Agreement on the Conservation of Albatrosses and Petrels

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# Trial of three methods to obtain population estimates of light-mantled sooty albatross *Phoebetria palpebrata* at Campbell and Auckland islands, New Zealand

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## SUMMARY

Light-mantled sooty albatross (LMSA) *Phoebetria palpebrata* is a circumpolar species that breeds on nine subantarctic island groups in the southern ocean. The species is classified as 'Near Threatened' by the IUCN and as 'At Risk - Declining' by the New Zealand Threat Classification System. Few quantitative data exist for LMSA, with population estimates of high accuracy from just two island groups, both in the south Indian Ocean (Prince Edward Islands and Île de la Possession in the Crozet Archipelago).

There are no quantitative estimates of population sizes of LMSA from the three island groups that the species breeds on in New Zealand (Auckland, Antipodes and Campbell islands). In the mid-1970s, the LMSA population at the Auckland Islands was thought to be the world's largest, with around 5,000 pairs or 25% of the global total. Although the species was recorded in New Zealand commercial fisheries as bycatch only once during the period 2002–2015 (tuna longline, 32–57% observer coverage), LMSA represented 6% of the total seabird bycatch from tuna longliners in New Zealand waters 1988–1997.

Annual counts of a small number of active LMSA nests have been conducted for 18 out of 19 years since 1999 at two localities on the southern cliffs of Adam Island, Auckland

Islands. Counts take place between mid-January and early February, and show a decline in the number of nests. The trend is similar to that for another biennial breeding albatross on Adams Island, the Gibson's wandering albatross *Diomedea antipodensis gibsoni*. Anecdotal observations also suggest that breeding LMSA are less common on inland ridges on Adams Island than they were in the 1990s.

Because no quantitative population estimates and very limited trend data exist for LMSA in New Zealand, we trialled three methods to obtain baseline breeding population estimates that will enable population trends to be estimated over time. Firstly, on Campbell Island, three observers using binoculars trialled boat-based counts of LMSA on coastal cliffs. Secondly, on Adams Island, two fieldworkers conducted ground counts and mapped active LMSA nests. Thirdly, the LMSA area counted on the ground on Adams Island was photographed from a helicopter and ground counts used to calibrate error associated with loafing birds. Ground counts also tested the feasibility of increasing the number of annual count sites from two to three, and therefore the number of nests counted annually on Adams Island from 10–52 to over 100.

Boat-based counts of Campbell Island LMSA proved inaccurate due to vessel movement. Ground counts at a new, third location on Adams Island included 83 active nests in mid-January 2017 (adults brooding chicks). This location can easily be included in future LMSA annual counts at Adams Island. Ground counts revealed that few loafing adult LMSAs were sitting on nest pedestals, so appear to represent a relatively small source of error when interpreting aerial photographs compared to other albatrosses (e.g. average 36% of white-capped albatross *Thalassarche steadi* apparent incubators did not have an egg). Comparing ground and aerial counts, eight of 48 birds interpreted as being breeders in aerial images were actually loafers, so aerial photography over-estimated the number of nests by 19.2%. Aerial survey using helicopters is an effective method for counting LMSAs on Adams Island, given calibration for apparent breeders. Considering the very difficult terrain throughout the Auckland Islands, counts from aerial photography, with ground calibration where possible, is probably the most cost-effective technique for rapidly assessing the size of the light-mantled sooty albatross population in the Auckland Islands.

## 1. INTRODUCTION

Light-mantled sooty albatross (LMSA) *Phoebetria palpebrata* is a circumpolar species that breeds on nine subantarctic island groups in the southern ocean. The species is classified as 'Near Threatened' by the IUCN and as 'At Risk - Declining' by the New Zealand Threat Classification System (BirdLife 2017; Robertson et al. 2017).

Globally, introduced mammals are linked to LMSA breeding failures via direct and indirect effects (ACAP 2010). In the New Zealand region for example, before sheep *Ovis aries* were removed from Campbell Island in the 1980's their trampling and disturbance of LMSA nests may have contributed to higher rates of predation by skuas *Catharacta antarctica* (Taylor 2000). Feral cats *Felis catus* are presumed to have had a deleterious effect on seabirds like LMSA on Campbell Island, but the scale of their impact is unknown as cats were reportedly scarce and died out when the sheep were removed (Moore 1997). Norway rats *Rattus norvegicus* were considered to have had no effect on eggs and chicks of small albatross species on Campbell Island (Taylor 1986), though nowadays this view seems somewhat

optimistic. Today on the Auckland Island mainland, pigs *Sus scrofa* and cats prey on eggs and chicks of any seabirds including LMSA, except those nesting on sheer cliffs.

Unlike many species of albatrosses, LMSA do not commonly follow vessels—including fishing vessels—at sea. Globally, records of the incidental capture of LMSA in commercial fisheries are rare compared to other albatross species (BirdLife 2017). However, little to no data exist on seabird captures in high-seas fisheries. Based on the amount of fishing effort 1981 to 1986, Brothers (1991) estimated 4,125 LMSA were incidentally caught in the southern ocean by Japanese longline vessels. LMSA were recorded caught in New Zealand commercial fisheries only twice during the period 2002–2016 (tuna longline, which has 20–57% of hooks observed) (Abraham and Thompson 2015). However, LMSA represented 6% of the total seabird bycatch from tuna longliners in New Zealand waters 1988–1997 (Baird et al. 1998 in Taylor 2000), but at least some capture events were clustered. For example there were just three capture events (of 30, 9 and a single individual) in tuna long-line vessels between 1 October 1996 and 31 December 1997 (Bartle 1998).

There is a recognised need for basic demographic data for LMSA to inform conservation status assessment and management action, particularly population size and trends, and at-sea distribution (BirdLife 2017). Globally, few quantitative estimates of LMSA population size exist, with population estimates of high accuracy from three island groups (Marion Island in the Prince Edward Islands, Île de la Possession in the Crozet Archipelago, and Macquarie Island) (ACAP 2010, 2017). Population trends are only known from the same island groups. At Possession the LMSA population decreased 13% over 15 years, followed by increases in the 2000s (Weimerskirch and Jouventin 1998; Delord et al. 2008). The Macquarie population appeared stable 2001–2009 (ACAP 2017). Trend analyses at Marion 1996–2014 showed marked fluctuations. Following a decrease over the period 1997–2002, the trend to 2008 indicated the population was increasing by approximately 6% per year (Ryan et al. 2003; Ryan et al. 2009). In the period 2007–2014 LMSAs were estimated to be declining at 7% per annum (Schoombie et al. 2016).

The lack of data to inform LMSA population estimates and population trends reflect the fact that LMSA is a difficult species to count and monitor (Schoombie et al. 2016). Nests are located on coastal and inland cliff shelves and on steep terrain, which are often difficult or impossible to access safely without rope access equipment. Further complicating studies of the species is that they can be sensitive to disturbance during courtship (Taylor 2000) and some birds may abandon nests if handled during early incubation (Moore 1996).

In the New Zealand region, there have been no quantitative estimates of LMSA population size, so population trends remain unknown. In the late 1990s, a preliminary study indicated that around 1,600 pairs were thought to nest on Campbell Island (Moore 1996) but this was later thought to be an underestimate (P. Moore pers. comm. in Taylor 2000). On the smaller Antipodes Islands, approximately 200–300 pairs were recorded breeding in 1995 (Taylor 2000).

In the mid-1970s, the LMSA population at the Auckland Islands was thought to be the world's largest, with around 5,000 pairs (Bell 1975) or approximately a quarter of the global total of 19,000–22,000 breeding pairs (ACAP 2010). However, this coarse estimate was based on very limited fieldwork (R. Russ pers. comm.). In a survey in 5–26 November 1989 of Adams Island, which supports most of the Auckland Island LMSA population, small breeding colonies were seen on nearly every suitable southern cliff (Buckingham et al. 1991). The biggest colony was just east of Astrolabe Stream mouth with more than 150 birds seen, of which at least 40–

50 were thought to be on eggs. A second large colony of about 100 birds was seen at Logan Point, with several hundred more nesting singly or in small groups scattered along the cliffs and ledges of the southern coast from Astrolabe Point to Gilroy Head, and on ledges in the inland cirque basins of Mt Dick–Lake Turbott, Fly Harbour and Bollons Bay–Lower Dome (Buckingham, Sanson, Elliott & Walker in lit.).

To accurately assess the conservation status of LMSA in the New Zealand region, and globally, a baseline census of populations on the Auckland Islands is needed (Taylor 2000). Taylor (2000) recommended Adams Island as a priority site, then Auckland Island, and finally Disappointment Island, and that a census be conducted over at least two consecutive years to overcome some of the variation caused by biennial breeding patterns (Taylor 2000). Importantly, population estimates must be robust and repeatable to enable eventual analysis of population trends.

This study broadly aimed to compare and contrast approaches to monitor LMSA numbers on New Zealand breeding islands. The four specific objectives of this work were to:

1. Examine data from a small annual-count study on Adams Island (Auckland Islands);
2. Conduct ground counts of breeding LMSA (Adams Island);
3. Test the feasibility of detecting breeding LMSA in images taken from a helicopter, corrected with ground truthing data (Adams Island); and
4. Trial the feasibility of boat-based surveys of breeding LMSA at Campbell Island.

## 2. METHODS

### 2.1. Light-mantled sooty albatross biology

Known breeding sites for LMSA in the Auckland Islands are Adams, Disappointment, Auckland, Enderby and Rose islands (Taylor 2000, Baker and Jensz 2014). LMSA are first observed around the breeding colonies in early October, both in the Auckland Islands (Turbott 2002) and at Campbell Island (Bailey and Sorensen 1962). Eggs are laid in late October to early November at Campbell Island (Bailey and Sorensen 1962) and laying dates are assumed to be similar at the Auckland Islands as birds were on eggs in November 1989 (Buckingham et al. 1991). LMSA eggs hatch from late December to early January and chicks are brooded for 19–21 days by both parents. LMSA chicks fledge after 140–157 days (data from other regions; ACAP 2010), and observations from the 1940s recorded all chicks in the Auckland Islands as having fledged by the first week of June (Turbott 2002).

### 2.2. Vantage-point counts Adams Island

Scan counts of a small number of active LMSA nests at two colonies on the southern cliffs of Adams Island, Auckland Islands have been conducted annually since 1999 (for 18 out of 19 years; Fig. 1). The largest of these count sites comprises the upper portion of the large east Amherst colony where 150+ birds were noted in 1989. A ground count at this site found 48 nests with eggs on 7 February 1998, so three vantage points were marked with poles and by GPS so that repeat counts by binocular could use the same vantage points each subsequent year. Nests at the second, much smaller, site can be safely visited on foot, with a ground count of 8 nests 11 February 1995. However, since 1999 this smaller site has also been counted from a marked vantage point.

Counts take place between mid-January and early February. Two observers scan the area with high-quality binoculars and record the total number of breeding LMSA attempts, with the position and status of each incubating adult or chick verified by a second observer.

Trends in the counts were examined using Poisson regression estimated using quasi-likelihood in the statistical package R (R Core Team 2016).

## 2.3. Ground count area Adams Island

Two fieldworkers on Adams Island conducted ground counts and mapped active LMSA nests in January and February 2017 in a much lower part of the same east Astrolabe large colony that was noted in 1989. The aims of conducting ground counts here were firstly to test the feasibility of adding a third, larger site to the two areas already counted annually with binoculars (Fig. 1) to enable breeding failure rates to be quantified without adding substantially more effort. Secondly, ground counts were used to estimate the error associated with 'loafing' birds (non-breeding or failed breeders) when interpreting digital images taken from a helicopter.

Both workers exhaustively searched the area via parallel transects across the slope, placed approximately 10 m apart. Adults on nests were approached and breeding status (incubating an egg, brooding a chick, not actively breeding) was recorded when they stood up. Clear cases of nest failure (large eggshell fragments, dead chick) were also recorded.

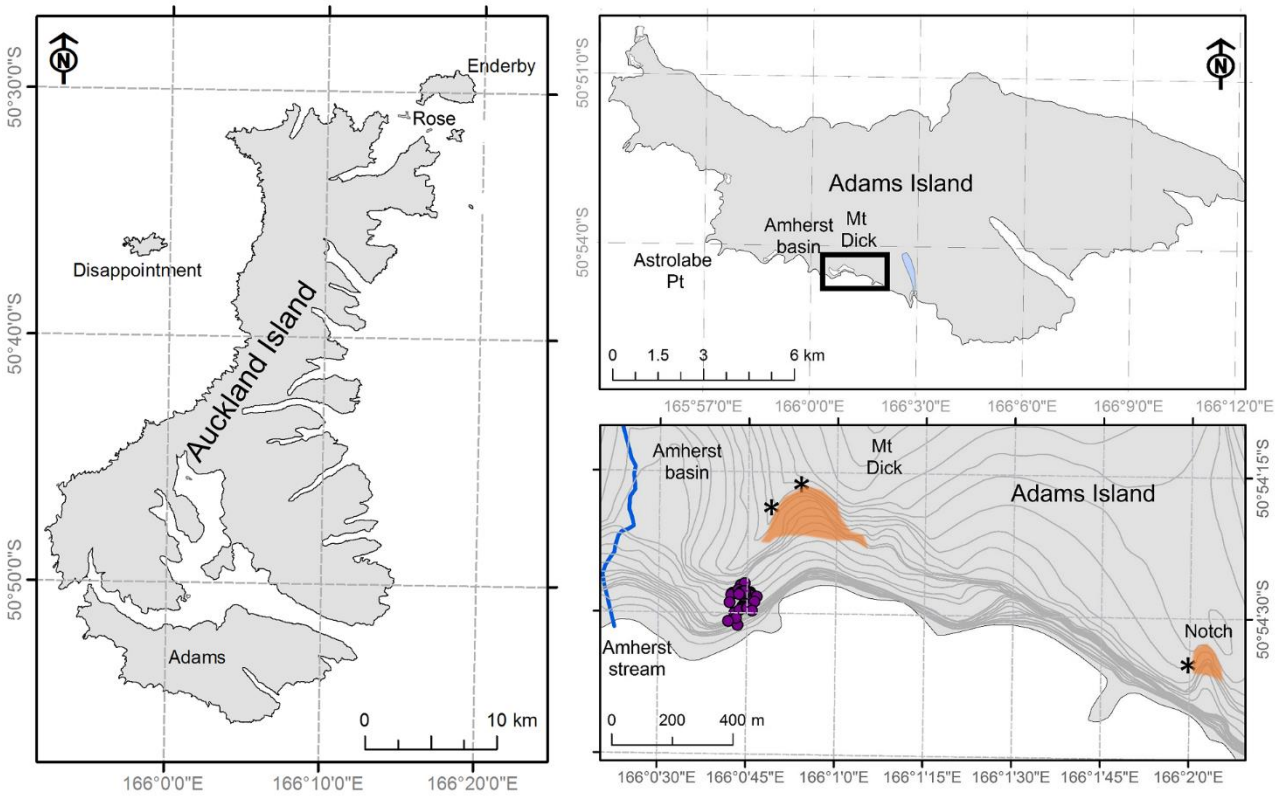


Figure 1. Auckland Island overview (left) showing named sites and at right, light-mantled sooty albatross count areas on Adams Island. Vantage points count areas are shown as orange polygons, with vantage points starred. The ground-count area photographed from helicopter is indicated in purple.

## 2.4. Aerial images using helicopter

Aerial photography was conducted on the 18th January 2017 from an AS350-B3 Squirrel helicopter. The site described above was overflown and photographed using high definition DSLR (digital single-lens reflex) cameras. All photographs were taken through the open port door with standard 35 mm photographic gear (Nikon D800 cameras, 70–200 mm F2.8 zoom lens), using shutter speeds >1/1000 s to minimise effects of helicopter vibration on image quality. GPS coordinates were stored in photograph metadata, which represent the location of the helicopter at the time photographs were taken, and were generally ~ 150 m to the seaward side of nesting sites. Photographs were taken at two heights, 213 m above sea level (asl) and 305 m asl. This allowed a complete series of overlapping images which could be used to compile a collage of all surfaces of sites where LMSAs occur. In other albatrosses, fewer non-breeding birds are present at breeding sites 1000–1700 hrs, so all LMSA photos were taken at ~ 1430 hrs.

Counting protocols followed those for aerial censuses of albatross colonies (Arata et al. 2003; Baker et al. 2014). In brief, photographic montages of the LMSA colony were constructed from overlapping photographs in Adobe Photoshop CS6 (www.adobe.com). Montages were magnified to view individuals and all birds counted, distinguishing Apparently Occupied Sites (birds occupying a nest) (for example, Fig. 5). Each single bird on a nest was assumed to represent a breeding pair. While most birds were alone at nest sites, instances when two birds were sitting close together (i.e. inside the pecking distance that defines the minimum distance between nests) were counted as a single breeding pair. Marked montages were archived.

## 2.5. Yacht-based counts, Campbell Island

On Campbell Island, boat-based counts of LMSA nesting on coastal cliffs were trialled 19–29 January 2015. Three observers with high quality 10 x 42 binoculars scanned cliff areas from the vessel (SV *Tiama*, 14 m length and 3 m draft with keel down, skipper Henk Haazen), motoring at approximately 5 knots about 500 m offshore and parallel with the coastline. Wind conditions were light (Beaufort 1) and sea state 3–4 with a moderate, long-period swell. Counts were timed to utilise favourable sea conditions (minimal swell) and light angles (no sun, or sun behind observers). All vessel tracks were recorded on GPS. Each observer separately estimated the number of chicks, and only those chicks detectable by two or more observers were included in the count. Count data were recorded directly onto maps.

# 3. RESULTS

## 3.1. Vantage-point counts Adams Island

Counts were undertaken between mid-January and early February and therefore mostly detected unguarded chicks.

Poisson regression of annual counts revealed a significant decline of 4.3% per annum in the number of LMSAs breeding at the two localities on Adams Island (Table 1 and Fig. 2). The date that annual counts were conducted varied from 13 January to 12 February, but generally clustered around the beginning of February. There was no significant effect of the timing of the counts (Table 1).

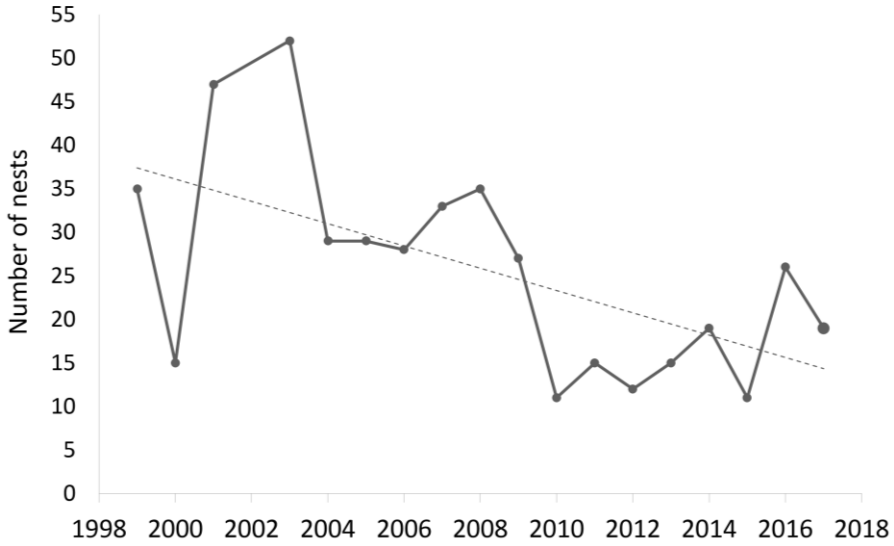


Figure 2. Vantage-point counts of light-mantled sooty albatross chicks in two southern cliff areas on Adams Island, Auckland Islands, 1999–2017 with a line fitted by Poisson regression. Note there are no count data from 2002.

Table 1. Analysis of deviance of Poisson regression (using quasi-likelihood) of counts of nests against year and the timing of counts.

| | df | Deviance | Residual df | Residual deviance | F | Pr(>F) |
|---|---|---|---|---|---|---|
| year | 1 | 68.46 | 52 | 481.9 | 8.875 | 0.004** |
| timing of count | 1 | 18.21 | 51 | 463.7 | 2.361 | 0.131 |

## 3.2. Ground count area 2017 Adams Island

Two people conducting ground counts at the third site on Adams Island counted 84 active nests in a small well-defined area in mid-January 2017 (adults incubating eggs) (Fig. 3, 4). The site is easily accessed and could be included in future LMSA annual counts at Adams Island. Ground counts revealed that 5% of apparent incubators were in fact loafing adult LMSAs sitting on nest pedestals (88 apparent incubators vs 84 actual incubators).

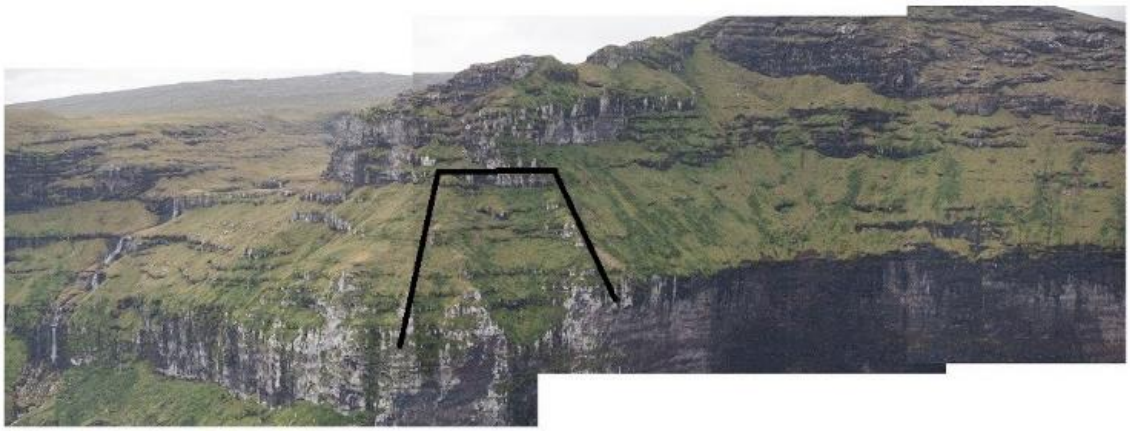

Figure 3. Bold dark lines indicate the area of counts of light-mantled sooty albatrosses counted both by ground and from helicopter at Adams Island, Auckland Islands.

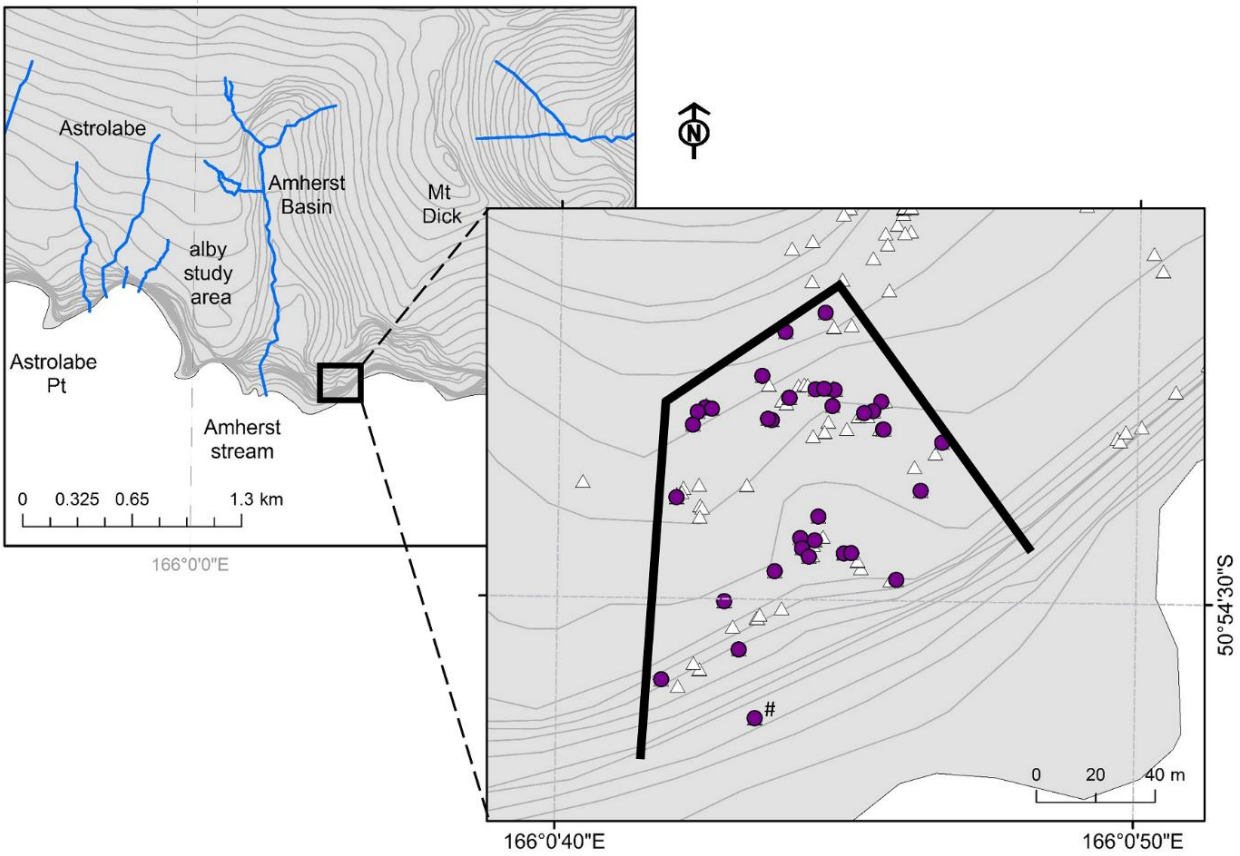


Figure 4. Light-mantled sooty albatross nest ground counts, Adams Island, Auckland Islands. Filled circles are active nests (adult incubating egg or brooding chick) counted on the ground within the area photographed aerially (bold lines). # indicates 7 active nests present at this site. White triangles show inactive nests (occupied by adult without egg or chick, empty nests).

### 3.3. Aerial images using helicopter

Weather conditions on the flight day 18 January (overcast, winds low, cloud base 1,500 m) permitted clear photographs of the site (bold lines, Fig. 3, 4). Counts from the aerial photographs identified 48 Apparently Occupied Sites (AOSs). A sample is show in Figure 5. There was no difference between the counts taken at 213 m and 305 m asl.

Ground counts showed that there was a total of 42 active nests in the photographed section of the study area. Eight (16.7%) of the 48 AOSs in aerial photos were not active nests, but sites occupied by loafers or non-breeding birds. In addition, two active nests were not visible in the photos. Based on these data, aerial counts overestimated the number of annual breeding pairs by 12.5%.

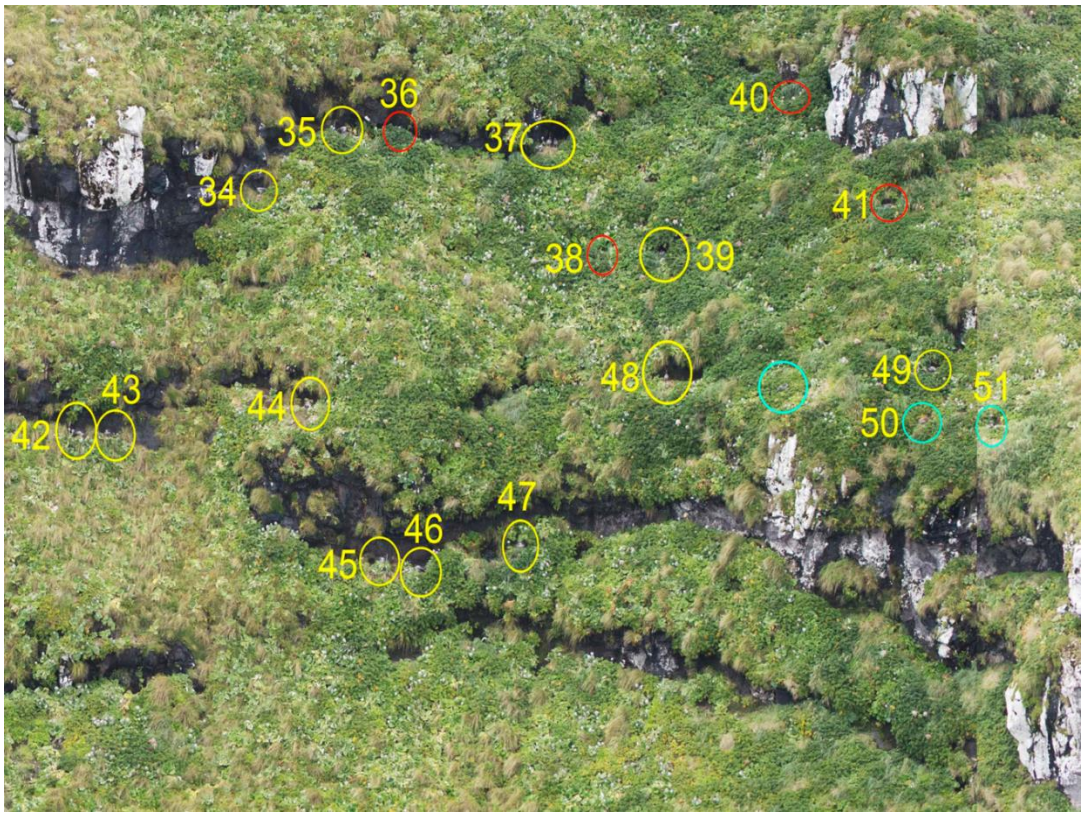


Figure 5. Sample montage of overlapping aerial photographs and counts of a light-mantled sooty albatross breeding area on the south coast of Adams Island, Auckland Islands. Circles are coloured according to inferred status: yellow for occupied nest, blue for an unattended chick, red for non-breeding bird.

### 3.4. Yacht based counts, Campbell Island

A total of 99.4 km, or 53.8 nautical miles of boat-based LMSA surveys and counts were conducted (Table 2, Fig. 6) during complete circumnavigation of the Campbell Island coastline. Offshore islands and rock-stacks were surveyed and counted whenever possible, but it was not possible to approach some areas closely (i.e. close enough to detect LMSA) as Campbell Island has poor bathymetry charting. The coastline with LMSA breeding populations was divided into five areas and these were counted on four separate days between 19 and 29 January 2015 (Table 2).

Table 2. Boat-based counts of light-mantled sooty albatross chicks on coastal cliffs, Campbell Island, New Zealand

| Coastal area | Date of survey | Duration hours | Distance km / nm | Number of chicks |
|---|---|---|---|---|
| Ramp Point to Monowai Island | 19/01/2015 | 2.5 | 17.2 / 9.3 | 20 |
| Monowai Island to Perseverance Harbour | 19/01/2015 | 2.5 | 25.5 / 13.8 | 59 |
| Perseverance Harbour to Northeast Harbour | 23/01/2015 | 1.5 | 22.7 / 12.3 | 18 |
| Northeast Harbour to Dent Island | 28/01/2015 | 3.0 | 25.0 / 13.5 | 21 |
| Gomez Island to Ramp Point | 29/01/2015 | 4.0 | 9.0 / 4.9 | 41 |
| Total | | 13.5 | 99.4 / 53.8 | 159 |

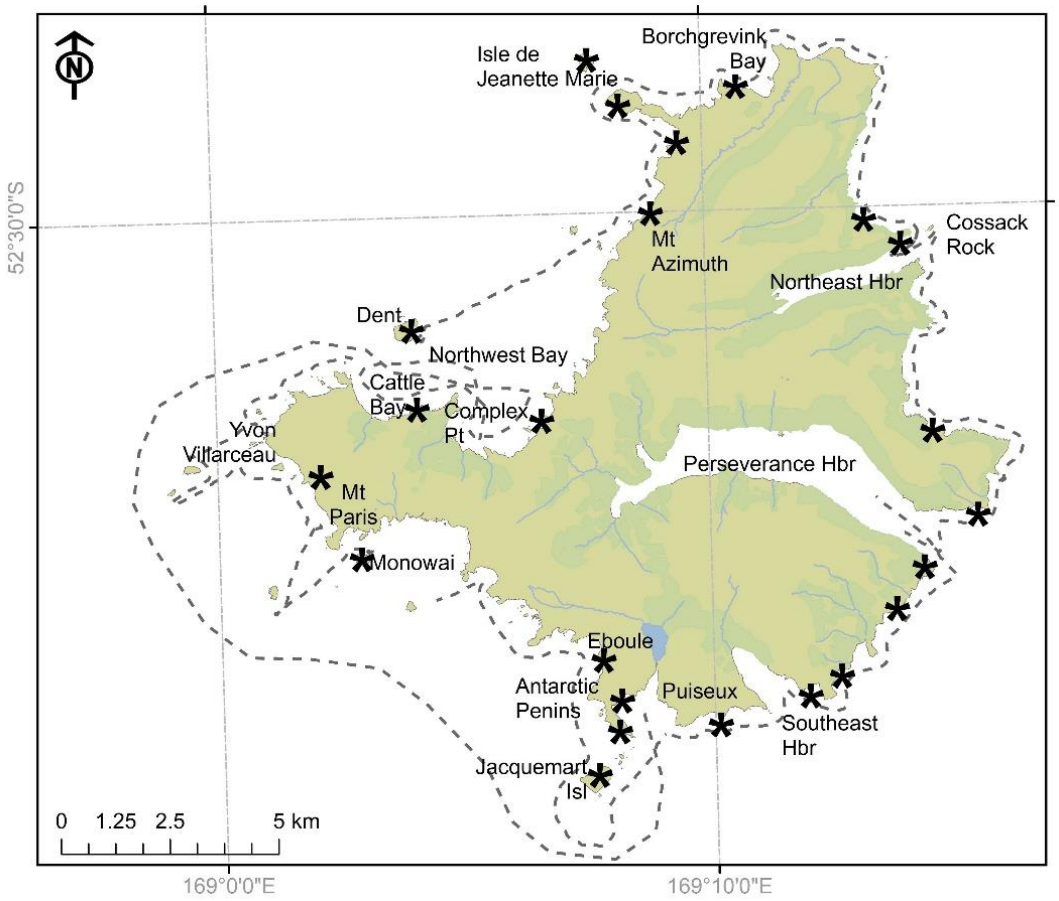


Figure 6. Map of Campbell Island coastline surveyed for LMSA January 19 – 29, 2015. Dashed lines represent survey transects and stars represent locations that light-mantled sooty albatross chicks were counted.

A minimum of 159 LMSA chicks were counted along the coastal cliffs (Table 2, Fig. 6), but detectability is likely poor using this method (defining detectability as the likelihood of a bird being detected). Detection rates of LMSA on Campbell's coastal cliffs could not be quantified with concurrent ground work because of the terrain, but we believe detectability was poor for several reasons. Firstly, the angle from a boat does not allow viewing into all ledges of cliffs up to 300 m high, and cliff-top vantage points showed some LMSA nesting in sites that would not be visible from the sea. Secondly, boat-based counts of Campbell Island LMSA were hindered by vessel movement, despite careful planning to utilise only the calmest sea conditions for surveys. Detectability was also affected by light conditions (sun in front or to the side of observers, haze) that could not always be avoided, despite best efforts.

Ground-truthing data to estimate the magnitude of these detection-related errors are not readily obtained for Campbell's coastal LMSA sites, so vessel-based counts remain a minimum count with poor confidence in the accuracy.

# 4. DISCUSSION

## 4.1. Vantage-point counts Adams Island

Annual counts of two LMSA areas on Adams Island from vantage point sites show a decline in the number of nests of 4.3% per annum over the period 1999–2017. The trend is similar to that for another biennially-breeding albatross on Adams Island, the Gibson's wandering albatross *Diomedea antipodensis gibsoni*. Breeding LMSA also appear to be less common on inland ridges on Adams Island than they were in the 1990s (G. Elliott and K. Walker pers. obs.). Although count dates range from mid-January to early February, count date variation does not explain the overall decrease in chick numbers over 19 years. The main limitations of vantage-point counts for LMSA at Adams Island are scale—a relatively small number of pairs breed in the two count areas each year—and timing, with an unknown rate of breeding failure occurring prior to counts each year. Since the date of vantage counts cannot be easily optimised due to logistic constraints, possibilities to increase scale are explored.

## 4.2. Ground count area Adams Island

The third location on Adams Island was selected as it can be safely accessed on foot, and can easily be included in future LMSA annual counts at Adams Island to increase the number of sites and number of pairs that are monitored.

A third LMSA site provides important opportunities to inform conservation management of LMSA. If it was visited both early in incubation and later when chicks are unguarded, nest failure rates could be estimated. Population dynamics in many seabirds hinge on the survival of adults and juveniles, and an accessible colony provides opportunity to estimate these parameters via leg-banding. Tracking devices deployed and retrieved on at this site could document the at-sea distribution of LMSA from the Auckland Islands region, which is entirely unknown.

## 4.3. Aerial images using helicopter

Birds that would appear to be breeding but in fact were 'loafing' (adult on nest pedestal without an egg or chick) appear to represent a relatively small source of error when interpreting aerial photographs of LMSA at this stage of the breeding cycle (late incubation/brood-guard period). Only 5% of apparently-incubating LMSA did not have an egg when counted on 13 January 2017, compared to on average 36% of white-capped albatross *Thalassarche steadi* apparent incubators that did not have an egg (Parker et al. 2017).

Considering the very difficult terrain favoured by LMSA for nesting sites, counts derived from aerial photography—with ground calibration where possible—probably represent the most cost-effective technique for rapid assessment of the size of the LMSA population in the Auckland Islands. High quality survey photographs enabled LMSA counts that showed good correspondence with nest detection on the ground, and comparison of breeding status assessed from photographs with ground-truthing showed a relatively small error rate. If the error rate proves consistent (similar over several sites, and over more than one count), it could provide a useful correction factor for aerial-photography counts of LMSA from other areas in the future.

Other areas could include northern breeding sites like Enderby, Rose and Disappointment islands. At Disappointment Island, aerial photographs taken to count white-capped albatrosses are also suitable for counting breeding LMSA (Baker and Jensz 2014). However, we concur

with Taylor (2000) that Adams Island should be the priority, particularly focussing on the southern and inland cliffs. We see the main Auckland Island as less of a priority, since few LMSA fly along the western and inland cliffs of main Auckland, except around South West Cape (authors' unpubl. data). However, main Auckland is the largest island in the archipelago, so cannot be excluded from efforts to compile an Auckland Islands LMSA population estimate.

The timing of the survey (late incubation / brood-guard period) meant that some birds that had bred may have failed, so counts at this time of year are conservative. As for ground counts, aerial counts would benefit from data on nest failure rates. Future aerial counts also require careful consideration of elevation, given the high cliffs of Adams Island where suitable LMSA breeding habitat exists on some upper and mid-level terraces. Attempting to photograph both terraces from one elevation point could compromise image quality, impairing detection and reducing count precision. The optimal helicopter elevation for photography (acceptable tolerance probably ±100 m) should be noted for each cliff face along with coordinates, and form part of study design for future surveys (Baker and Jensz 2014).

Another avenue to explore is aerial photography via unmanned aerial vehicles (UAV) such as drones, which have been used to count albatrosses in other regions where access is difficult (e.g. McClelland et al. 2016). Drones have been used successfully for other research in the Auckland Islands (S. Dawson, W. Rayment pers. comm.), albeit not on cliff-nesting seabirds. UAV-based methods are likely possible at some scale in the New Zealand subantarctic, and may be explored in the future as drone technology advances.

## 4.4. Yacht based counts, Campbell Island

Boat-based counts of Campbell Island LMSA proved very challenging due to vessel movement, despite targeting good sea conditions for the four survey days. Most of the Campbell Island coastline is fully exposed to open ocean swell, so we consider it unlikely that better conditions will be encountered within a given week-long survey period.

Boat-based counts were subject to difficult light conditions in parts, and lacked the ability to calibrate for loafing birds that were counted as incubators from the boat. Loafers may not be a major error source, considering the relatively small proportion of nesting LMSA that were actually loafers on Adams Island (Auckland Islands), but assumes LMSA behaviours on Campbell Island are similar to those on Adams Island. Overall, boat-based counts of LMSA on the coastal cliffs of Campbell Island were primarily useful for survey assessing presence-absence, but of little use for accurately estimating breeding numbers.

There are no obvious areas along the Campbell coastline where ground-counts similar to those on Adams Island cliff shelves might be possible. The landward face of Folly Island is accessible, but supports too few nests to be a useful sample. However, counts from land-based vantage points have been explored on Campbell Island before (Moore 1996), and may provide a way forward. Vantage-point counts in that study were challenged by similar light and viewing-angle factors to those that hindered boat-based counts here, and suitable vantage points are not available for all areas of the coastline. However, we show here that repeatable counts from the same vantage points over time can provide useful data for monitoring even when from a very small sub-set of breeding sites (Adams Island). Replicating counts from vantage points used by Moore (1996) would provide comparable data to rapidly assess trends of LMSA at Campbell Island since 1995 and enable monitoring over time.

## 4.5. Conclusions

Counts of small numbers of LMSA chicks in two areas on Adams Island suggest the population may be declining. Globally, there is a recognised need for population estimates and population trends for LMSA (BirdLife 2017), and the Auckland Island colony was highlighted as a regional priority (Taylor 2000). Given the biennial breeding pattern of LMSA, counts over at least two consecutive years are required (Taylor 2000).

We show that the number of breeding birds monitored annually can be increased at Adams Island via a combination of aerial and ground counts. Our work in 2017 could form a foundation of an annual monitoring program, as sites, once established, can be quickly and easily re-surveyed. Counts over larger areas, including more individuals, provide better resolution for detecting trends. We recommend that sites are visited as early in the breeding season as possible and again at the end of the brood-guard period. We also recommend that further sites be added as time and resources permit, such that in each year approximately 300 nesting pairs are monitored. An area visited annually for ground counts provides opportunity to collect tracking and nesting success data, as well as resightings of marked birds to contribute to adult survival estimates. Survival and productivity data for LMSA, along with their at-sea distribution, are required to inform the conservation status of LMSA in the New Zealand region.

Similarly, a full count for the Auckland Islands is needed, and for New Zealand as a whole. We suggest that an approach combining aerial survey and ground counts could plausibly extend to produce counts for the whole Auckland Islands group, corrected with failure rates from the Adams Island colony. At Campbell and Antipodes islands, which are too far from mainland New Zealand for helicopter-based work to be practical, drone-based technologies could provide opportunities for aerial survey in future. For now, we suggest that a mix of ground counts and vantage counts are the most feasible way to obtain population size estimates of LMSA at Antipodes and Campbell islands.

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