Birds: complete counts—aerial photo counts

Version 1.0

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Inventory and monitoring toolbox: birds

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Department of Conservation
Te Papa Atawhai

Synopsis

Periodic surveys from light planes or helicopters in many countries, including New Zealand, have been used to locate and count patchily distributed wildlife populations, particularly of large and mobile mammals, such as feral horses (*Equus caballus*) (Linklater et al. 2001) and Hector's dolphins (Slooten et al. 2002). Also, aerial photos have been used to count the pairs of gannets (*Sula serrator*) nesting about New Zealand (Wodzicki et al. 1984), northern royal albatross (*Diomedea sanfordi*) nesting at the Chatham Islands (Robertson 1991), mollymawks (*Thalassarche* spp.) nesting on Campbell Island (Moore 2004) and Disappointment Island (Baker et al. 2007), and black-billed gulls (*Larus bulleri*) nesting along Canterbury and Southland riverbeds (Powlesland 1998).

Advantages of carrying out an aerial survey are that it enables a large area of remote or difficult-to-access country to be searched within a day; and it provides an efficient method of locating patchily distributed flocks or colonies, as well as flock or colony sites that change from year to year. Also, the task can be completed during a brief period of good weather that would be too short for a ground-based operation.

When photographs or digital images are taken, a permanent record of the site or colony is available. Therefore the method is suitable to *inventory* flock or colony locations. In addition, counts of birds from aerial photographs provide an *index of population size* at one point in time, and because it is repeatable, they offer an *index of population trends*. Where an entire colony can be photographed the counts are the equivalent of a *census*. It is desirable to carry out ground-truthing to determine how representative the counts are. For example, it may be important to know what proportion of birds that appear as dots on photographs are on a nest with an egg (breeders), on an empty nest (having failed, are yet to lay, or are a non-breeder), a partner sitting on the ground near its occupied nest, or a non-breeder on the ground. Also, it may be important to know how numbers vary with time of day, stage of the breeding cycle, or season. Given these possible complications to interpretation of counts, not only is ground-truthing advisable, but carrying out a pilot study would be prudent when a new species is to be monitored by aerial photography.

As well as a census, aerial photography can be used to monitor population trends over time when most or a consistent proportion of a population is exposed to the survey and can be accurately counted. Counting of birds or occupied nests on photographs can be carried out directly by eye, by viewing through a binocular microscope, or on a computer screen. Such counts have the potential to detect population trends over a > 10 year period, between study periods > 10 years apart, and/or during rapid changes in numbers (> 10%). Experienced counters can have observer error of < 10%. Minimum attributes that need to be recorded are: observer name, flock or colony location, date, time, weather conditions, identifiers of images for each site, and tally of individuals, such as birds in a flock or occupied nests in a colony. Storage of data can be either manual (survey sheets), electronic (spreadsheet), or preferably both.

Disadvantages of using aerial photography include the need for high contrast in colour between the target animals and their surroundings; at colonies breeders may not be separable from non-

breeders; and much time is often required to assess photos. While hiring an aircraft is relatively expensive, for some species it is the only practical method of locating and/or obtaining counts at colonies or flocks, and is often less expensive than employing one or more land-based teams to carry out the same task.

Once colonial surface-nesting colonies or flocking sites are located, photographic techniques can be used to obtain counts of individuals or occupied nests. Both low-level oblique and low-level vertical photographic techniques may be used. Medium format cameras or high-resolution digital cameras will generally improve detail and accuracy. Ideally, ground counts at a few sites should be carried out at the same time as aerial photographs are taken to determine the accuracy of the counts. Although the process of photographing from the air tends to be specific to each situation (e.g. aircraft available, behaviour of species, habitat), many of the general procedures are similar. The various staff skills and resources required are described, as well as factors likely to influence the accuracy of counts from aerial photographs. Suggestions are provided for data storage, and details are given of procedures to input and analyse the data.

Assumptions

- The aerial view is representative of the population.
- All individuals or colonies are equally likely to be detected during an aerial survey, but see Pollock & Kendall (1987) regarding visibility bias in aerial surveys.
- Counts have small errors in terms of precision (normal variation) and accuracy (biases) (Bibby et al. 2000).
- Nesting birds can be distinguished from other birds in a colony.
- Birds sitting on nests are breeders (rather than non-breeders sitting on empty nests).

Advantages

- Remote areas can be searched during a brief period of good weather.
- Time required in the field is minimal when locations are already known—all that is required is a map/guide to the locations of sites, instructions as to height and path of aircraft travel, example photographs, and a camera and film.
- Wetlands can be surveyed that are often difficult to traverse by any other method.
- Improved accuracy when estimating numbers in dense aggregations (flocks and breeding colonies) from photographic images compared to peripheral counts using binoculars or telescopes.
- A permanent record of the colony is created when photos are taken.
- Photographs can be archived indefinitely, and can be counted at a later date when time and resources are available.
- Counting of objects on photographs can be repeated using different observers to compare counter bias, and using different technologies to compare accuracy.
- Photo counts can be compared with ground counts to ground-truth the data, and for better interpretation of subsequent photos when ground counts are not available.

Disadvantages

- Relatively high cost of chartering passenger aircraft (currently about $450 per hour for a fixed-wing).
- Much time required at a later date to assess images to determine numbers of birds in flocks or occupied nests in colonies.
- Possible scattering of birds due to aircraft noise.
- Need high contrast in colour between birds and their nests and surrounds. Not possible to obtain accurate census counts of furtive or well-camouflaged species, e.g. species that often nest in the open, but also nest under edge vegetation (black-backed gull—*Larus domincanus*), and species of similar colouration to their nesting habitat that occasionally nest in small colonies (black-fronted terns—*Sterna albostriata*) nesting among similarly coloured riverbed stones).
- Nesting birds and non-breeders may not be readily distinguishable.
- Height and angle from the colony are important. Oblique views may distort the image and obscure individuals, too low a pass means that multiple photographs must be pieced together, and too high means that breeders and non-breeders may be confused.
- Quality of photograph may vary with weather conditions, the lens used, exposure, and in the case of digital imaging, the resolution selected.
- Counter bias will affect accuracy of counts. This bias can be minimised through training.
- Experienced counters can have an error of < 10% (Bibby et al. 2000), and therefore the method is not suitable for monitoring fine scale changes over a short period.
- Number of birds in a colony can vary with time of day or stage of the breeding cycle; this mainly involves non-breeders, and these may be confused with, or obscure, breeders. Ground-truthing establishes the best time of day and stage of the breeding cycle for the taking of photographs, and so helps to minimise these effects.
- Numbers of birds breeding can vary annually; e.g. through variation in breeding frequency caused by birds being in poor condition, or through the variable levels of breeding success affecting return rates of biennially breeding albatrosses. Having counts for 3–5 consecutive years will indicate the degree of annual variation in counts.
- In mixed species colonies the species may be indistinguishable in the photographs, hence trends shown by the whole colony may be spurious.

Suitability for inventory

Colonial seabirds often nest on cliff sites, islands or rock stacks which are inaccessible to people, or prone to disturbance when visited. Therefore, aerial photography may be the only suitable inventory method.

Suitability for monitoring

Aerial surveys have good potential for carrying out a census of a population, particularly of breeders. Also the technique can be useful to detect population trends if most or a consistent proportion of a population is exposed to the survey, and the number of individuals can be accurately

counted from photographs. Seabirds that nest in dense colonies may do so in their thousands, hence photographs may be the only practicable method of determining numbers, and trends in numbers over time. Also, aerial photographs offer an excellent means of monitoring colony boundary changes which can be used to infer population change.

The best method for counting colonial nesting species which are readily visible from the air is by taking either vertical or oblique black and white photographs or colour images (transparencies or digital images) (Robertson 1991). For example, if the species is site-faithful from year to year, and contrasts well against the substrate, such as predominately white gannets or albatrosses nesting over a dark substrate (Wodzicki et al. 1984, Robertson 1991), then counts from photographs can be accurate. Ideally, ground counts at a few colonies need to be made at the same time as the aerial photographs are taken in order to determine the accuracy of the counts from the photographs, such as the proportion of nesting birds that are detected, and the proportion that are present but not actually nesting (Wodzicki et al. 1984; Moore 2004). Surface-nesting seabirds, such as albatrosses, are often large birds with striking white plumages. They build large obvious nests which are regularly spaced apart in the colony. Visiting the colonies can cause disturbance and nest failures. These attributes lend themselves to counts from photographs being used for population estimates.

Photograph counts have potential for detecting population trends over a > 10 year period, between study periods > 10 years apart, and/or during rapid change in numbers (> 10%). Photograph counts should be done for at least 3 consecutive years to obtain an average count and to mitigate the effects of annual, seasonal and other variation. This is particularly important for biennially breeding species, where poor breeding years can affect colony attendance. Experienced counters can have observer error of < 10% (Bibby et al. 2000); e.g. replicated counts from ground-based photographs of mollymawk colonies varied by 6.6% (CV) (Moore 2004). Hence the method is not suitable for monitoring fine-scale changes over a short period.

Skills required

Staff need to:

- Have had previous experience of the task or have been involved in a training flight, such that they know what the target species looks like from the air, and are able to take suitable photographs.
- Be able to operate appropriate camera equipment and understand the different lens requirements and resolution settings if using a digital camera. Digital images should be reviewed in the field after each photo, if possible, and adjustments made to camera settings to ensure optimal exposures are obtained.
- Be comfortable with photographing from an aircraft, and be able to cope with moderate turbulence and irregular flight patterns (e.g. steep turns).
- Be able to replicate the views in previous photographs and not omit any section of a colony.
- Be familiar with the operation of a GPS unit in order to record locations while involved in an aerial survey.
- Recognise and be familiar with the terrain as seen from the air. Ideally navigation would be the role of a second survey team member.

- Be able to brief a pilot about what sort of flying will be required and communicate effectively to the pilot while in the air (slow, low altitude, occasional quick turns to re-check a location, etc.). Contracting a pilot that has had experience of the process would be advantageous.

Counting objects on photographs requires skill and training, and/or an on-the-ground knowledge of the species. Staff need to:

- Familiarise themselves with the posture and shape of birds sitting on nests to distinguish breeders from non-breeders (if birds are being categorised).
- Be able to distinguish birds from rocks, tussocks and other similar objects.
- Be meticulous and careful for long hours while 'counting the dots'.
- Be able to look through a binocular microscope for long periods without suffering eye strain (when counting from photograph prints).
- Be able to operate appropriate computer software (if counting using digital technology).
- Accurately transcribe count data into computer files.

Resources

Resources required for taking photographs:

- Appropriate aircraft (fixed-wing or helicopter); be familiar with the 'Aircraft hire and carriage of passengers' best practice (docdm-384993), and the 'Helicopter safety' standard operating procedure (SOP) (docdm-208219).
- Appropriate camera and lens; 35 mm format camera (SLR or dSLR) with 50–150 mm zoom lens, automatic exposure (which requires 400 ASA film (preferably transparency), constant f-stop and good light-metering system), and automatic wind-on of film or equivalent digital camera setup is required. See Warner et al. (1996) for further information about suitable film camera makes and models for aerial surveys, camera mounts, survey planning and operational procedures.
- Film if using traditional methods, but use of digital technology is recommended.
- Memory cards or laptop for downloading digital images.
- GPS or detailed instructions for finding colonies or islands.
- Sample photographs from a previous survey.
- Notebook and pencil.
- Sunglasses for use when flying to and from sites.
- Aircraft-installed GPS navigation system to record locations of sites of interest. If such a system is not installed, a hand-held GPS unit will be required.
- Topographic maps covering the expected flight path on which to mark locations of interest.
- Aircraft with sufficient headphones for the pilot and each observer in order to ensure communication between all members of the party.
- Ensure camera equipment will not fall out of the aircraft when operating with a window open or door off by having the camera shoulder-belt attached to the person or safety belt.

- Consider having two photographers operating at the same time so that the best images can be chosen, and to avoid issues of camera breakdown or memory card corruption—especially important for expensive flights to remote sites (e.g. subantarctic islands).

Aircraft specifications

The Civil Aviation Authority (CAA) has oversight responsibility for all commercial and private aviation standards and certification within New Zealand. However, DOC has developed its own internal guidelines for the use of aircraft (see 'Aircraft hire and carriage of passengers'—docdm-384993). Briefly, these guidelines require aircraft used (hired or otherwise) by DOC for the transportation of staff or DOC-related associates to be appropriately maintained and operated, and flown by people with the appropriate CAA documentation. Also, when DOC passengers are carried in an aircraft for any reason, the flight company must have an operations specification that specifies the carriage of passengers on that aircraft.

Project leaders and pilots need to be aware that there may be limitations to aerial surveying in some areas, such as where people may object to aircraft noise, where aerial traffic is already heavy, where there are topographic risks, and where civil aviation regulations prohibit low-altitude flight.

Resources required for counting photographs:

- Large black and white prints and plastic overlays to mark nests with permanent markers while counting under a binocular microscope.
- Colour slides, projector and A3 sheets of paper for marking nests while counting the projected image.
- Digital software (e.g. Adobe Photoshop) to mark nests and boundaries of portions of colonies onto computer-generated image files from digital photographs. Also, the software can be used to 'stitch together' images of two or more portions of a colony as one image file.

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to 'Full details of technique and best practice'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

Minimum attributes to record:

- Observer's name, colony/flock location, date and time
- Weather conditions
- Identification numbers of the images taken at each site
- Any observations made at the colony (e.g. proportions of the species present, breeders/non-breeders, birds on eggs)

When counting objects on photographs:

- Tally the number of birds on nests.
- Tally the number of other birds in the colony.
- Tally separately the different species.
- If a colony is too big to get on to one photograph or the density of birds is so great that you are likely to lose count of the birds, subdivide the colony by drawing boundaries using topographic features.

For searches to determine the locations of flocks, roost sites or breeding colonies (inventory), record:

- Team leader
- Aircraft company, aircraft make and model, pilot's name
- Project name
- Date
- Weather conditions (use Beaufort scale for temperature, sunshine, wind and precipitation)
- Start and finish times of flight
- Description of search flight path
- Species searched for
- GPS location and general description of location for each sighting

For photographic counts of flocks or nesting colonies (monitoring), record:

- Team leader
- Aircraft company, aircraft make and model, pilot's name
- Project name
- Date
- Weather conditions
- Aircraft speed and altitude
- Time of photograph
- Camera identity, focal length of lens, imaging medium
- General location
- Species being counted
- Identifier of image
- Name of person that carried out the count from each photograph
- Tally and a description of any interpretations or correction factors involved

Data storage

Forward copies of completed survey sheets to the survey administrator, or enter data into an appropriate spreadsheet as soon as possible. Collate, consolidate and store survey information securely, also as soon as possible, and preferably immediately on return from the field. The key steps here are data entry, storage and maintenance for later analysis, followed by copying and data backup for security.

Summarise the results in a spreadsheet or equivalent. Arrange data as ‘column variables’—i.e. arrange data from each field on the data sheet (date, time, location, plot designation, number seen, identity, etc.) in columns, with each row representing the occasion on which a given survey plot was sampled.

If data storage is designed well at the outset, it will make the job of analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Storage tools can be either manual or electronic systems (or both, preferably). They will usually be summary sheets, other physical filing systems, or electronic spreadsheets and databases. Use appropriate file formats such as .xls, .txt, .dbf or specific analysis software formats. Copy and/or backup all data, whether electronic, data sheets, metadata or site access descriptions, preferably offline if the primary storage location is part of a networked system. Store the copy at a separate location for security purposes.

Analysis, interpretation and reporting

Seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis.

Results can be presented in a number of ways. Distribution maps of colony position can be drawn (e.g. Moore 2004). Total numbers at each colony per year can be graphed to illustrate change over time; and regression lines or a log scale graph can be used to illustrate positive or negative growth rates.

Detailed statistical analysis of population trends requires specialist skills and conservation managers should seek advice on the best ways to analyse counts.

Case study A

Case study A: distribution and numbers of pairs of gannets in New Zealand in 1980/81

Synopsis

A census of pairs at all gannetries was carried out in 1969/70 using aerial photography. All photographs were taken through an open door or window using a 35 mm SLR camera with a 200 mm zoom telephoto lens. All photographs were taken with colour transparency or black and white film.

In November–December 1968, the accuracy of counts was determined by comparing counts from aerial photographs with ground counts (where the content of each nest was checked) at a small gannetry of about 300 occupied sites (positions occupied by nesting or roosting birds). This comparison showed that, although aerial photographs did not enable the breeding status of gannets

to be assessed reliably, the aerial site counts were accurate to within ± 3% of sites counted by ground observation.

Objectives

- Where were colonies of nesting gannets located in New Zealand?
- How many pairs were present at each site?

Sampling design and methods

- Photographic (colour transparencies) coverage of all known gannetries in New Zealand during October–November 1980
- Counts of site-occupying singles or pairs determined from the transparencies for each colony

Results

- Table of date and time each gannetry was photographed (table 1 in Wodzicki et al. 1984)
- Distribution map of all gannetries (figures 1 & 2 in Wodzicki et al. 1984)
- Table of survey results, and comparison with previous surveys for each gannetry, including percentage annual change in abundance (table 2 in Wodzicki et al. 1984)

Limitations and points to consider

The counts from the transparencies were of site-occupying gannets, and so does not indicate whether each of the sites was occupied by a nesting pair or just a roosting bird. However, because of ground-truthing (comparison of simultaneous aerial and ground counts) at a small colony during a previous survey, it is known that most gannets counted on the photographs represented nesting pairs.

References for case study A

Wodzicki, K.; Robertson, C.J.R.; Thompson, H.R.; Alderton, C.J.T. 1984: The distribution and numbers of gannets (*Sula serrator*) in New Zealand. *Notornis 31*: 232–261.

Full details of technique and best practice

General rules

- Aerial views should be repeated in a set pattern and provide an unobstructed view of the colony—ideally at an appropriate angle to the face of the nesting cliffs or island.
- Photographs should be taken at peak colony attendance (e.g. at end of egg laying), or at stages of the breeding season to estimate breeding success.

- Photographs should be taken during the middle part of the day (0900–1700 hrs) as colony attendance tends to be at its most stable then, and this limits the problem of non-breeders being miscounted as breeders. Angle of the sun is an important consideration to ensure that no areas are in shadow that would hinder detection of individuals.
- Replicate the views taken by photographs taken in previous years, paying attention to include the colony periphery.
- Photograph counters should receive training or be familiar with the nesting colonies and bird behaviour (note that inexperienced workers produce the least accurate counts).

Preliminary procedures

Start by determining whether previous aerial counts have been made of the species within the area of interest. If there has been a previous survey:

- Reassess the time period during which aerial counts have occurred, the technique used, area covered, and pilot and aircraft company used to see whether improvements need to be made.
- Prepare a map showing the previous locations of flocks/colonies.
- Use the map as the basis for determining a possible flight path of the survey, and therefore estimating flight time and cost.
- Not all intended staff may be available at short notice and so extra staff may have to be trained at the outset.

If there has been no previous survey:

- Determine a flight path to cover likely locations of flocks/colonies based on habitat preferences, and local knowledge of the species and its distribution.
- The team leader should assess how many people will be required for the survey, the skills each will need, equipment requirements and availability, and the availability of a suitable aircraft.

Flight

- Weather conditions will dictate when the aerial survey can be carried out. Once the appropriate time period for the survey (based on timing of the moult, particular nesting phase, etc. of the target species) has begun, hopefully availability of suitable weather, trained staff, and aircraft will all coincide so that the counts and/or photographs are carried out before the end of the period.
- Detecting roost sites or colonies of a particular species of bird may depend on the movement of some individuals (birds flying to or from the site), or a contrast in colouration between the birds and the substrate (e.g. large black and white bird on green pasture) to aid detection. Generally, large flocks or colonies can be readily located because some birds will be flying to or from the site. Also, an accumulation of white faecal material over the site, such as over a grey riverbed or green trees, will help detection of the site. However, small flocks or colonies that differ little in colouration from that of the substrate may be difficult to detect, such as a small colony of the black-fronted tern.

- Aerial surveys using photography to count nesting pairs of gannets and albatrosses have generally been carried out at a speed of 80–110 knots and at 150–500 m altitude (Wodzicki et al. 1984; C.J.R. Robertson, pers. comm.).
- Vertical aerial photographs with medium format cameras could be done at 80 knots.
- Heights of between 500 and 800 m, depending on width of swath required, will disturb birds least of all. Such altitudes enable better resolution and movement free images; lower altitudes run the risk of insufficient swath width, increased blurring and loss of orientation by the observer.

Post-flight debrief

- Ideally, this should occur within 2 days of the flight.
- Staff involved should discuss and record the outcomes of the flight and photography, and how the operation could be improved in the future.
- Carry out a scan of the photos/images to ensure they are all of suitable quality for counts, and that all colonies, and portions of each colony have been photographed.
- Ensure that the photos/images have been labelled and stored in a logical sequence.

Sampling variance

To estimate sampling variance, including effects of light, colony attendance, etc., it is useful to repeat the photography on a different day, or days, within a few days of the first flight. However, it is acknowledged that this would require significant extra funding to accomplish. Carrying out a pilot study can be useful in improving precision of counts by identifying times of day or stage of breeding cycle when it is the ideal time to take the aerial photographs (e.g. fewest non-breeders present when you are interested only in the number of breeders). Variance as a result of observer bias (under-counting, multiple-counting) can be minimised by employing suitable people for the task (careful and methodical), having a suitable training programme (viewing photographs and doing sample counts with a supervisor), and it can be estimated by more than one observer counting the same photographs.

Counts from images

Traditional techniques

There are a number of ways that birds or occupied sites on images can be counted. If colour transparencies are taken, they can be projected onto a large sheet of paper, the birds or sites marked on the paper, and then the marks counted. Where parts of a large colony are in separate images or within one large image containing a high density of animals, then physical features can be used to demarcate portions of a colony in order to reduce double-counting or under-counting. Photographic prints can be counted by using a pin to poke through the paper at each bird or occupied site, and then the holes are counted from the reverse side. Alternatively, prints can be viewed under a binocular microscope and the dots marked on a transparent overlay (e.g. Moore &

Blezard 1999). Whichever of these techniques is used, the original image is not destroyed, and therefore the count can be repeated to determine the consistency of interpretation.

Counts using computer software

Advances in digital photography now allow computer-based counting techniques that largely make the above traditional methods redundant. High-definition digital Single Lens Reflex cameras produce images that can be copied and manipulated using photo editing software. An advantage is that quality is not lost during the printing process and expensive printing is not necessary. Digital copies of colony views are made, and demarcation lines and counting zones are marked on using software such as Adobe Photoshop (Baker et al. 2007; Robertson et al. 2008). Similarly the birds can be marked by placing a coloured dot on the digital image and the observer keeps a tally manually (e.g. with a number clicker or tally sheet) or by using counting software (Baker et al. 2007; Robertson et al. 2008).

Use of stereoscope

A technique that has been routinely used by archaeologists when using aerial photography to survey archaeological sites has been the taking of photographs that overlap by about 60% (Warner et al. 1996; Jones & Tanner 2002). Viewing the paired photographs with a pocket or mirror stereoscope provides a high-resolution 3D effect, and should enable improved accuracy in differentiating birds from other objects. Such photography has involved the use of a medium-format camera that produces 6 × 6 cm or 6 × 4.5 cm negatives, connected to a custom-made intervalometer that enabled fairly accurate 60% overlapping photographs to be taken (Jones & Tanner 2002). Purchasing such specialised equipment is an extra cost for a project, and looking through a stereoscope for long periods can be a strain on the eyes.

Transcription of data

Ideally, counts should be transcribed from data sheets into an electronic spreadsheet within a week or two so that any unusual results can be discussed between members of the survey team in case there have been any transcription errors. Also, comments about particular results or suggestions for improvements for future surveys can be added as footnotes.

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-384993	Aircraft hire and carriage of passengers
docdm-208219	Helicoptor safety SOP
docdm-146272	Standard inventory and monitoring project plan