level fixed points MP10, MP10a	1/395-1/1328 s	F5.6-10.0	250	60 mm	60 mm	95
Bull Rock South	Ground-level fixed point MP12	1/395-1/1328 s	F5.6-10.0	250	60 mm	60 mm	91
Hooker's Finger	Ground-level fixed points MP2-MP6	1/256-1/790 s	F5.0-10.0	250	60 mm	60 mm	49
Hooker's Peninsula	Ground-level fixed points MP7-MP9	1/166-256 s	F4.0-5.6	250	60 mm	60 mm	18
Courrejolles Peninsula	Ground-level fixed points C1, C2	1/256-1/395 s	F5.6-7.1	250	75-300 mm	75-300 mm	152
Courrejolles Peninsula	DJI Mavic Pro Drone (aerial)	1/200 s	F6.3-8.0	100	10.3 mm	28 mm	66
Courrejolles Isthmus	Ground-level fixed point MP1	1/664 s	F8.0	250	60 mm	60 mm	42
North-east and north coast	Sea Sprite Helicopter (aerial)	1/160 s	F2.8	100	6.3 mm	35 mm	45
Sorensen Tarn	Sea Sprite Helicopter (aerial)	1/200 s	F3.2	100	6.3 mm	35 mm	2



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.

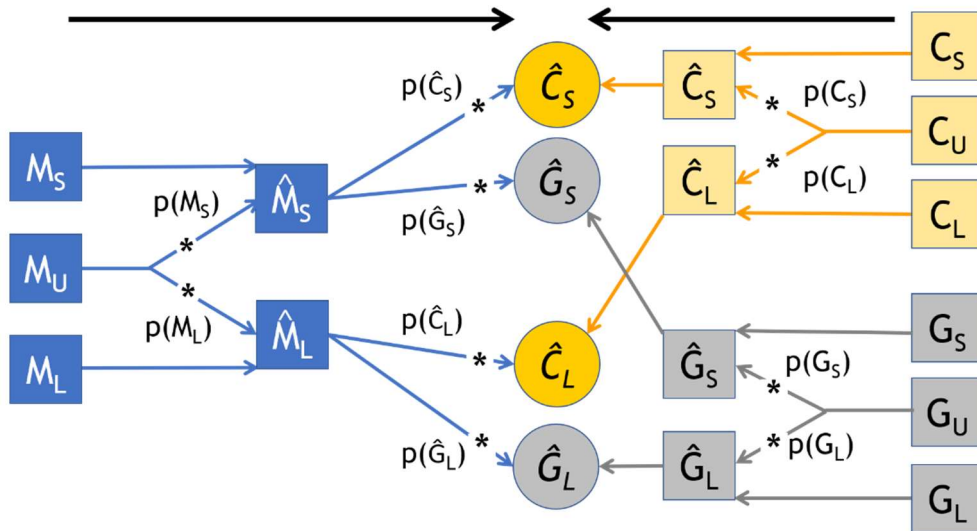
All birds seen on the images were counted and catalogued using DotDotGoose [v 1.5.0] (<http://cbc.amnh.org>; Erts 2019). Individuals were classed as follows: Campbell Mollymawk; or Grey-headed Mollymawk; or Mollymawk unspecified (species not determinable). Individuals in each of these classes were in turn classified by activity (sitting, loafing, flying or undetermined). Determining if an individual was loafing or sitting was problematic at times, especially because some apparently sitting birds were, on closer examination, loafing, such as those sitting on the tops of tussock, or on bare, rocky, usually wet seep zones. In such cases, a bird had to be seen clearly sitting on a nest to be classed as sitting. 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 to estimating the number of individuals of each species on the ground in each colony to either sitting on a nest and apparently nesting or loafing (i.e. partners of sitting birds, pre-breeders [usually in pairs and displaying], failed breeders standing around, small groups (2-4 birds), or other individuals just standing around) is shown in Figure 2.



**Figure 2.** Approach used to estimate the number of Campbell [C] and Grey-headed [G] Mollymawks apparently occupying nest sites (S) or loafing (L), derived from counts of birds on aerial and ground-level images. Birds not determined to be either sitting or loafing are designated with the subscript u.

$p(M_S)$ , proportion of unclassified mollymawks observed to be sitting

$p(M_L)$ , proportion of unclassified mollymawks counted as loafing

$p(C_S)$  and  $p(C_L)$ , proportions of Campbell Mollymawks classed or estimated— $p(\hat{C}_S)$  and  $p(\hat{C}_L)$ —as either sitting on a nest, or loafing, respectively

$p(G_S)$  and  $p(G_L)$ , proportions of Grey-headed Mollymawks correspondingly classed or estimated— $p(\hat{G}_S)$  and  $p(\hat{G}_L)$ —as sitting on a nest or loafing.

See text for further explanation.

Individuals visible in images were classed by **species** (or simply as 'Mollymawk spp' [M] if unknown), and by **activity** (apparently *sitting* on a nest [ $X_S$ , where X is one or other of the species or was not classified]; *loafing* [ $X_L$ ]; or *unknown* [ $X_U$ , where it is not clear what the bird is doing]). Figure 2 shows how unknown individuals were progressively allocated, first, to one of the two activity classes, then second to species, using observed proportions of activity classes and species (in that order). An asterisk (\*) indicates that the source quantity is multiplied by the relevant proportional value. Links that lack an asterisk represent the straightforward transfer of the source quantity to the sink. All estimates ( $\hat{x}$ ) are a combination of a transferred quantity plus a proportional amount calculated from the applicable unknown class ( $X_U$ ). 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 22,766 Campbell Mollymawks and 5937 Grey-headed Mollymawks were apparently sitting on nests, although not all nests necessarily contained an egg. Rexter-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 18,668 and 4868 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 various regression formulae given in Moore (2004), the final counts were adjusted to their likely early-October 2019 numbers of apparently nesting pairs: Campbell Mollymawk, 24,338 pairs; Grey-headed Mollymawk, 6,429 pairs. For comparative purposes, the same was done with the earlier counts (Moore & Blezard 1999; Moore 2004; DOC unpublished).

In addition to the apparently nesting birds, many loafing birds were counted (Table 3). From observations of such birds seen in the images, these comprised individuals 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; and others 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.

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 <sup>1</sup>	Campbell Mollymawk		Grey-headed Mollymawk	
		Sitting	Loafing	Sitting	Loafing
Courrejolles Peninsula	AC, GC	7305	1438	3089	739
Courrejolles Isthmus	GC	133	45	128	89
Hooker's Finger	GC	1127	154	850	137
Hooker's Peninsula	AA, GC	459	93	342	100
Bull Rock North	AA, GC	3251	850	556	84
Bull Rock South	AA, GC	8213	1886	464	114
Sorensen Tarn	GC	141	41	0	0
Eastern Colonies	AA	2137	426	508	81
<b>Total</b>		<b>22,766</b>	<b>4,933</b>	<b>5,937</b>	<b>1,344</b>

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

### Courrejolles Peninsula

The Courrejolles Peninsula supported just over 32 % of all Campbell and 52 % 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. (An examination of a short video taken during one of the helicopter flights showed no colonies on the northern side.)

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 less well 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 (see Moore 1999 for an illustration of the extents of those areas). Nevertheless, 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, 16% classed as loafing, and the balance (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.

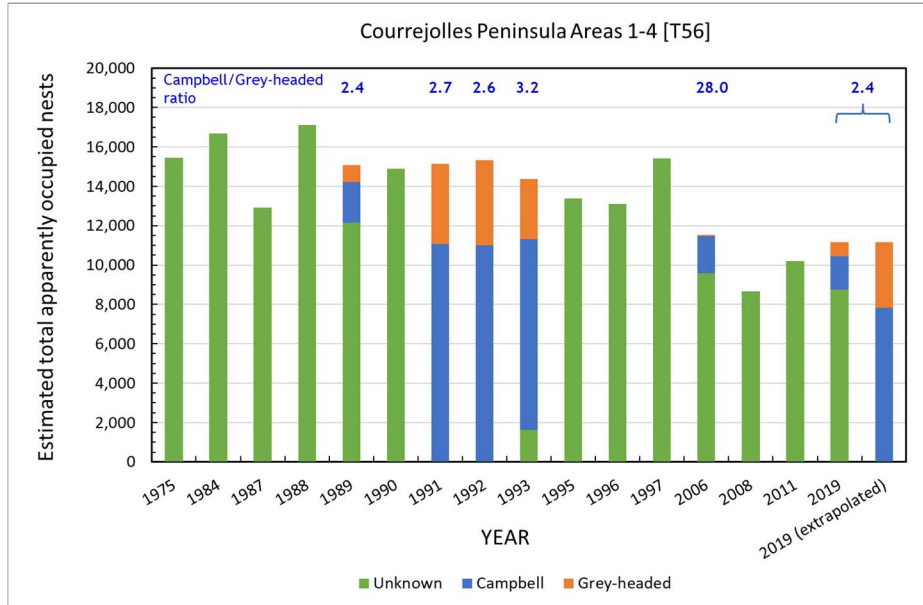
Area 4 was situated 1.2–1.5 km from vantage point C2. Photographs taken with a 300 mm telephoto lens were sufficiently resolved to determine the identity of 71 % of the 3871 individuals counted in this area. The balance (29 %) were unspecified although, as with the identified individuals, it was generally possible to classify them as to whether they were sitting or loafing. Overall, around 77% of these Area 4 birds were judged to be sitting, just under 19% to be loafing, and the balance (just under 4%) were unclassified (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	11	0	16	0	982	174	84	1267
Area 2	0	0	0	0	2437	560	23	3020
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	752	123	328	64				1267
Area 2	1726	372	729	193				3020
Area 3a	1840	276	773	141				3030
Area 3b	795	168	335	85				1383
Area 4	2192	499	924	256				3871
<b>Total</b>	<b>7305</b>	<b>1438</b>	<b>3089</b>	<b>739</b>				<b>12,571</b>

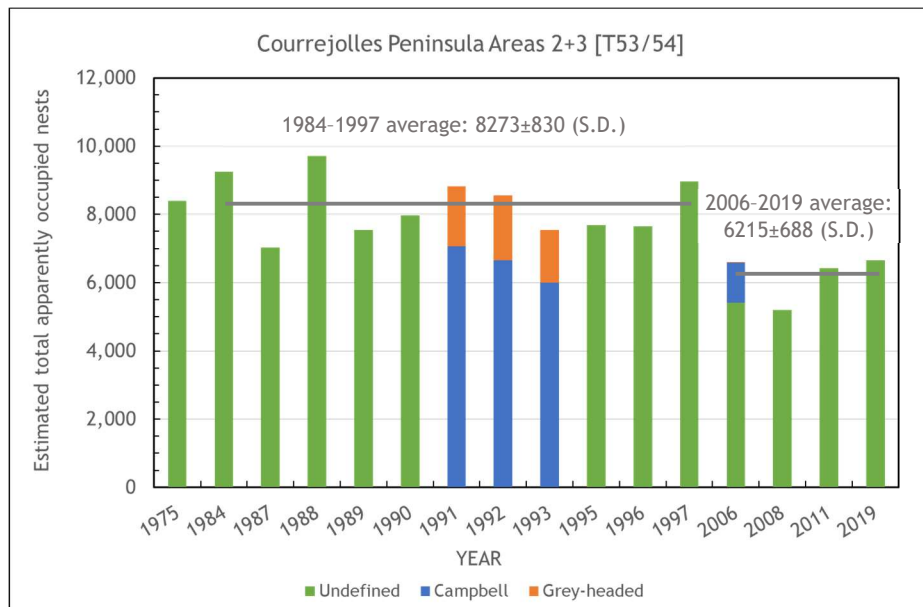
Backdating these data to their expected early-October numbers using the regression equations developed by Moore (2004) gives 7838 Campbell Mollymawk and 3314 Grey-headed Mollymawk apparently nesting on the peninsula, for a total of 11,152 pairs.

Compared with earlier counts, the Courrejolles Peninsula colonies overall appear to have declined substantially since the 1980-90s, when the average number of apparently occupied nests across the peninsula, adjusted to their early October expected values, was 14,853 (S.D.  $\pm 1303$ ). In contrast, since the mid-2000s the equivalent average has been 10,389 (S.D.  $\pm 1273$ ), a decline of around 30%. This decline occurred sometime between 1997 and 2006 (Figure 3).



**Figure 3.** Comparison of the number of apparently nesting mollymawks on the Courrejolles Peninsula in 2019 with those recorded in earlier years. To make the numbers from the various surveys at different dates more comparable, numbers have been standardised to the expected early-October numbers using the regression equations provided by Moore (2004). Distinctions between Campbell and Grey-headed Mollymawks was not always possible, so the numbers for those periods cover both species. See text for further details.

A broadly similar pattern is apparent in middle sections of the Courrejolles Peninsula (Areas 2 and 3), although the decline is marginally less (25%: Figure 4).



**Figure 4.** Comparison of the number of apparently nesting mollymawks on Courrejolles Peninsula areas 2 and 3 in 2019 with those recorded in earlier years, all adjusted to the expected October numbers using the regression equations provided by Moore (2004).

## Courrejolles Isthmus

The Courrejolles Isthmus supports one major colony that descends a series of terraces below fixed 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 128 Grey-headed Mollymawks were estimated to be sitting on nests in Colony 1 in November 2019 (Table 3). A further 45 Campbell Mollymawks and 89 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 under 4 % and 7 % of Campbell Mollymawks and Grey-headed Mollymawks, respectively, 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 1,127 Campbell Mollymawks and 850 Grey-headed Mollymawks were apparently occupying nests on Hooker's Finger, with a further 154 and 137 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.

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 estimates of Campbell Mollymawks from Colony 2, as seen from MP3; Grey-headed Mollymawks from Colony 2 as seen from MP2; and all of Colony 3 as seen from MP3.

A. Ground-level counts	Campbell Mollymawk			Grey-headed Mollymawk			Mollymawk spp.			Total
	Colony	sitting	loafing	undefined	sitting	loafing	undefined	sitting	loafing	
2 (from MP2)	115	10	13	220	35	21	0	0	12	426
2 (from MP3)	81	5	0	402	50	0	106	8	42	694
3 (from MP3)	124	8	21	62	12	13	0	0	7	247
3 (from MP4)	210	19	1	115	16	0	0	0	9	370
5 (from MP5)	419	71	66	42	8	8	0	0	5	619
6 (from MP6)	272	43	27	150	48	4	0	0	8	552

B. Calculated	Estimated numbers				Total in area
	Campbell Mollymawk		Grey-headed Mollymawk		
Colony	sitting	loafing	sitting	loafing	
2 (from MP2)	130	11	246	39	836
2 (from MP3)	102	6	526	60	694
3 (from MP3)	147	9	79	12	247
3 (from MP4)	216	19	118	17	370
5 (from MP5)	481	78	50	10	619
6 (from MP6)	300	46	156	50	552
<b>Total</b>	<b>1127</b>	<b>154</b>	<b>850</b>	<b>137</b>	<b>2268</b>



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 93 (~17 %) and 100 (~23 %) 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.

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 141 birds were sitting, along with a further 41 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 5).

A large 8-image composite was produced and divided into sections following Moore (1999). 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.

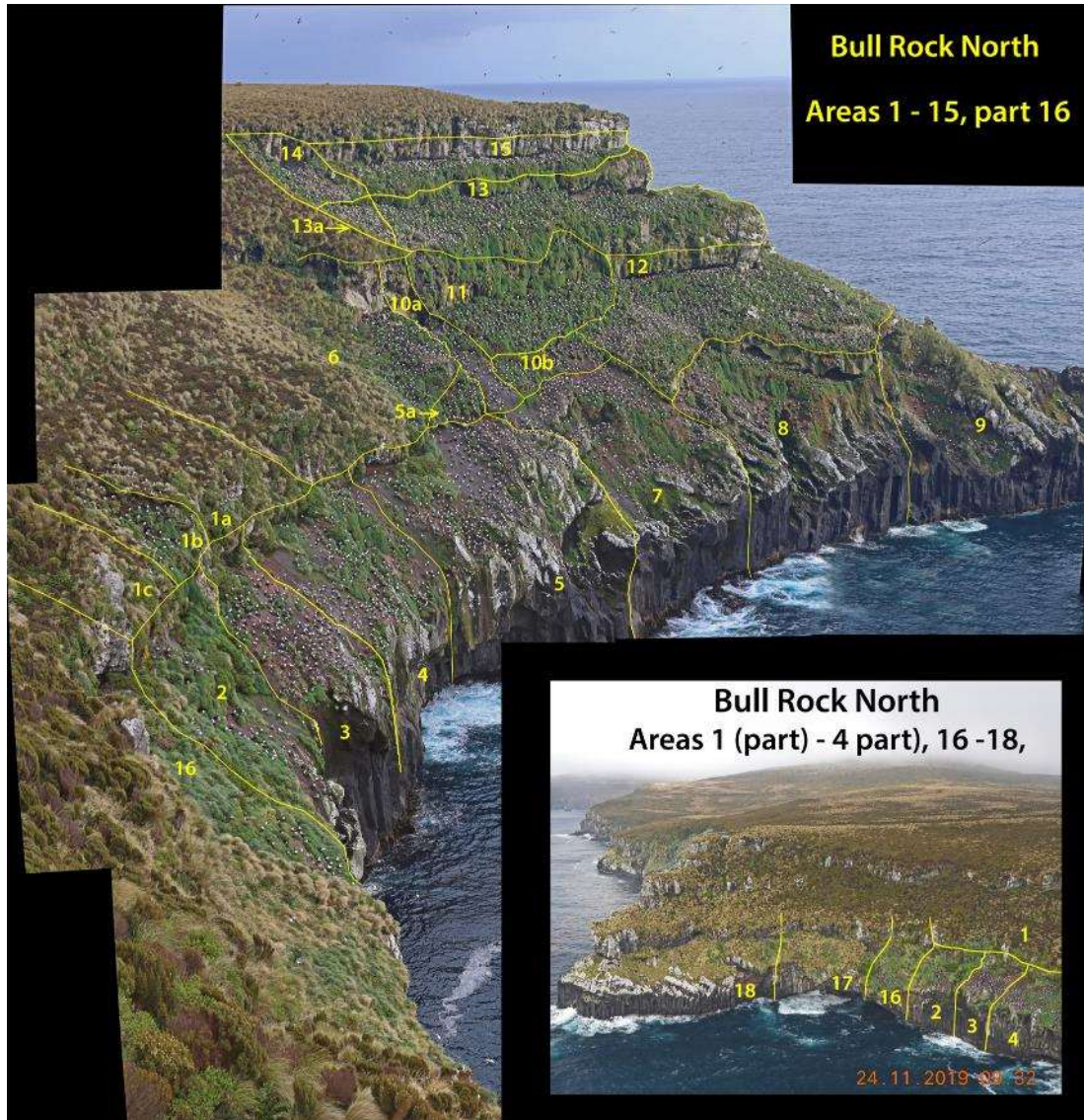
Once this initial analysis had been completed, it was clear from examining the helicopter images, taken a few days before and after the ground-level photographs, that there were some birds on the slopes immediately below MP11 that had not been covered at all, and others towards the main colony that were hidden by topography or intervening vegetation.

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			
	sitting	loafing	undefined	Total	Campbell Mollymawk sitting	loafing	Grey-headed Mollymawk sitting	loafing
Colony 1	380	116	21	517	296	75	100	46
Colony 2	115	28	11	154	0	0	124	30
Colony 3	244	37	26	307	163	18	104	22
Colony 4	14	2	0	16	0	0	14	2
Colony 5	Not present				-	-	-	-
<b>Total</b>	<b>754</b>	<b>183</b>	<b>56</b>	<b>994</b>	<b>459</b>	<b>93</b>	<b>342</b>	<b>100</b>

These areas were identified on an aerial image taken during the second, Sea Sprite, helicopter flight. The area was partitioned into the sections shown in Moore (1999) and the birds and their activity in each identified, where possible, and then counted. 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.



**Figure 5.** View over the Bull Rock North colony as viewed from vantage point MP11 (main image) showing the core of the colony (areas 5–15), and the middle section (count area 1a, b and 2–4). Not all the birds in the colony can be seen from MP11. Areas in which these hidden birds occur are shown in the inset (parts of areas 1c, 2–4, where hidden by the vegetation and topography, and 16–18).

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 3,251 nesting Campbell Mollymawks and 556 nesting Grey-headed Mollymawks were calculated from the combined aerial and ground-level images (Table 7). In addition, a further 850 Campbell Mollymawks (just under 21 % of that species total) and 84 Grey-head Mollymawks (13 %) were estimated to be loafers.

Status of mixed mollymawk colonies on Campbell Island

Table 7. A. Counts of mollymawks at Bull Rock North, mostly from ground-level photographs (GC) except for sections 1c and 16–18 which were counted from aerial images taken during a helicopter fly-past offshore a day later, because they were not visible from vantage point MP11. B. Estimates of the number of nesting and loafing birds of the two species based on a proportional allocation of the uncertain individuals.

Section	Campbell Mollymawk			Grey-headed mollymawk			Mollymawk (unspecified)
	Sitting	Loafing	Uncertain	Sitting	Loafing	Uncertain	Uncertain
1a	1	0	0	11	6	0	0
1b	28	3	3	15	1	0	0
1c	0	0	0	3	1	1	0
2	42	3	4	15	1	0	1
3	133	48	8	1	0	0	0
4	185	54	11	2	1	0	6
5	307	132	18	2	0	0	0
5a	46	7	5	0	0	0	0
6	144	28	21	45	5	4	5
7	309	75	14	0	0	0	0
8	195	25	22	44	8	1	3
9	72	9	1	0	0	0	0
10a	72	21	4	0	0	0	0
10b	87	20	4	0	0	0	0
11	249	53	6	20	1	0	0
12	522	146	36	144	29	1	3
13	445	79	45	91	11	2	4
13a	37	14	9	2	0	0	1
14	61	15	8	19	5	0	3
15	54	15	5	86	9	6	0
16	35	19	7	19	3	0	8
17	7	12	0	5	0	0	29
18	3	4	0	9	2	0	0
<b>Totals</b>	<b>3034</b>	<b>782</b>	<b>231</b>	<b>533</b>	<b>83</b>	<b>15</b>	<b>63</b>

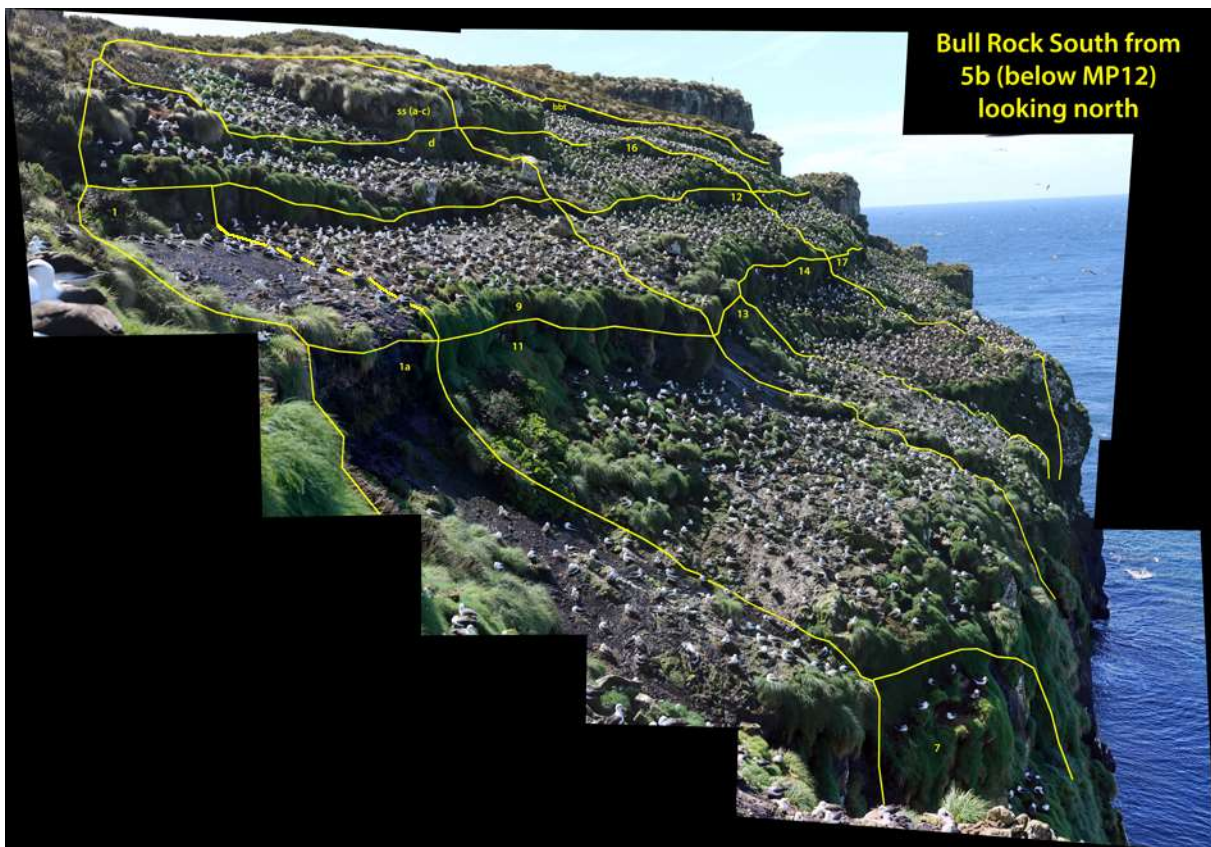
B. Calculated	Estimated numbers				Total in area
	Campbell Mollymawk		Grey-headed Mollymawk		
	sitting	loafing	sitting	loafing	
<b>Total</b>	<b>3251</b>	<b>850</b>	<b>556</b>	<b>84</b>	<b>4741</b>



## 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 6.



**Figure 6.** 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.



Status of mixed mollymawk colonies on Campbell Island

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
<b>Totals</b>	<b>4056</b>	<b>796</b>	<b>1076</b>	<b>251</b>	<b>40</b>	<b>39</b>	<b>33</b>

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.

Overall, 8,677 birds were judged to be sitting on nests, around 95 % (8,213) 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 (464) is more than the 318 nesting birds of this species recorded by Rexer-Huber *et al.* (2020), primarily because those 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 nearly 19 % of Campbell Mollymawks and almost 20 % 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 not many vantage points from which to photograph the colonies, so only a few surveys have been carried out, including some from yachts sailing offshore or aerial photographs taken helicopters flying past. 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 was 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.

Both sets of images were counted without reference to each other. Despite the differences in image quality, the counts gave surprisingly similar results: 3,155 birds counted overall in the first set (NH90 helicopter flight); 3,152 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).

Status of mixed mollymawk colonies on Campbell Island

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
1	13	8	0	21	12	7	1	1
1a	35	15	0	50	35	15	0	0
2	83	21	0	104	51	16	32	5
3	589	84	5	678	539	77	54	8
4	126	23	1	150	115	21	12	2
5a	354	71	4	429	302	69	55	3
5b	623	231	13	867	632	235	0	0
6	253	56	8	317	254	57	6	0
7	21	8	0	29	20	8	1	0
9	260	44	3	307	263	44	0	0
10	239	81	3	323	222	76	19	5
11	291	61	3	355	288	62	5	0
12	250	54	2	306	250	54	2	0
13	171	48	8	227	175	50	2	0
14	304	53	4	361	303	54	4	0
15	344	63	7	414	350	64	0	0
16	203	42	3	248	199	43	6	0
17	559	140	6	705	547	141	17	0
18	135	34	0	169	135	34	0	0
19	234	42	4	280	228	41	9	2
20	180	58	3	241	174	56	8	3
21a	701	162	5	868	673	155	32	8
21b	528	165	13	706	514	159	24	9
22	296	89	3	388	201	59	97	31
bbt	1351	222	13	1586	1332	224	30	0
SS, a-c	239	41	16	296	253	43	0	0
d	126	28	2	156	115	24	13	4
GH-2	66	30	0	96	43	0	23	30
<b>Totals</b>	<b>8574</b>	<b>1974</b>	<b>129</b>	<b>10,677</b>	<b>8213</b>	<b>1886</b>	<b>464</b>	<b>114</b>

Overall, the Eastern colonies were estimated to contain 2,645 apparently nesting mollymawks. Determining the number of Campbell and Grey-headed mollymawks was complicated by relatively low resolution of the images and the absence of any supporting ground-level photographs from which to determine the proportion of each species present. To overcome this, albeit with considerable uncertainty, 628 birds along the northern edge of colony E15 and colonies E16-E20 were examined closely. This was the point of closest approach of the helicopter to the island at this point, and some Grey-headed Mollymawk were marginally distinguishable. A total of 101 apparently nesting birds and 16 loafing individuals seemed to be Grey-headed Mollymawk. Assuming that the other 427 sitting and 84 loafing birds were Campbell Mollymawks, then the proportions of apparently nesting Grey-headed and Campbell mollymawks were 0.191 and 0.809, respectively. Likewise, the corresponding proportions of loafing birds were 0.160 and 0.840.

There are only two previous estimates of the ratios of Grey-headed to Campbell mollymawks in these Eastern Colonies: 1:6.1 estimated in a survey carried out in September 1988, and 1:4.4, estimated similarly in late September 1994. Nesting and loafing birds were not separated in these estimates. The equivalent overall ratio in 2019—1:5.4—is broadly similar. On this basis, it was decided to use the 2019 proportions to allocate the birds counted on the aerial images to species. An estimated 2,173 Campbell and 508 Grey-headed mollymawks are assumed to have been nesting in November 2019, with a further 426 Campbell and 81 Grey-headed mollymawks present as loafers (Table 10).

## 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 a small sample of birds in colonies E15–E20)). 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.

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. First, in late November 2019, an estimated 22,766 Campbell Mollymawks and 5,937 Grey-headed Mollymawks overall appeared to be occupying nests ('apparently occupied nests'), although not all of these necessarily involved a bird incubating an egg. For both species, the estimated number of active nests could be substantially lower, considering that 18 % of a sample of occupied nests in the Bull Rock South colony were found to be empty (Rexer-Huber *et al.* 2020). If this percentage is more widely applicable, the number of active nests in the late incubation period in November 2019 could have been as low as 19,362 and 4,355 for the Campbell and Grey-headed mollymawks, respectively. Whereas this problem has previously been highlighted (e.g., Moore 2004), it is unclear whether earlier reported numbers were adjusted for this.

Status of mixed mollymawk colonies on Campbell Island

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 a sample of 628 birds along the northern edge of colony E15 and colonies E16–E20 where some Grey-headed Mollymawk were marginally distinguishable. Birds other than these were assumed to be Campbell Mollymawks. See text for further details.

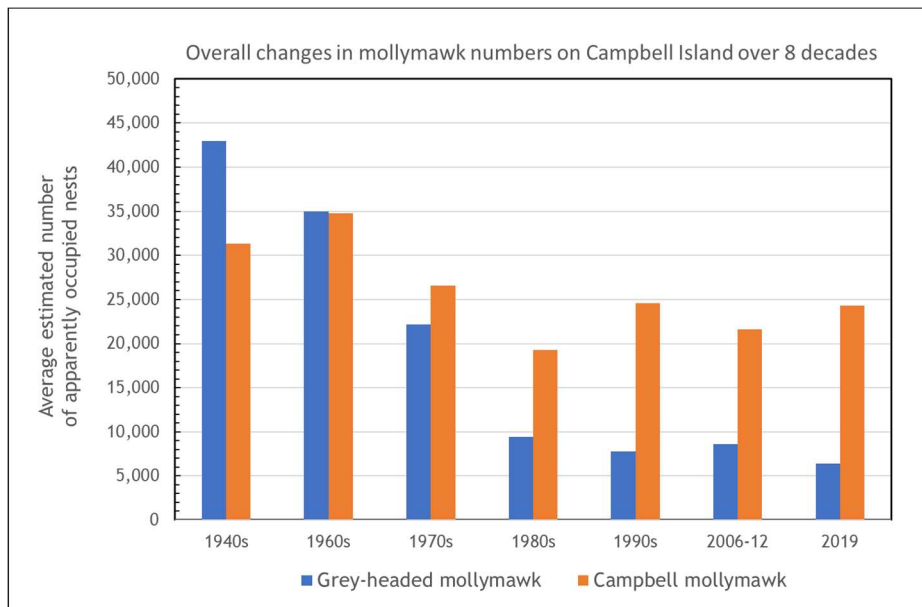
Colony	Counted from aerial photos			Estimated			
	Mollymawk (unspecified)			Campbell Mollymawk		Grey-headed mollymawk	
	Sitting	Loafing	Unclear	Sitting	Loafing	Sitting	Loafing
<i>Applied ratio from sample survey</i>				<i>0.809</i>	<i>0.840</i>	<i>0.191</i>	<i>0.160</i>
E1	26	17	7	24	17	6	3
E2	19	5	0	15	4	4	1
E3	44	9	0	36	8	8	1
E4	19	10	2	16	9	4	2
E5a	64	14	15	61	14	15	3
E5b	24	8	7	23	8	6	2
E6a	59	6	11	56	6	13	1
E6b	39	14	5	35	13	8	2
E7	74	12	9	66	11	16	2
E8a	59	8	3	50	7	12	1
E8b	21	5	2	19	4	4	1
E8c	0	0	0	0	0	0	0
E9	18	5	2	16	4	4	1
E10a	3	0	0	2	0	1	0
E10b	22	4	3	20	3	5	1
E11a	10	2	1	9	2	2	0
E11b	32	3	3	28	3	7	0
E12	33	5	8	32	5	8	1
E13a	87	18	2	72	15	17	3
E13b/14	24	4	2	21	3	5	1
E15 upper	1027	195	29	892	180	210	34
E15 lower	332	47	3	230	28	54	5
E16/17	76	18	2	63	15	15	3
E18	4	0	1	4	0	1	0
E19	16	3	0	13	3	3	0
E20	48	5	0	39	4	9	1
E23a	93	16	7	80	14	19	3
E23b	52	15	11	49	14	12	3
E23c	113	19	13	100	18	24	3
E24	79	16	4	66	14	16	3
<b>Total</b>	<b>2517</b>	<b>483</b>	<b>152</b>	<b>2173</b>	<b>426</b>	<b>508</b>	<b>81</b>



Second, the November 2019 survey was carried out about three-fifths of the way through the species' incubation period, assuming peak egg laying around 10<sup>th</sup> October. By the time of the survey, some nests will have failed, so the initial number of nests would have been higher. Using regression formulae developed during earlier surveys to account for these losses (Moore 2004), the number of nesting Campbell and Grey-headed Mollymawk pairs at the start of the 2019 breeding season was estimated to be 24,338 and 6,429, respectively.

With this adjustment, the total number of apparently nesting Campbell Mollymawks in 2019 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 estimated 2,295 nests from the current survey, both adjusted to number expected at the start of the breeding season), the differences across time are minimal. This suggests that, overall, the current Campbell Mollymawk population is relatively stable, although still 22-30 % below the numbers recorded in the 1940s and 1960s (Figure 7).

Conversely, the number of apparently nesting Grey-headed Mollymawk in 2019, adjusted to likely number present at the start of the nesting season (6429 nests) is considerably lower than the average of around 7800 nesting pairs reported by Moore (2004) for the period 1995–97, and the average of 8,611 apparently nesting pairs for the years 2006–2012, estimated by Sagar (2014). These earlier numbers are 21 % and 34 % respectively above the current estimate, suggesting a decline of 18–25 % 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 (Figure 7).



**Figure 7.** Overall change in the numbers of Campbell and Grey-headed mollymawks apparently nesting on Campbell Island since the 1940s. All numbers have been extrapolated back to the expected number at the start of each breeding season using the regression equations developed by Moore (2004) to account for nest failures throughout the incubation period. The number and accuracy of the surveys in each time period varies (see Moore 2004 and Sagar 2014 for details of the earlier surveys).

## Acknowledgements

The ground-level and drone images were taken by Kalinka Rexer-Huber and Kevin Parker, who also arrange for aerial photographs to be taken by Navy personnel during two helicopter flypasts of these colonies. Kalinka Rexer-Huber and Graham Parker kindly provided additional information and made useful suggestions regarding these data sets, their analysis, and interpretation. Thank you.

Peter Moore helpfully provided much information, including a guide to the material from the earlier surveys and where it ought to be in the Department of Conservation archives. He also scanned many images from the appendices to his reports, which are not present in their online versions. I am most grateful to him for his willingness to put up with numerous requests in this regard. Igor Debski and Paul Sagar provided more recent data, some of it unpublished. Igor also supplied copies of two Department of Conservation spreadsheets, originally compiled by Peter Moore, containing the original counts in a more easily extractable form than the printed versions.

I am also grateful to Dr Peter Ersts, Center for Biodiversity and Conservation, American Museum of Natural History, who developed the DotDotGoose animal counting software. On request, he quickly made some changes to the programme, making it easier to use. Finally, I am extremely grateful to Graeme Taylor for supporting this work and providing welcome encouragement, comments and some additional information at regular intervals.

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