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Guideline census methodologies for albatrosses and petrels

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Introduction

Accurate estimation of numbers is critical for determining conservation status, and for identifying the key factors influencing changes in population size and demography of seabirds. Diagnosing the causes of declines (or other population trajectories) is much harder without information on the timing and magnitude of population changes observed at different sites. Albatrosses and petrels are among the world's most threatened birds (Brooke, 2004, Robertson and Gales, 1998). Presently, 17 of the 22 species of albatrosses are listed on the IUCN Red List as threatened with extinction (BirdLife International 2011). Ongoing declines in many populations of albatrosses and petrels led to the establishment of the Agreement on the Conservation of Albatrosses and Petrels (ACAP), which came into force in 2004, and is currently ratified by 13 countries (www.acap.aq). The ACAP Agreement, together with its Action Plan, describes a number of conservation measures that contracting Parties need to implement to improve the conservation status of these threatened seabirds, including monitoring the status and trends of ACAP-listed species (Anon 2006). When considering population monitoring of ACAP listed species, it is useful to distinguish between annual (or regular) monitoring of study plots/sites and intermittent much larger-scale censuses of entire islands or archipelagos. The focus of this paper is on the latter (censuses), but also considers population monitoring more generally.

A range of different methods have been used to census surface nesting ACAP-listed species including ground counts and scans, transect and quadrat sampling to estimate densities, which are then extrapolated to larger areas, aerial photographs, and boat-based photography (e.g. Prince 1982; Moore 1996; Cuthbert & Sommer 2004; Poncet et al. 2006; Robertson et al. 2007; Huin & Reid 2007; Delord et al. 2008; Robertson et al. 2008; Strange 2008; Ryan et al. 2009; Baker et al. 2009).

Robertson et al. (2008) compared the accuracy and practicality of five different methods to census Black-browed Albatrosses *Thalassarche melanophris* at the Ildefonso Archipelago, Chile: 1) ground-truthed aerial photography, 2) yacht-based photography, 3) ground counts, 4) quadrat sampling, and 5) point-distance sampling. Of the five methods, the ground-truthed aerial photography was considered to be the most accurate; the other methods underestimated the population from 9% (quadrat sampling) to 55% (yacht-based photography) (Robertson et al. 2008).

The purpose of this paper is to provide guidelines to assist ACAP Parties in the development and implementation of plans to census ACAP species. It focuses mostly on surface-nesting species, but also includes some guidelines for surveying burrow nesting species.

Some guiding principles

- It is important to be clear at the outset what the objectives of a population monitoring programme are, as these objectives will largely determine the best approach. When considering censuses of breeding populations, it is important to decide whether the priority is to obtain an overall estimate of the population size, or if the focus should be on monitoring population trends. Of course, the two methods are not mutually exclusive, but if the priority is to monitor population trends, this can be done by regularly monitoring a representative sample of colonies, without having to survey the entire population (see later section on long-term monitoring).

- The monitoring programme should be at a sufficient scale i.e, involve a large enough sample, to be able to detect statistically significant changes in population size. This will depend on the sampling error, and the degree of annual variation in breeding numbers.
- The method should be practicable, and tailored for the species and colonies in question. A method that works well in one context may not necessarily be translatable to all other sites for that species.
- The method should produce the most accurate estimate possible, given practical constraints.
- No matter which method is used, there will always be errors associated with the estimate. It is important to acknowledge the existence of these errors, to minimise the errors through rigorous planning, and to quantify the errors wherever possible in order to adjust the counts accordingly.
- The method should be repeatable by different observers in the long-term, to avoid difficulties in distinguishing population changes from methodological changes.
- The method should keep disturbance to wildlife and habitats to within acceptable limits.

Census methods

A number of different methods have been used to census surface nesting ACAP species. These include:

- *Direct counts* – a ground count of all incubating birds. Each nest is inspected for the presence of an egg. Direct counts have generally been conducted when researchers have easy access to the colony, in colonies of up to several thousand birds and when the counting team has sufficient time at the breeding site. This approach is often used in combination with scan counts.
- *Scan counts* – a visual (*in situ*) count of occupied, or apparently occupied, nests conducted from a distance (outside of the colony), either because of the topography (e.g. the cliff-nesting *Phoebetria* albatrosses), size of the area to be surveyed, or because the species is prone to human disturbance (e.g. Southern Giant Petrels at some locations). Scan counts can be conducted on land (e.g. Cuthbert & Sommer 2004; Ryan et al. 2009), or from a vessel (Poncet et al. 2006).
- *Area and density method* – this method has been used at the very large colonies that are difficult to fully count directly, and involves measuring the areas of the colonies, the densities of nests within the colonies using transects or quadrats, and combining these two measurements to estimate the total number of active nests (Huin & Reid 2007).

- *Land or boat-based photography* – involves taking photographs of colonies from the land or a vessel. The photographs are later merged and counted (e.g. Lawton et al. 2003; Poncet et al. 2006).
- *Aerial photography* – taking photographs of a colony from a fixed-wing aircraft or helicopter. Some early attempts made use of high altitude (4156m) vertical aerial photographs to estimate the size (area) of Black-browed Albatross breeding colonies in the Falkland Islands, in combination with density estimates from direct ground counts in quadrats (Prince 1982; Thompson & Rothery 1991). More recently aerial surveys have involved flying low altitude circuits over colonies and taking sequential overlapping photographs which are later stitched together using software to form photomontages, from which apparently occupied nests can be counted on-screen (e.g. Arata et al. 2003; Robertson et al. 2007; Strange 2008; Robertson et al. 2008; Baker et al. 2009). With recent technological advances in both cameras and lenses, and image processing software, aerial photography has become much easier to use and a more accurate method of surveying breeding populations. It is becoming increasingly preferred as the census method of choice for surface nesting seabirds, especially in remote locations, e.g. Black-browed and Grey-headed *Thalassarche chrysostoma* Albatrosses in Chile (Arata et al. 2003; Lawton et al. 2003; Robertson et al. 2007; Robertson et al. 2008), Black-browed Albatrosses in the Falkland Islands (Strange 2007; 2008), White-capped Albatrosses in New Zealand (Baker et al. 2007; 2008; 2009), Southern Giant Petrels *Macronectes giganteus* in the Falkland Islands (Reid & Huin 2008) and Northern Gannets *Morus bassanus* in Britain and Ireland (Wanless et al. 2005). Given the recent advances in photographic equipment and software, high-definition aerial photography is now used to conduct surveys of seabirds at sea in the UK (Thaxter & Burton 2009, I. Mitchell, JNCC, in litt.

The counting unit and timing of the census

The objective of a breeding bird census is to estimate the total number of pairs that attempt to breed (lay an egg) in a given year. It is important that the counting unit is clearly defined, and the census is timed to take place as close as possible to the optimum period to measure this parameter. If the census is conducted too early in the breeding season, the count will not include all the birds that attempt to breed, and if it is too late it will not include birds that have laid eggs, but failed and left the colony prior to the census. In both cases, the census results will underestimate the number of birds attempting to breed, although it will often be possible to apply suitable correction factors. Censuses can also overestimate breeding population size if loafing birds (mates and non-breeders) are included in the count (see the section on sources of error).

In order to minimise these biases, it is considered best practice to survey the population (by counting the number of active nest sites) soon after the majority of birds have laid eggs, and to correct for breeding failures prior to the time of the survey, and if possible, also for count and detection errors (see below). There are obviously a range of logistical and weather-related factors which will influence when it is possible to undertake the census, but the aim should be to conduct the count as close as possible to this optimum period, and ideally to correct for differences between the number of birds that actually laid eggs and the number that were counted on the survey date. As the time-lag between the optimum census period and the survey date increases, the accuracy of the count as an estimate of the population decreases, and the need for appropriate correction factors increases. Indeed, considerable extrapolation between the optimum date and the census date will result in a much lower level of confidence in the population estimate.

It is much easier to correct for nest failures than to estimate the number of additional pairs that will lay eggs after a census that takes place in the middle of the laying period, which is why the optimum time to count the colonies is soon after all, or virtually all, birds have laid eggs.

It is also important to have clearly defined, and mapped, counting areas or zones that are easily recognised by future researchers. Standardisation of these areas will facilitate repeat counts in successive years, enabling a more fine-scale assessment of population changes over time. Such an approach will also allow the use of software such as TRIM (Pannekoek & van Strien 2005) – the software generally used by ACAP for species assessments - to impute missing data, estimate population sizes with appropriate confidence intervals, and to test for trends in population estimates in a statistically robust manner.

Sources of error

There are a number of sources of error associated with surveying breeding albatrosses, some of which are of a general nature and others which are more specific to the census method. It is important that these potential biases are recognised, that they are minimised through rigorous planning, and ideally that they are corrected through appropriate calibration studies.

1) Timing of the census

See above. If the census takes place too early it will not capture all the birds that attempted to breed that year, and if it is too late it will miss birds that failed before the census took place. To highlight the potential magnitude of this error, it has been found that more than 20% of Black-browed Albatrosses at Bird Island, South Georgia, fail by mid-incubation (Poncet et al. 2006; BAS, unpubl. data).

2) State uncertainty (ability to determine bird status)

(a) *Birds sitting on empty nests*. Robertson et al. (2008) found that ca. 7% of Black-browed Albatross nests inspected at the Ildefonso Archipelago, Chile, were occupied by birds without eggs, but suggested that these were likely to be birds that had actually laid eggs, which had been lost prior to the count, and so should be included in the estimate of the number of birds attempting to breed. This suggestion is supported by data from Bird Island, South Georgia, where most of the apparent nonbreeders occupying nest sites at the time of the census were failed breeders (Poncet et al., 2006). However, at New Island in the Falkland Islands non-breeders (i.e. not failed breeders) are frequently observed sitting on nests (P. Catry *in litt.*), so it cannot be assumed that all birds on nests are breeders or failed breeders.

(b) *Loafing birds*. These are considered here to be birds standing around in the colony, which could be mates of birds on nests at the time, failed breeders or nonbreeders. This error is mostly an issue for surveying using aerial and yacht-based photography, but potentially also applies to other census methods.

It is important to note that the number of birds sitting on empty nests/loafing, and hence the ratio of birds counted to number of breeders, varies diurnally and according to the prevailing weather conditions (Poncet et al. 2006; Robertson et al. 2008).

3) Detection errors

(a) *Perception bias (observer or count error)*. This reflects a number of factors, including the increasing difficulty of counting accurately in large colonies, prevailing weather conditions (wind speed, precipitation, fog etc.), variation among observers (particularly in level of experience), and the ability at distance to distinguish birds from other features (snow, rocks etc.) and to assign species in mixed colonies, which can all influence the accuracy of the count. The comparison of head colour, bill shape, and body size, and shape are usually sufficient to distinguish albatrosses in mixed colonies with shags and penguins, and this and other biases can be minimised by the use of high resolution photographs (Robertson et al. 2008). On-screen counting of breeding birds from aerial photographs is relatively straightforward using available software, and can be done slowly and systematically by marking each bird counted with a dot. In this respect, the approach may be easier and is probably more accurate than field counts of large colonies, but has the disadvantages that stitching photographs is often very time consuming.

(b) *Availability bias*. This reflects the ability to sample or count all available habitat, which is reduced if nests are obscured from the vantage point by topographic features. This is particularly an issue when topography is complex or nests are widely dispersed, such as for Northern Giant Petrels *Macronectes halli.* It is not only an issue for aerial photography. Indeed, in some cases, particularly in heterogeneous or complex terrain, it is possible to miss small colonies in ground counts that may be easily observed from the air (Robertson et al. 2008), or those on headlands with an aspect that is not visible from the land. Due to their cliff-nesting habitat and dark plumage Sooty *Phoebetria fusca* and Light-mantled Sooty Albatrosses *P. palpebrata* can often be difficult to detect from a distance, especially in inclement weather conditions (Ryan et al. 2009).

4) Technical and statistical issues

(a) *Errors associated with poor stitching of photographs*. This is obviously restricted to photographic surveys, which could be conducted from the air, sea or land. Once the photographs have been taken, they will be stitched together using appropriate software to form photomontages (Lawton & Robertson 2006). It is possible that a small number of albatrosses near the stitch lines are omitted or counted twice (Robertson et al. 2008). This is due to parallax, which is the displacement or difference in the apparent position of an object viewed along different lines of sight, and arises if the photographs were taken at different angles. This source of error is considered to be trivial. In the survey of Black-browed Albatrosses on Ildefonso 1.3% of birds on stitch lines were not counted, with stitch lines affecting less than 6% of the albatross nesting habitat (Robertson et al. 2008). Similarly, the error associated with stitch lines of photomontages of White-capped Albatrosses *Thalassarche steadi* was thought to be less than 200 birds of the total count of ca. 97,000 (Baker et al. 2009). Even though it is a minor source of error, parallax can be minimised by ensuring photographs are taken from a position as close as possible to perpendicular to the colony or landscape, and ensuring that the focal length of the lens remains constant for sequential photos that will form a montage.

(b) *Extrapolation errors*. When extrapolating from density figures derived in transects or quadrats to the total breeding population, it is important to minimise sampling errors. A hand-held GPS is probably the simplest and most practical device to measure the size of the sampling areas and that of the entire colony. The accuracy of standard GPS devices has improved significantly, but will have at least 5-10m of error, the accuracy of which is dependent on a number of factors, including satellite positions, noise in the radio signal, atmospheric conditions, and natural barriers to the signal (tree cover or topographic). The error can be minimised by using differential or assisted GPS technology, but this is much more expensive than a standard GPS. Measurements of the density of nesting birds from quadrats or transects must be representative of the variation of density in the colony. Even with a properly designed sampling protocol, there will be errors in the estimates derived from these samples.

Minimising and correcting errors

In order to derive accurate estimates of the total breeding population from count data, every effort should be made to minimise the errors identified above through rigorous planning of the surveys, and to correct the counts through appropriate calibration studies. Key recommendations include:

- Count the colonies as close as possible to the optimum survey period (see above).
- Colonies should be divided into manageable counting units, using topographic features or other reference points that are clearly defined and mapped.
- Corrections for nest failure between laying and the dates on which colonies are surveyed can be derived from nest failure rates obtained from intensively studied sample plots. These plots should be small enough to count accurately on a daily basis (potentially up to 500 nests for species breeding at sufficient density), and should ideally be monitored daily from the first arrival of birds until the end of the egg-laying period, and a minimum of 3 to 4 day intervals thereafter until the end of the census. These daily checks should ideally count the number of birds in the following categories: 1) active breeders on nests, 2) partners adjacent to nests 3) failed/deferring/subadult birds on nests (without egg) and 4) loafers (failed/deferring/subadult birds) standing in the colony. These surveys should ideally be carried out in more than one study plot, and preferably at more than one island site, to ensure the failure rates obtained are as representative of the whole population as possible.
- To correct for diurnal variation in the ratio of active nests to failed/deferring/subadult birds (categories 3 and 4 above), which is a particular source of error when using photography, systematic counts as described above should be undertaken at sample plots throughout the day during the census period. Previous studies have undertaken such counts at two-hourly intervals from 08h00 to 18h00 (Poncet et al. 2006; Robertson et al. 2008).
- Ground counts of colonies will only serve as useful calibration studies, or ground-truthing, for the aerial photographs if they are carried out at the same time as the aerial photographs are taken.
- To gain a measure of the precision (repeatability) of the counts, and the difference between counters, multiple counts of sample areas by more than one observer,

should be conducted. This is advisable both for ground counts and on-screen counting of aerial photographs.

- It is possible to quantify the error associated with stitching photographs together into a photomontage. This can be done by comparing the number of nests on the edge of a stitch line with the number counted near the centre of photographs of the same area taken on a subsequent flight path (Robertson et al. 2008). In uniform habitats it may not be possible to define the edges of stitch lines for overlapped montages, in which case it would be difficult to quantify the stitching error. Given that the magnitude of this error is likely to be very small (Robertson et al. 2008; Baker et al. 2009), it is not as important as some of the sources of error mentioned already.

Choice of census method

The choice of census method will depend on a number of factors, including the species being censused, the site, logistical and practical constraints and the budget available. Robertson et al. (2008) considered aerial photography to be the most accurate census method for Black-browed Albatrosses at the Illdefonso Archipelago. For those species and sites that can be surveyed using aerial photography, this method has a number of advantages over other approaches. These include:

- The survey can be timed so that the all colonies are surveyed during the optimum period (soon after most birds have laid eggs). This is because the process of taking the aerial photographs is much less time consuming than ground-counts. The time consuming component of aerial photographic censuses is the processing, stitching together of photomontages and on-screen counting of the processed images, which can all take place after the optimal period for censusing the population. See Lawton and Robertson (2006) for a useful guide on processing photographs from a seabird census.
- Once the protocols have been established, they are relatively easy to standardise.
- Aerial photography avoids the need for field workers to census entire colonies on the ground, which inevitably results in some disturbance. It is advisable to combine aerial photography with simultaneous ground-truthing counts to maximise accuracy, but this can be achieved by counting birds in a few study plots. Aerial photographs of albatross colonies have generally been taken at an altitude of 120m-400m, with no obvious signs of disturbance to nesting birds (Robertson *et al.*, 2008, Strange, 2008).
- Aerial photographs provide a permanent archival record of the census. In this respect it is the most objective and transparent of the census methods available, and allows future researchers to re-examine the original photographs, repeat the process of stitching together the photomontages and re-count the nesting birds. This objective archival quality means that if methodologies were to change in the future, the aerial photographs could still be used to assess population changes. Storage and access protocols should be clearly defined so that the aerial photographs and associated data are readily accessible by all parties.

Not all colonies lend themselves to being censused accurately by aerial photography. Whatever method is used should consider and account for the various sources of error, and be implemented in a standardised manner so that one can be confident that differences in estimates are due to real population changes rather than methodological differences or changes.

Larger-scale censuses as part of a population monitoring programme

The ultimate aims of a seabird census are to obtain a recent estimate for the population at that site or group of sites, and to use the estimates to monitor population trends. Ideally, a population monitoring programme should include both intermittent large-scale censuses of the entire site, together with more regular and intensive monitoring of population numbers, breeding success, and other parameters such as survival, at long-term study sites. From a conservation perspective, monitoring population trends is particularly important.

The use of large-scale censuses alone to monitor population trends has a number of challenges. The high annual variability in breeding numbers of some species, especially biennial species (Croxall et al. 1998; Nel et al. 2002; Delord et al. 2008), make analysis of long-term trends more difficult, especially if the analysis is based on a few data points from intermittent censuses. This is complicated further by site-specific differences. For example, although on average 75% of Black-browed Albatrosses that breed successfully at South Georgia, and 67% of failed breeders, return to breed the following year, levels of breeding deferral by established birds is much greater during years of poor food availability (Croxall et al. 1998). By comparison, the incidence of deferred breeding by Black-browed Albatrosses at New Island, in the Falkland Islands archipelago, is unusually low for a *Thalassarche* albatross (Catry et al. 2011). Rates of nest failure can also be highly variable among years (e.g. Prince et al. 1994), and it is important that this annual variation in breeding probability is accounted for when interpreting population trends from a limited number of data points.

The annual, or regular, implementation of ongoing population monitoring activities at study sites or plots, combined with less frequent (every 5-10 years) censuses of the entire breeding site or archipelago, is therefore considered the optimum approach to monitoring the status and trends of ACAP species. This approach will facilitate a better understanding of the inter-annual variation in breeding numbers and thus a more informed assessment of population trends over time.

Censusing burrowing nesting species

Although the previous sections have focussed mostly on surface nesting species, many of the principles and guidelines are broadly applicable to burrow nesting species. However, given that the survey methods used for these two groups of birds are quite different, the following section provides some additional guidelines for use in burrowing petrel censuses.

Censusing burrowing petrel colonies inevitably involves sampling a proportion of the population, and extrapolating density, area and occupancy estimates to determine the number of ‘active or ‘occupied’ burrows at the breeding site. It is important that the counting unit is clearly defined. ‘Active’ burrows may, for example, refer to the number of nests which contain any bird, breeders and/or nonbreeders, whereas ‘occupied’ burrows may refer to nests in which breeding has been confirmed (e.g. Cuthbert and Davis 2002). In many cases, it will be difficult, or intrusive, to confirm breeding, and so population estimates are often of apparently occupied nests.

Population estimates of burrow nesting seabirds are generally based on the number or density of nests in a particular area or habitat, the proportion of these nests that are considered to be occupied by breeding birds, and the total area of the different habitats surveyed at the breeding site (if only a sample of the habits was surveyed). The density of nests will generally differ between habitat or vegetation types (e.g. Lawton et al. 2006), and so it is important to derive habitat-specific density estimates, to ensure that transects or quadrats are representative of the range of habitats at the breeding site, and to estimate accurately the areas of each habitat type or colony.

Guiding principles and issues to consider when conducting a census of burrowing petrels

- When conducting scan counts of burrows, a proportion of burrow nests will not be detected, especially in areas with dense vegetation. Even experienced observers may underestimate the number of burrows in an area by 15-20% (Ryan & Moloney 2000, Ryan & Dorse 2006). This highlights the importance of conducting more intensive inspections of sample areas to account for this counter bias.
- Multiple burrows may share a common entrance, and a single burrow may have multiple entrances. Detailed burrow occupancy assessments (see below) are required to resolve this potential source of error.
- The burrow entrance of the species being surveyed may be confused with other species of burrow nesting seabirds. In these cases, it is important to establish objective criteria to discriminate between the nests of different species.
- Burrows may be occupied by nonbreeding birds, and the proportion of burrows occupied by nonbreeders may be influenced by the prevailing weather conditions (Ryan et al. 2006).
- Burrow occupancy rates can be assessed using a number of different methods, which can be used in combination. Use of tape-playback of the call of the species at the burrow entrance is considered a relatively objective and accurate measure of burrow occupancy for many species. This tends to be most successful during the early incubation period (Berrow 2000, Ryan et al. 2006, Ryan & Ronconi 2011). Response rates of burrow nesting species to playback calls may vary annually depending on the prevailing weather conditions (Berrow 2000). Birds in shallow burrows may not respond to playback calls (Ryan et al. 2006). Given that a proportion of breeding birds may not respond to playback calls, burrow entrances can be inspected for signs of recent activity, including the presence of fresh nesting material, signs of digging or disturbance at the entrance or within the burrow. This approach can be subjective, and it is best to use a number of standard criteria to score signs of recent use. Inserting an arm down the length of the burrow can also be used to assess occupancy, either by feeling the bird, or soliciting a response from the bird. This method can also be used to confirm the presence of an egg, and thus breeding status. However, it will not always be possible to confirm breeding status (if the burrow is too deep), in which case the burrow should be classified as indeterminate. Intensive inspections of sample nests can be used to determine how many of these indeterminate nests were actually occupied. This will involve opening burrows and/or digging access holes, which is intrusive and should be kept to a minimum. Finally, an infra-red burrowscope can be used to provide an accurate assessment of burrow

occupancy (Dyer & Hill 1992), but these are not practicable and accurate for all species and sites (Hamilton 2000, Cuthbert & Davis 2002, Ryan et al. 2006).

- Ensure that quadrats or transects are representative of the range of habitats at the breeding site.

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