

Guidelines for aerial survey of seabird colonies

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Cover: Aerial photograph of south-western end of Little Sister I., Chatham Is, showing positions of royal albatross chicks (red) and northern giant petrels (green) in one of the counting zones (photo credit: Sarah Matthews)

Preamble

These notes are written from the perspective of someone who has been counting nesting seabirds of various species from aerial photographs. These photographs have been taken by several photographers using a range of cameras and lenses from both helicopters and high- and low-wing aircraft. The guidelines incorporate my own reflections on the merits of these images and how, in a few cases, things could be done differently.

The guidelines should be read in conjunction with the Department of Conservation's own guidelines, *Birds: complete counts—airial photo counts* (Version 1.0), prepared by Peter Moore and Ralph Powlesland (2012), available at <http://www.doc.govt.nz/Documents/science-and-technical/inventory-monitoring/im-toolbox-birds-complete-airial-photo-counts.pdf>. This provides the background to aerial counts; the aims of taking and analysing such photographs; their assumptions, advantages, disadvantages and limitations; and some of the practical issues to consider when planning aerial surveys. Actual counting methods and what ideally is required from aerial photographs to achieve accurate and precise counts are only briefly covered. Some of this background is summarised here to provide a context for the guidelines.

Introduction

Most seabirds breed colonially and usually synchronously. Aerial survey is generally the quickest, most cost-efficient and least disruptive means of locating and surveying the colonies of surface-nesting species, especially on remote and inaccessible sites such as islands. Aerial photographs provide an opportunity to determine the composition, size and breeding status of the birds present at a site at a specific time of year. When processed and catalogued, they can become a permanent record of the status of that colony on that occasion. Provided the methods employed over time produce comparable results, repeated surveys can be used to monitor trends in seabird populations.

Aims

Two key aims of colony surveys are to establish the size of a species' breeding population and, when carried out at regular intervals at one or more colonies, to track both site-specific and region-wide trends in population abundance. For some species, suitably timed surveys within a season can also be used to estimate productivity.

The number of birds present at a colony varies both seasonally and with time of day. Much of this variability is due to fluctuating numbers of non-breeding birds—partners of active breeders, failed breeders that have not yet abandoned their site, sub-adults prospecting for partners and a nest site, and immature birds loafing in the colony—on top of the number that are actively breeding, which should be constant on any one day.

The focus of analysis is therefore to determine the number of active nests, those with either an incubating or brooding parent in attendance, or one or more chicks in a nest in the absence of the parents. If all nests in a colony can be accounted for, the count becomes a census of the breeding population, itself an index of total population size.

Where a survey cannot cover an entire colony, for whatever reason, then photographs of representative subsets of that colony can be used to provide an index of the population. Such subsets should cover a reasonable proportion of a colony, be randomly distributed, and sufficiently well demarcated so that the same areas can be picked out and precisely delineated in photographs taken in subsequent years. If total population size is to be estimated from sample counts, then the overall area of the colony must be known, as well as what proportion of the whole has been surveyed. The surveyed areas must be randomly selected so that each bird in the colony has the same probability of being sampled.

Where breeding is highly synchronous, photographs taken at the peak of egg-laying and incubation, and then again when chicks are almost ready fledge, can be used to estimate annual breeding productivity. For species that lay only one egg, such as albatrosses, mollymawks and gannets, annual productivity is simply the number of fledglings produced as a percentage of the initial number of active nests. For species that lay more than one egg, estimating productivity requires knowing the average number of eggs laid per nest, against which the number of fledglings can be compared. That cannot be determined through aerial survey.

Aerial photography surveys cannot be used to census species that nest in burrows, under rocks or in crevices, or in which nesting birds are widely and irregularly spaced. Used alone, they also cannot explain the reasons for changes in population size or breeding productivity.

Sources of error

There are three potential sources of error when estimating population size from aerial surveys: (1) spatial variability in the distribution of nesting individuals; (2) temporal variability in colony attendance; and (3) variation in detection probability.

Spatial variability

Spatial variability in the distribution of nesting individuals contributes to error when estimating population size from sample counts. Even if both the size of the whole area and what proportion of it has been sampled are known, there can still be error if the surveyed areas are not a truly random subset of the whole (i.e. every individual in the population has an equal probability of being sampled).

This error can be addressed by using a statistically valid sampling framework, something that is difficult to do in an aerial survey unless the positions of randomly selected sample plots are marked out beforehand. For that reason, attempts to overcome the spatial variability of birds in an area rely on surveying the entire colony, so that the resulting tally of individuals is a total count of all birds present. This in turn can be broken down into different classes of individuals: e.g. incubating or brooding birds; partners of nesting birds resting alongside; pairs of birds that either have not started to breed or have fail but have not yet abandoned their breeding site; and immature and sub-adult birds, either loafing or prospecting for potential mates and nest-sites.

For those taking aerial photographs, this means:

- 1) undertaking full photographic coverage of a colony;
- 2) taking images of sufficient quality to allow individual birds to be identified; and
- 3) photographing at least substantial subsets of the colony close-up, so that the status of individual birds can be determined.

Temporal variability

Temporal variability arises because the numbers of individuals present in a colony varies with the stage of the breeding cycle, time of day, weather conditions, and other factors. For many colonial breeding seabirds, nesting is relatively synchronous, which reduces but does not eliminate one of these sources of error. A survey carried out ahead of the peak in egg laying will underestimate colony size because pairs that have not yet started laying will be missed. Likewise, a survey carried out after the peak also risks underestimating colony size, depending how many nests failed between the peak in egg laying and when the survey was conducted.

The numbers of birds present in a colony at the time of a survey also varies with the time of day and weather conditions, as birds that are not actively attending a nest come and go through the day. For a survey, this means:

- (1) timing the survey so that it coincides with the peak of egg laying and early incubation, if known, and takes place at a time of day when the number of non-breeding individuals present is at a minimum (usually from mid-morning to mid-afternoon); and,
- (2) photographing sections of a colony close-up, so that one can determine what proportion of the individuals present are nesting, as opposed to just sitting or standing around. Ideally, these close-up photographs should be taken randomly (or cover the entire colony) so that every individual present has an equal probability of being included.

Detection probability

The probability of detecting an individual in an aerial photograph can be influenced by several factors including topography, vegetation cover, species coloration, behaviour, and the experience of the analyst. Where birds are difficult to distinguish from their surroundings, because they are partially obscured or hidden from view in broken topography or in well-vegetated areas, or if photographs are not reasonably sharply focused, the probability of missing individuals, or assigning them incorrectly to a class, can lead to errors. This is a potentially serious source of error, given that a total count of individuals, whether nesting or not, assumes that every individual present is visible and has been counted.

This means:

- (1) considering vegetation cover and topography when planning the photographs (usually done on an initial scoping fly-pass), so that the most appropriate flight height, angle and focal length of lens can be chosen to maximise the chance of capturing all individuals in the images, while still ensuring that the whole colony is covered;
- (2) taking sufficiently high-resolution photographs so that individuals can be distinguished from their background, a consideration that favours higher shutter speeds over aperture size (i.e. reducing motion blur is more important than depth of field); and,
- (3) taking a widespread series of close-up photographs, preferably of randomly selected areas of a colony, in which one can be checked for cryptic or partially hidden individuals, including chicks in nests without an attending parent.

Approach

An effective aerial survey comprises three key elements: planning, preparation, and performance (including data analysis and interpretation).

Planning

It may seem obvious, but time spent beforehand developing a flight plan is time well spent. Bringing together what is known about the site to be surveyed; its location, topography, vegetation cover and aspect; and the likely time of peak egg laying, all allow some aspects of the survey to be thought through beforehand. For example, is the site on open, flat ground, such as the top of an island (Figure 1A), or is it predominantly on cliffs, with birds nesting in crevices, on narrow ledges and shelves, or between boulders (Figure 1B)? Which parts of the site will be in sunlight, and which in the shade, at different times of day, and from which direction the site should be approached to minimise the effects of shadow?

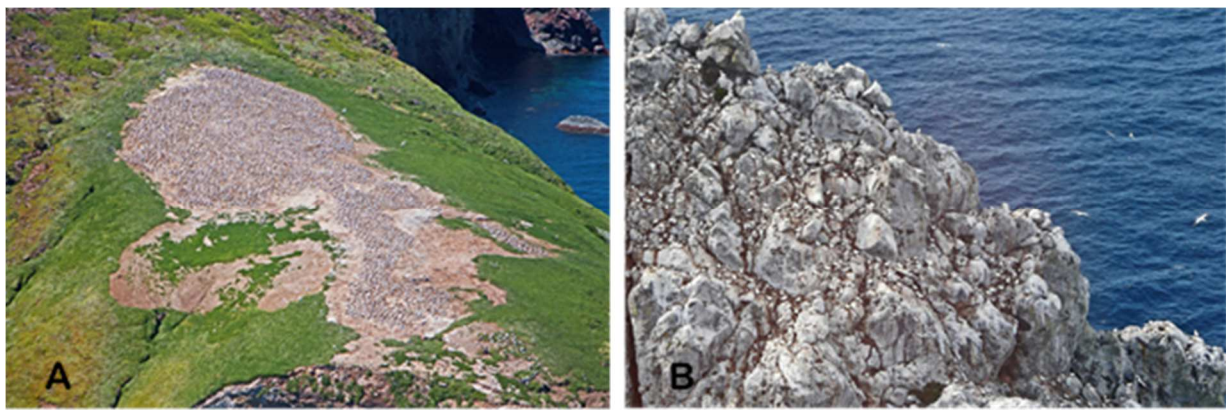


Figure 1. Australasian gannets nesting in two contrasting situations: A. on open relatively flat ground (Otaketake East, White Island); B. on small ledges and crevices among boulders in fractured, steep-sided terrain (Sugarloaf Rock, Poor Knights Islands). The second site is much more challenging to photograph and analyse than the first (Photo credits: [A] Julian Fitter; [B] Alan Tennyson).

Knowing these details beforehand allows one to judge when a site would best be surveyed, at what time(s) of day, and from which altitudes and angles for best effect. Photographs taken into the sun are generally more difficult to analyse than those where the sun is behind or to the side of the aircraft and photographer, so knowledge of a site can be used to determine the best direction(s) from which to approach it.

Preparation

Apart from organising seating on the aircraft, so that the photographer has the best view and as much space as possible in which to operate, the other main preparatory task is to ensuring synchrony among the various devices to be used during the survey. Because the time on the GPS is determined automatically by the atomic clocks in the GPS ground control stations and the GPS satellites themselves, other devices (e.g. camera, watches, and video and voice recorders, if used), should all be synchronized with GPS time. GPS time (GPST) was zero at 00h00 on 6 January 1980 and has not been adjusted since for leap seconds, so that GPST is now 18 seconds ahead of Coordinated Universal Time (UTC). A GPS receiver subtracts this offset from the time received from the GPS satellites to calculate UTC and the specific time-zone value. It is much easier to synchronize devices beforehand, rather than calculate the individual offsets and then adjust the time on the images later.

Ensure that the GPS is set to record the aircraft's track. The track log can be downloaded and inspected later, with each track point, automatically recorded, showing its position (Latitude/Longitude); altitude (m a.s.l.); date and time. Note that although both GPS units and cameras can show local time, if that has been set, the dates and times of the tracks, waypoints and images are displayed as UTC time. The appropriate time zone offset therefore needs to be applied afterward so that these data correspond to any written or voice-recorded notes.

The GPS records the point from where a photograph was taken, not the position of whatever is being photographed, which could be anywhere within a 90° arc, often at an unknown distance. Even then, there is usually an offset of up to 120 m between the actual position from where a photograph was taken, and the position recorded by the GPS at the same time. Having someone keep notes of what is being photographed at the time will help.

Performance

The basic unit of measurement of colony size is the breeding pair, so that ideally a survey should produce a count of breeding pairs. Counting pairs of birds at a colony is generally impractical because, for much of the time, members of a pair are seldom at their nest simultaneously. Moreover, besides individuals that are actively breeding (i.e. incubating eggs or brooding chicks), the birds present at a colony can also include non-breeding birds prospecting for potential mates and nest-sites, or individuals loafing between feeding bouts. Some nests may have chicks with both parents away foraging.

Aerial photographs therefore needed to be analysed closely to distinguish among these different classes. Because it is seldom possible to determine if eggs or small chicks are always present (a bird could be sitting on an empty nest, for whatever reason), the basic unit of colony size therefore usually becomes the number of Apparently Occupied Sites (AOS)—sites where there is an adult bird present and either apparently incubating eggs or brooding chicks—plus those nests where one or more chicks are clearly present without an accompanying adult. Empty nests with one or both members of a pair present are counted and reported separately; these may be pairs that are yet to lay, or nests that have recently failed.

Where only a total count of all individuals is possible, e.g. large, densely packed colonies, a correction factor is needed to convert the number of individuals to the number of pairs. This can be done using close-up photographs of subsets of a colony in which the number of active nests (AOS and nests with chicks alone) can be counted. The correction factor then becomes the average ratio of the number of active nests to the total number of individuals present in the sample areas, applied to the number of individuals counted overall. Its variance can be used to place confidence limits on this colony-wide estimate of the numbers of nesting pairs. Correction factors are species-, site- and time-specific and so can only be applied within those limits.

To estimate the number of breeding pairs in a colony therefore requires three complementary sets of photographs. The relationships among these is shown in Figure 2.

- **Wide-angle photographs** of the area being surveyed should be taken with sufficient overlap to allow a composite picture to be built up of the whole area, with sufficient resolution to show key features (e.g. prominently shaped rocks, fissures, islands of vegetation, pools of water etc.) that can be picked out in closer-focused images and used to identify their positions relative to other closer-focused images (Figure 3). Such images allow close-up photos to be positioned accurately. Such scene-setting photographs are typically taken at **35-50 mm focal length**.

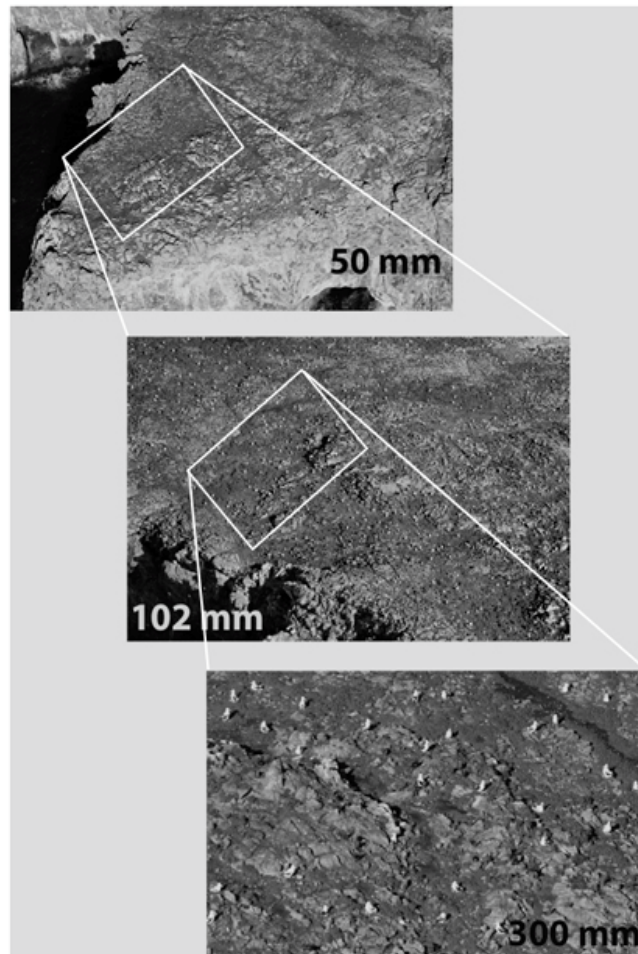


Figure 2. Photographs of the same area of the Forty-Fours I., Chatham Is, showing wide-angle (top), medium-scale (middle) and close-up images (lower), all taken from slightly different angles, showing the range of features visible in each (Photo credit: Sarah Matthews).

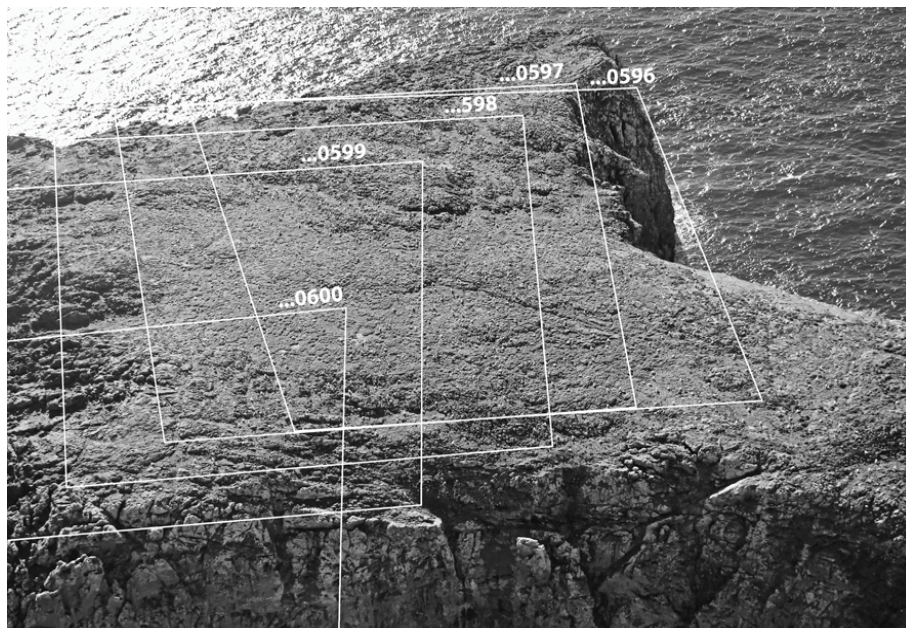


Figure 3. Wide-angle image (FL 42 mm) of part of Forty-Fours Island, showing the locations of and overlap among five medium-scale images (FL 102 mm). The high amount of overlap shown here (60-80%) produced considerable redundancy (Photo credit: Sarah Matthews).

- **Medium-scale images** should show nesting and other birds sufficiently clearly that they can be counted. Because these images cover only some of a colony, together they should form an overlapping series in which shared areas and those delineated as unique to each image can be demarcated. Only those birds appearing in an image's unique area are counted. Designating these areas on adjacent images in a sequence requires identifying a series of conjugate or control points that, when connected, separate the area defined as unique to an image from those shared with adjacent images (Figure 4). All unique areas, when aggregated, should cover the whole colony with no over- or under-lap. Such photographs generally require a **focal length of 85-135 mm**, depending on the distance to the objects being photographed.

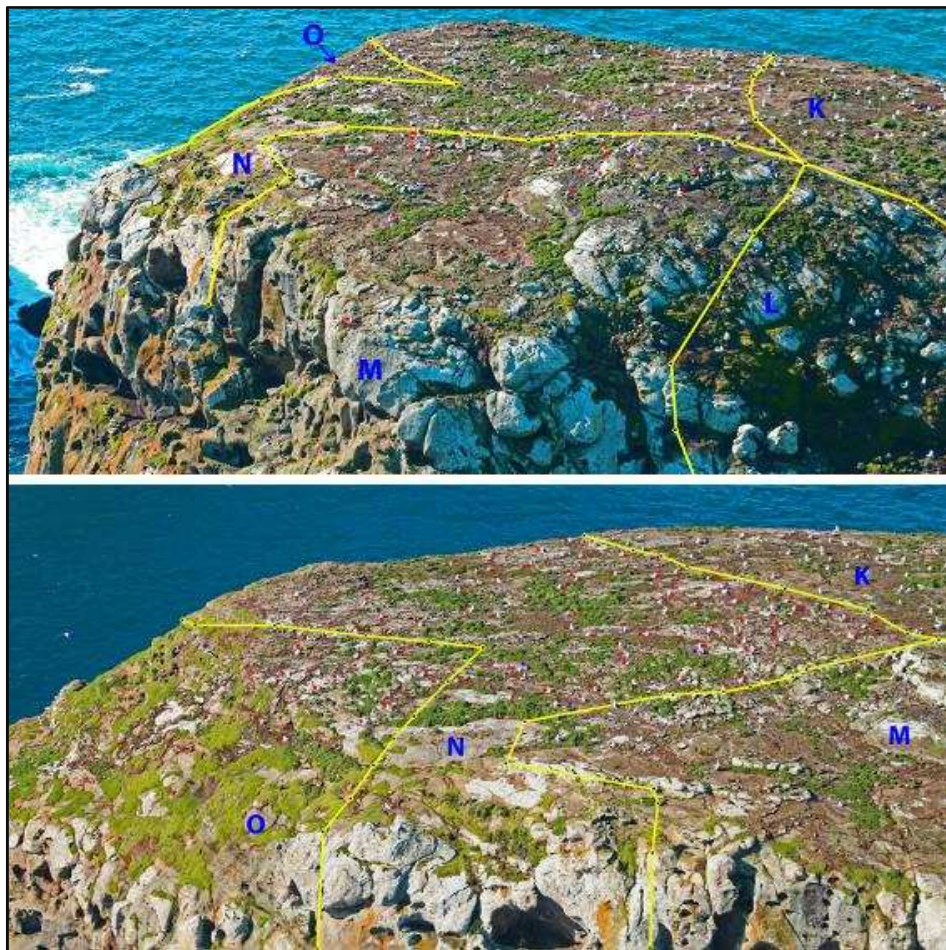


Figure 4. Demarcated zones (K, M-O) at the northern end of Big Sister I., Chatham Is, used for counting Northern royal albatross chicks (red dots) in zone M (upper image) and zones N and O (lower image). The dividing lines connect control points common to both images and ensured that individual birds were only counted once (Photo credit: Sarah Matthews).

Where colonies extend over large areas, on cliffs, or across ridges to the opposite side of an island, separate sets of photographs will need to be taken that overlap both horizontally ('end lap') and vertically ('side lap': Figure 5). Birds visible in both sets of images will need to be clearly distinguished so that they are counted once only.

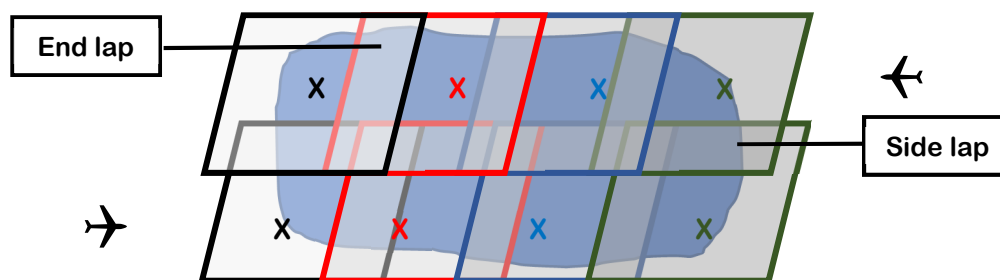


Figure 5. Idealised set of two rows of sequential photographs with sufficient overlap (end lap among successive images and side lap across successive rows) ensuring complete coverage of a colony (blue background). In each case, birds are counted only in those areas marked with solid (not faded) boundaries, with 'x' marking the approximate centre of each area.

About 60 percent overlap horizontally and 30 percent overlap vertically is ideal. Well-overlapped images make it easier to identify coincident points ('control points') used to demarcate areas that are unique to an image from those that overlap with adjacent images. Only individuals in the unique areas are counted (Figure 5).

Suitable control points include conspicuous or distinctive rocks or fissures, well-demarcated bare or eroded areas, notable patches of vegetation, or any other prominent feature. Thinking about possible control points when photographing a colony can make later processing of the images simpler. Note that an apparently prominent control point in one image can become indistinct when seen from a different angle in another image.

Prominent control points also help when merging images digitally to form a panorama (Figure 6). Where the images to be merged are too cluttered visually for coincident points to be easily distinguished or, at the other extreme, where the images are too uniform and lack suitable coincident points, these points can be added artificially to common points in both images before merging, to provide foci for the photo-merge.

The perspectives of images taken from an aircraft can shift appreciably, even when taken only a second apart. For example, images taken a second apart from an aircraft flying at 90 kph will be 25 m apart. The inscribed angle between these two successive positions and an object 200 m away is about 7°, which is can be sufficient to distort the boundary zone between the images. This can make them difficult to merge, sometimes resulting in duplication (Figure 6 inset) or deletion of points of interest. Panoramas are best produced from images taken from one position (e.g. from a hovering helicopter). They are generally not practical to create otherwise.

- **Close-up photographs** should show individual birds sufficiently clearly that their status can be determined (e.g. incubating adult, chick, adult on nest but not incubating, non-breeder). Together, these do not have to cover the whole colony but should cover reasonably random subsets of the colony, including central, peripheral and outlying areas. Such photographs generally need to be taken with **200-300 mm focal length**, although this depends on the distance from the camera to the objects being photographed.

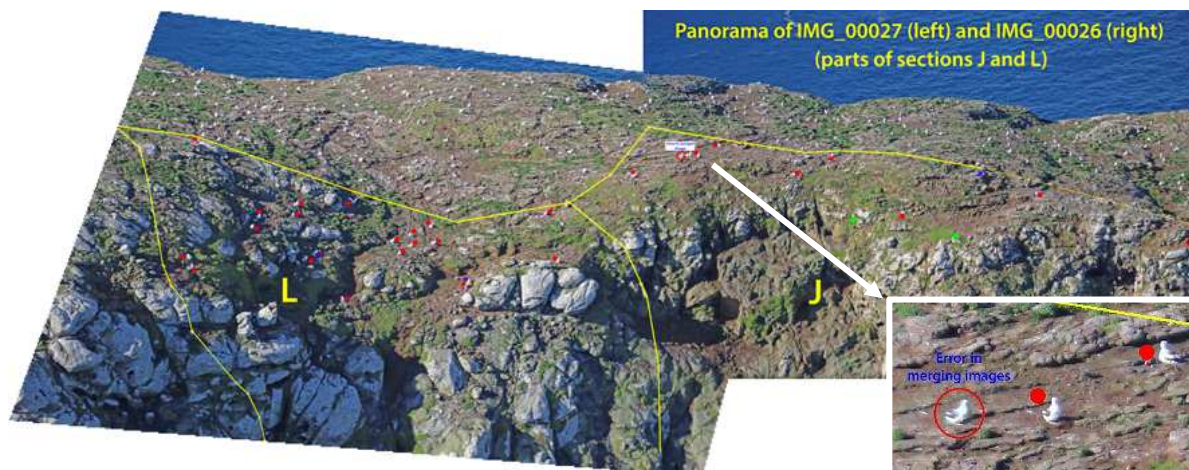


Figure 6. A panorama created by merging two successive images of a cliff face on Big Sister (Chatham Is). The small white rectangle in the centre of the image points to a duplicated individual (see inset). Coloured dots are counted individuals: royal albatross chicks (red), royal albatross adult (purple), and northern giant petrel (bright green). Individuals outside sections J and L were not counted on this merged image (Photo credit: Sarah Matthews).

On flat topography, photographs taken from oblique angles are generally preferred to those taken vertically, but colonies on cliffs or sloping ground are best photographed more-or-less perpendicular to the land surface. Low-angle oblique photographs (20-30° from the vertical) are most suitable for relatively shallow slopes, whereas high-angle oblique photographs (usually 50-60° from the vertical) are better for steep slopes (Figure 7).

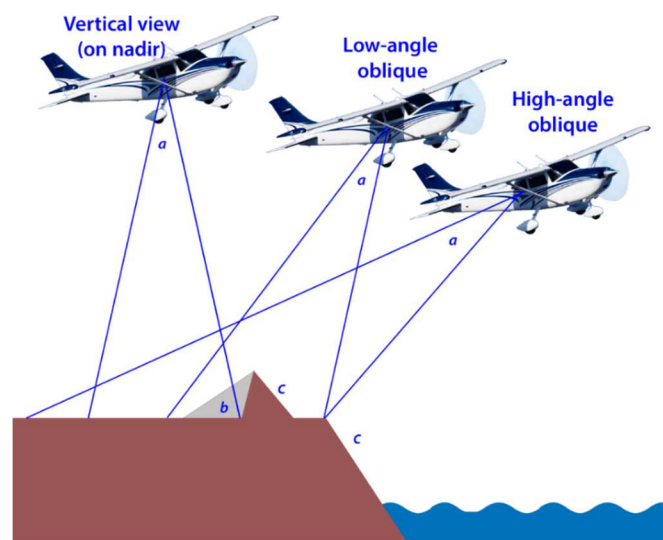


Figure 7. Different perspectives gained from aerial photographs taken at different angles: *vertical* (angle from nadir = 0°); *low-angle oblique* (25° off nadir); *high-angle oblique* (55° off nadir). In this illustration, the camera angle of view (*a*) is the same in all three cases, as is the distance from the aircraft to the cliff edge for both oblique-angle positions. A disadvantage of high-angle oblique photographs of uneven terrain is that they can have blind spots (*b*) in which objects of interest can be obscured, but they produce better views of tilted surfaces, such as cliffs or steep slopes (*c*).

Although counting birds in densely packed colonies is often easier from photographs taken vertically, as individuals are generally regularly spaced, it is less easy to distinguish between birds on a nest and those just sitting or standing around, because of difficulties in discerning individual postures (Figure 8). That makes it harder to estimate accurately the number of breeding pairs alongside non-breeding individuals.

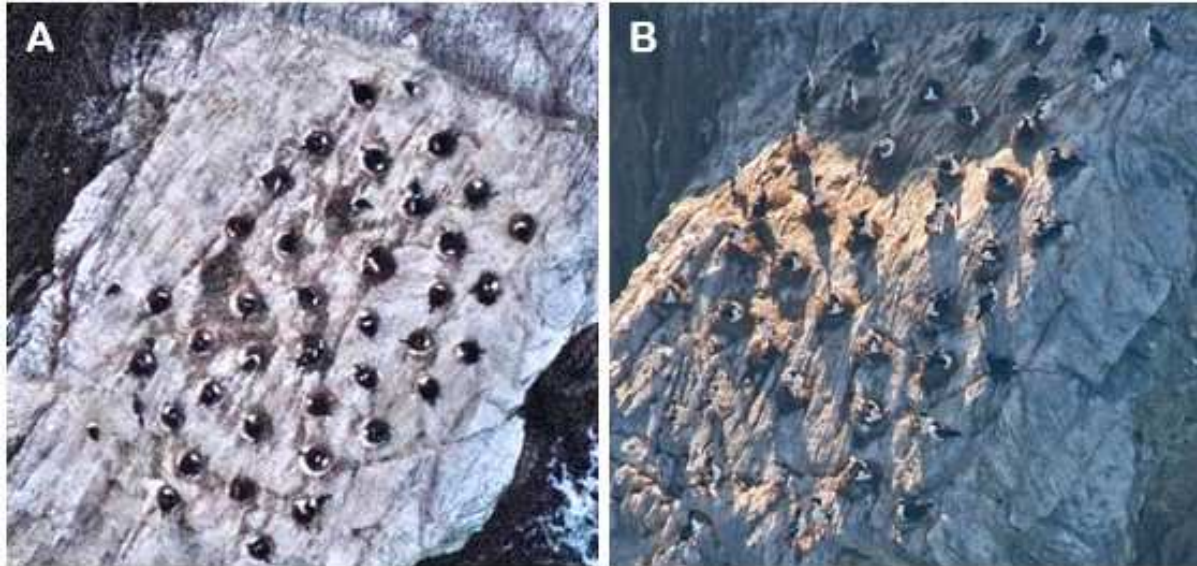


Figure 8. Comparison of views of the White Rocks king shag colony: (A) taken vertically, 21 June 2017; taken obliquely, 1 July 2016. The oblique view provides much more information on what the birds in the colony are doing. (Photo credits: [A] Terry Greene; [B] Mike Bell)

Distinguishing individuals and what they are doing is easier from oblique aerial photographs because the combination of shape and shadow makes an object stand out from its immediate background. Conversely, oblique photographs of undulating or broken topography can mean birds being hidden behind or obscured by rocks, vegetation or folds in the landscape. The most obvious problem with oblique images, however, is distortion to both the size of and distance to objects. Although photographic images are rectangular, the ground area covered in oblique photographs is trapezoid, more so in the case of high-angle oblique images (Figure 9). Among other things, this makes it difficult to merge photographs digitally because it complicates finding coincident points in common areas of different images. Changing the focal length of the camera between images in a sequence adds to this difficulty.

It therefore usually pays to do an initial fly past. This provides an opportunity to:

1. orientate oneself and get a broad overview of the locations of nesting birds;
2. identify any prominent landmarks that can be incorporated in the images, which can be used later to orientate them in relation to one another;
3. consider if sun angle is going to create problems (excessive shadow, over-exposure, lens flare), and therefore whether flying a different tangent would be preferable; and,
4. judge if the birds are being disturbed, which is likely if one flies too close to a colony.

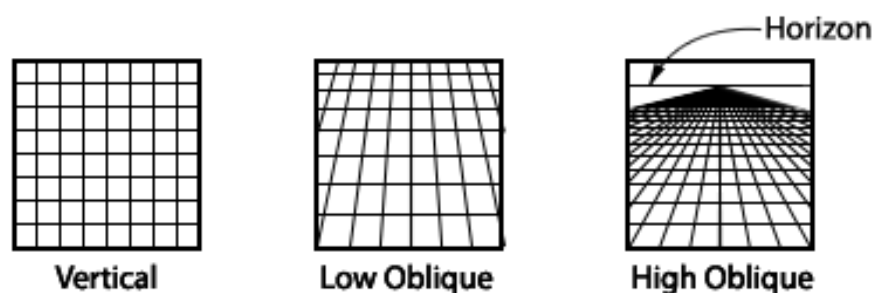


Figure 9. Different perspectives produced by vertical, low-angle oblique and high-angle oblique images, showing the vertical and horizontal distortion that occurs (after DeWitt, BA and Wolf, PR. 2000. *Elements of Photogrammetry (with Applications in GIS)*. McGraw-Hill).

Taking wide-angle photos during the initial fly-past should eliminate the need to zoom out to take such photographs on the second or subsequent passes. It is also an opportunity to take some test close-up images to see if the resolution is adequate, and whether the airplane is being flown at the most appropriate altitude.

Apart from disturbing the birds, thereby compromising the counts, low altitude flying carries with it the risk of bird strike. CAA rules specify a minimum altitude of 152 m, but there may be special restrictions applied to flying over a designated wildlife area. Data from GPS tracks of flights over royal albatross colonies on the The Sisters (60~80 m a.s.l.) and the Forty-Fours (~60 m) in the Chatham Is suggest that 170-250 m altitude is suitable for both medium-scale and close-up photographs (up to 300 m for wide-angle images, before coming around on the same or an adjusted flight path to photograph the colony systematically, starting at one end and going through to the other along the same line. If a colony is spread out in different places, three or more passes may be needed, with each successive pass focusing on an adjacent level vertically (Figure 5). Keep written notes of locations, time and activity if possible.

Summary

1. The aims of colony surveys are two-fold: to establish the size of a species' breeding population; and, when repeated at regular intervals, to track trends in population abundance.
2. Taking aerial photographs of colonies, from which nesting birds can be counted, is the quickest, least disruptive and most cost-effective means of surveying birds breeding in remote and often inaccessible locations.
3. The focus is to determine the number of active nests, those with either an incubating or brooding parent in attendance, or one or more chicks in a nest in the absence of the parents, separate from other birds present at the time of the survey. Because it is not always possible to determine the exact status of every apparently nesting individual, the basic unit of colony size therefore usually becomes the number of Apparently Occupied Sites (AOS).
4. For colonial-breeding species that nest more-or-less synchronously, the optimum time of such a survey is around the peak of egg laying.
5. Three potential sources of error when estimating population size from aerial surveys are: (i) spatial variability in the distribution of nesting individuals; (ii) temporal variability in colony attendance; and (iii) variation in detection probability. These can be minimised by photographing the whole colony, where possible, ideally at peak egg laying and at times of the day when fewest non-

breeding birds are present. Images, including close-ups of subsets of the colony, should have sufficient resolution to allow individual birds and their status to be differentiated.

6. Well thought-through planning and preparation ahead of a survey is crucial. This includes collating what is known about the topography, vegetation and aspect of the site; noting the location of the colonies and the likely period of peak egg laying; and developing an appropriate flight plan.
7. Synchronising cameras, watches and other recording equipment with the aircraft's or other GPS beforehand makes it easier to locate the positions of photographs without the need for later complicated adjustments. Even then, despite GPS and cameras displaying local date and time (if set to do so), these are reported in Coordinated Universal Time (UTC) when downloaded, and need to be converted to local time to correspond to any written notes taken during the flight.
8. To estimate the number of breeding pairs in a colony requires three complementary sets of photographs: wide-angle photographs (focal length [FL] 35-50 mm) to allow a composite picture to be built up of the whole area; medium-scale images showing nesting and other birds sufficiently clearly that they can be counted (FL 85-135 mm); and close-up photographs of randomly selected areas of a colony that allow the precise status of individual birds to be determined (FL 200-300 mm) and from which any correction factors, if needed, can be calculated.
9. Photographs taken from oblique angles are generally preferred to those taken vertically, although colonies on cliffs or sloping ground are best photographed more-or-less perpendicular to the land surface. Low-angle oblique photographs (20-30° from the vertical) are most suitable for relatively shallow slopes, whereas high-angle oblique photographs (usually 50-60° from the vertical) are better for steep slopes. Nevertheless, oblique-angle photographs produce somewhat distorted images, especially for high oblique angles over relatively level terrain. This can complicate interpretation.
10. An initial fly past is suggested. This provides an opportunity to obtain a broad overview of the locations of nesting birds and take wide-angle photographs of the colonies; identify any prominent landmarks that can be used as markers in later images and for orientating photo-sequences; and consider potential problems (excessive shadow, over-exposure, lens flare; disturbance) that might be resolved by flying a different path.
11. CAA rules specify a minimum altitude of 152 m, but there may be special restrictions applied to flying over designated wildlife areas. Most colonies being photographed obliquely can be adequately covered from 170-250 m altitude (higher for wide-angle photographs).
12. Colonies should ideally be photographed in horizontal strips, with about 60 percent overlap between successive images horizontally and 30 percent overlap between strips vertically. This makes it easier to identify coincident points for demarcating areas of overlap from those that are unique to an image and in which birds are marked and counted.
13. Adjusting the focal length of the lens while taking a specific sequence makes it difficult to relate successive images to each other. Medium-scale and close-up photographs are best taken on separate flypasts.

Feedback on these guidelines would be appreciated.