9 Birds

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Introduction

Birds are among the easiest of animals to census. They are often brightly coloured, highly vocal at certain times of the year and relatively easy to see. They are also very popular, with the result that high-quality field guides are available in most parts of the world and there are many professionals and amateurs with a high level of identification skills. Because of this popularity, they are undoubtedly the most frequently surveyed of all taxonomic groups. The widespread involvement of volunteers in many schemes makes bird surveys an extremely cost-effective way of monitoring the overall health of the environment, as demonstrated by the inclusion of an indicator based on wild-bird population trends in the UK Government's list of headline indicators of sustainable development (Anon 2002; Gregory *et al.* 2003; http://www.sustainable-development.gov.uk/indicators/headline/h13.htm).

Before you start counting

Before undertaking a survey you must decide on your objectives and plan accordingly. The temptation at this stage is often to be too ambitious, so careful thought should be given to your key objectives and priorities (see also Chapter 1). You may be interested in an inventory of a site, the population size (i.e. total or absolute numbers) of a species or set of species in a particular area, or a population index (i.e. relative numbers). In many instances, your aim may well be to estimate the total numbers of a particular species in an area. If, however, you are interested only in whether a population is increasing, decreasing or stable, then a population index will suffice. Ideally, changes in a population index should be directly proportional to changes in population size; if the population halved then so would the index. Whether or not this assumption is valid, however, will not always be known and is difficult to ascertain. By obtaining repeated measures of population size or index over time, the population can be monitored. In general, monitoring with an index is more cost-effective and less demanding of time, and a reliable index may be preferable to a poor census.

Once you have decided on whether to obtain an index or a measure of total numbers, you need to consider the survey design. While this is covered in detail in Chapter 2, Bibby *et al*. (2000) and

Ecological Census Techniques: A Handbook, ed. William J. Sutherland.
Published by Cambridge University Press.

Gregory *et al*. (2004), a very brief introduction is given here. The key issues at this stage revolve around understanding the subtle differences among precision, accuracy and bias, and how such factors influence survey design (Gregory *et al*. 2004).

First, you must consider where to count by setting the survey boundaries. In many cases, these will be self-evident. If, for example, you wish to estimate the population size of a species in a particular habitat patch, island or country, then the survey boundaries may well be the boundary of the patch, island or country. However, the efficiency of your survey could be dramatically improved by ensuring that, even within that patch, island or country, you are not counting in entirely unsuitable areas. You could use existing information, such as from an atlas of bird distributions, to help you further refine your survey boundaries or, alternatively, you could do this using the species' known or likely habitat preferences.

Second, you must decide whether the survey is to be a complete census (all individuals counted), or a sample survey. For common and widespread species, it is usually preferable to survey representative samples of the population. For rare species, or those with clumped distributions, it may be more desirable and practical to count all individuals. Surveys can be a mix of census (for example, in the core of a species' range) and sample (at the edges). If you do plan to sample, you must decide on the sampling units and the sampling design. Units could, for example, be grid squares or habitat patches, and should be selected at random to ensure that they are truly representative.

Third, once you have decided where to count, you must decide on how to count, i.e. the field census method. The rest of this chapter will help you with this decision by providing a range of options suitable for various species and conditions.

Finally, of course, you must report your results, although this chapter will not dwell on this subject.

Choice of census method

Table 9.1 lists the many methods that have been used for surveying birds. Though several methods are listed, there are broadly two types: those for species that are evenly distributed across the landscape; and those for species that are not (i.e. are highly clumped). Listing methods, territory mapping, point counts and transects, for example, are best for species that are evenly distributed (e.g. territorial species), whereas counts of colonies, roosts and flocks are best for species with clumped distributions. Do bear in mind, however, that the dispersion of a species may vary throughout the annual cycle. For example, seabirds often gather at breeding colonies in the spring, but are out at sea for much of the rest of the year. In contrast, many waterfowl are distributed widely across the landscape while breeding, but commonly congregate outside the breeding season and are then much easier to count. Different methods would thus be required for different seasons, though it is often much simpler to count birds when they are clumped than it is when they are dispersed.

The methods outlined in Table 9.1 also differ in their ability to provide absolute or relative measures of abundance. Timed species counts and listing approaches, though efficient at providing rapid inventories of the species in a particular area, will yield information only on the relative

Table 9.1. *A summary of methods suitable for various groups*

Method	Water-birds	Seabirds	Wading birds	Raptors	Game-birds	Near-passerines	Passerines	Page
Listing methods	*	*	*	**	**	**	**	000
Timed species counts	*	*	*	**	**	**	**	000
Territory mapping	**		**	**	**	**	***	000
Line transects	**	***	**	**	**	**	***	000
Point transects	*		*	*	*	**	***	000
Capture–mark–recapture	*	*	*	*	*	*	*	000
Catch per unit effort						*	**	000
Counting colonial nests	**	***		*		**	*	000
Counting roosts and flocks	***		***			*	*	000
Counting migrants				**			*	000
Indirect counts	**		*		**			000
Tape playback		**		**		*	*	000
Vocal individuality	*	*	*	*	*	*	*	000

*Method usually applicable, + method often applicable?, method sometimes applicable. The page number for each method is given.

abundance of species. Many of the other methods yield estimates of absolute abundance. Under most circumstances, census methods that involve catching birds are not preferred; most bird species are easier to see or hear than to catch, and catching involves extra investment in equipment and training. Occasionally, however, this is not the case and capture may be the only practical method.

Where to look for further information

Bibby *et al*. (2000) give an excellent and detailed review of techniques, while Bibby *et al*. (1998) discuss methods with particular reference to bird expeditions. Gregory *et al*. (2004) cover survey design and general census techniques; Bennun & Howell (2002) present methods suitable for African forest birds; and Javed & Kaul (2002) do the same for Asian birds. Verner (1985) and Dawson (1985) review census methods, Koskimies & Väisänen (1991) describe those used in Finland, while the proceedings of the Asilomar Symposium (Ralph & Scott 1981) and of the European Bird Census Council conferences (Czech Stastný & Bejcek 1990, Hagemeijer & Verstrael 1994, Helbig & Flade 1999, Anselin 2004) contain many individual research papers on census and survey techniques. Gilbert *et al*. (1998) and Steinkamp *et al.* (2003) outline a variety of species-specific methods, Greenwood and Robinson (Chapters 2 and 3 in this volume) introduce much underlying theory, while Buckland *et al*. (2001) describe advanced methods for density estimation. Finally, Underhill and Gibbons (2002) outline the uses of bird-census information.

Listing methods

Listing methods are applicable to a wide range of species and habitats, but most widely used in tropical habitats. They are suitable for rapid assessments of poorly known areas. They can be used in population monitoring.

Method

Lists of birds recorded by birdwatchers are collected for a particular geographical area. Common species will occur on many lists, rare species on only a few. Thus the frequency of occurrence of species on lists, termed the 'reporting rate' by Harrison *et al.* (1997), is a crude measure of relative abundance.

Bart & Klosiewski (1989) compared the frequency of occurrence of birds at 50 counting stations (equivalent to 50 lists) with estimates of abundance from point counts (see below) at the same stations. Trends in species' populations were similar from the two methods, though those obtained from lists were about 40% lower when several individuals of a species were counted at stations. They concluded that such listing approaches were suitable for detecting change, but not necessarily the magnitude, and that listing would be preferable to counts only if they allowed many more observers to become involved; in practice this may often be the case because of the simplicity of listing. Roberts *et al*. (2004) have similarly shown that changes in frequency of occurrence on

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lists are a reasonable measure of changes in abundance over decadal time periods obtained from much more intensive territory-mapping and capture techniques.

Inevitably, the more effort that is put into generating each list, the longer that list is likely to be, making comparisons between areas with different levels of effort problematic. To overcome this, lists should ideally be produced for specific time periods, such as an hour or a day. Lists can also be constrained to a more precise geographical area. Hewish & Loyn (1989) found that producing species lists for 2-ha plots during 20-min periods appealed to observers because they felt that they were able to record all species present within the time period. The more lists that are produced, the more precise the reporting rates will be, so a reasonable number of lists, perhaps 15 or more, is required.

McKinnon lists (McKinnon & Phillips 1993) are a specific form of listing that records species on fixed-length lists rather than within fixed periods. To produce a McKinnon list, walk slowly around the study area listing the first *n* species encountered, where *n* could be, for example, 10, 15 or 20. List the names of all new species encountered and when *n* have been listed, start a new list and continue surveying until, again, *n* species have been encountered. Repeat this process until a reasonable number (>15) of lists has been produced. To give you an idea of what proportion of species present in your study area have been found, plot out the cumulative number of species recorded across the lists. This species-accumulation curve will begin to plateau when you have recorded a high proportion of the species present. As for other listing approaches, the relative abundance of each species is the proportion of lists on which it was recorded.

Advantages and disadvantages

The great appeal of listing methods is their simplicity. Counts of individuals are not needed, allowing more time to be spent on identification, which is particularly valuable for inexperienced observers and in bird-rich habitats. They provide a simple measure of relative abundance, allowing indices to be compared between species and sites. However, the index produced will be most useful for moderately abundant species. Very common species will be recorded on all lists – and thus true variation in abundance of these species will be masked and trends dampened. Very rare species will be recorded on no, or few, lists, giving little variation in abundance between species and sites, often no better than recording their presence or absence. An advantage of the McKinnon lists over time-limited lists is that, because observers are not restricted to particular time periods, less skilled observers – who take longer to find and identify species – can still produce lists that will be comparable with those of more experienced observers. The more skilled observers will simply collect more lists. Data from such lists can be used to produce maps of distribution and geographical patterns of abundance. However, this approach has the considerable weakness that the index of abundance it produces is relative to that of other species (see Chapter 3)

Biases

Relative densities of vocal and highly detectable species will be overestimated. Unless told not to, observers may seek out rare species, thus inflating their proportional occurrence. Lists should be time-limited, or else abundances in areas with greater fieldwork effort (e.g. more accessible sites) will be higher than those in areas with lower effort. Abundances of species that flock will be underestimated, since the method is best suited to species that are evenly distributed across the landscape.

Timed species counts

This method is used for high-diversity communities, particularly tropical forests, and also for birds of savannah and semi-arid areas. It is suitable for rapid assessments of poorly known areas.

Method

Timed species counts (TSCs) are repeated species lists that yield indices of relative abundance and are a specific type of listing method. They are based on the simplistic assumption that, when birdwatching, on average common birds are noted first, whereas rare birds take longer to locate. The average time to first observation is thus a crude measure of abundance and can be used to make comparisons both between and within species.

In practice, counters divide the entire period of observation in the study area into a reasonably large number of shorter time periods (e.g. 6–12) within, say, 1 or 2 h. For example, walk slowly through the study area for 1 h and record the time or the block of time in which each species was first seen. Ignore subsequent observations of that species within the hour. If a species was recorded in the first 10-min interval it is allocated a score of 6, in the second a score of 5, in the third a score of 4 and so on. Score unrecorded species as 0. Repeat the 1-h count, e.g. 10–15 times, and ensure that the TSCs are spread well over the study area. For each species, calculate a mean score across all 1-h counts to give a relative measure of abundance (Pomeroy & Tengecho 1986; Pomeroy & Dranzoa 1997).

The method can be made increasingly complex by recording birds within set distance bands, e.g. up to and beyond 25 m from the observer (to remove biases due to noisy or conspicuous species) or within set height bands, e.g. above and below 3 m (to overcome problems with hard-to-detect understorey species that are better censused by capture methods).

Measures of abundance for individual species from TSCs correlate well with those from line transects (Bennun & Waiyaki 1993; Pomeroy & Dranzoa 1997).

Advantages and disadvantages

Many of the advantages and disadvantages of general listing methods apply to TSCs and, again, this method has the major advantage of being quick. Common species are ignored once first seen and thus effort can be concentrated on finding less common species. A reasonably large area can be covered in the allocated time. The method is easy and does not require prior mapping or cutting of transect lines, and is a good way of rapidly evaluating the importance of sites. If, however, densities of common species are of interest then this is not a suitable method. Timed species counts provide only crude, relative indices of abundance. Maps of distribution and geographical patterns of abundance could be produced using this method.

Biases

Many of the biases of listing methods in general also apply to TSCs. Species vary greatly in their detectability (the probability of finding a species when it is present), and thus comparisons between species need to be interpreted cautiously. Flocking species or those that aggregate (e.g. in fruiting trees) may have lower or higher indices than those that are dispersed more widely across the study area, depending on the counting behaviour of the observers.

Territory mapping

Territory mapping is used for territorial breeding species, e.g. some ducks, game birds and raptors, and most temperate passerines. It is widely used, but can be very time-consuming.

Method

During the breeding season, many species of birds are territorial and, in temperate areas, such behaviour is strongly synchronised. Males sing to defend their territories, nests are built within them, and the boundaries between territories are often clearly defined by disputes with neighbouring birds. The breeding territory can thus be used as a census unit, and territory (or spot) mapping, in which all signs of territory occupancy are marked on a large-scale map of a plot, can be used as an effective means to estimate absolute abundance. The aim of territory mapping is to determine how many territories of each species there are on a given plot. Standardised techniques are given in Kendeigh (1944), Enemar (1959), IBCC (1969), Marchant *et al*. (1990) and Bibby *et al*. (2000).

First, the study plot needs to be mapped at a scale of about 1:2500. To enable species' registrations to be located accurately on the map, any obvious features that can be easily identified during each visit (e.g. buildings, ponds, isolated trees, tracks, rides, hedges, etc.) should be marked on the map. The size of the plot should be such that a reasonable number of territories of each species is present. A realistic goal would be to ensure that there are five or more territories for half of the species on the plot (Terborgh 1989). Though these numbers may be minimal for statistical purposes, in practice they require a great deal of fieldwork. Plot size will vary with habitat, because bird density, diversity and conspicuousness vary with habitat too; 15–20 ha in closed habitats such as temperate woodland would be suitable (though perhaps half this in tropical forest), with 60–80 ha in open habitats (e.g. agricultural, moorland, grassland and steppe). If the census is being undertaken for long-term population monitoring, it might be important to ensure that the habitat is not strongly successional in nature.

Long, thin plots are unsuitable for territory mapping because the ratio of edge to area is high and many bird territories will overlap the plot boundary. Territories along the edge of the plot

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cause problems because it is often difficult to determine whether a particular territory belongs to the plot. Round or square plots are preferable. In addition, try to avoid using a species-rich feature of the landscape (e.g. a hedge) as a plot boundary, since this will serve to exacerbate any edge problems.

Several visits need to be made to each plot during the breeding season. In temperate regions, where breeding seasons are clearly defined, 5–10 visits per plot would be suitable; open habitats would be at the bottom end of this range, whereas woodland with high densities of birds would be at the top. The visits should be spread out throughout the season to ensure that both early- and late-breeding species are included in the censuses. In tropical areas with less clearly defined seasons, the number and timing of visits needs careful consideration; it is true to say that this method is less used in the tropics.

Many birds sing most during the first hour after dawn. In consequence, this period can be confusing in areas with high densities of birds, and is probably best avoided. Surveys should commence an hour after dawn and be completed well before mid-day because many species sing less and are less active later in the day. Temperate forest can be surveyed at a rate of about 5 ha per hour, tropical forests at about half this rate and more open habitats at about 20 ha per hour, depending on the precise objectives of the study. Each visit to a plot can thus be undertaken during a morning.

Prior to the start of the season, you will need to produce several copies of the plot map, one for each field visit and, ultimately, one for each species' map (see below). Large maps can be awkward to use in the field, and are best attached to a clipboard. Cover maps with a large polythene bag if it is likely to rain. The plot should be covered at a slow walking pace with the route approaching within 50 m of every point on the plot. Each bird encountered is marked on the map using standard codes (Box 9.1). Evidence of nesting, such as nests, alarm calling and birds carrying nesting material or food, is particularly useful, as are simultaneous observations of different individuals of the same species (e.g. counter-singing or fighting males). Without these, the subsequent analysis of the maps (see below) is much less accurate (Tomiałojć 1980). It is necessary to work slowly and carefully to build up these records and to record inconspicuous species, though covering the plot too slowly may lead to unintentional double-counting of the same individuals. Mapping should extend slightly outside the study area to ensure that the territory boundaries of species at the edge of the plot are recorded (see 'Analysis of maps', below).

The territory-mapping method can be extended to cover a much larger geographical area simply by ignoring common species and mapping at a much bigger scale (e.g. 1 : 10,000; Robertson & Skoglund (1985)). By doing this, species that range over a much larger area, but are nevertheless territorial, can be censused (e.g. raptors).

Analysis of maps

At the end of the season all the information from the individual visit maps is transferred onto species' maps (one per species). Transfer registrations from the first-visit map and denote them by the letter 'A', those from the second-visit map by 'B' and so on. All the records of a particular species from the first visit are transferred to its species map, but with 'A' replacing the species

Box 9.1. Activity codes for use in mapping censuses in Finland

These activity codes have been developed from, and are very similar to, the mapping codes used by the British Trust for Ornithology in the UK. Most examples are for the chaffinch *Fringilla coelebs*. Some countries have standard codes for each species name (e.g. in the UK, CH = chaffinch).

 A chaffinch in song.

 A chaffinch in song (exact location shown by the point).

 A chaffinch in song (location is not exact; the point where the observation was made is shown by the cross).

$\underline{\underline{F_{coe}}}$ ♂ — A male chaffinch repeatedly giving alarm calls or other vocalisations (not song) thought to have strong territorial significance.

$\underline{F_{coe}}$ ♂ — A male chaffinch calling.

F_{coe}♂, F_{coe}♀, F_{coe}, F_{coe} 2♂1♀, 3 F_{coe}juv

Chaffinch sight records, with age, sex, or number of birds if appropriate. Use F_{coe} ♂♀ to indicate one pair of chaffinches, i.e. 2 F_{coe} ♂♀ means two pairs together.

F_{coe}♂^{f} — A male chaffinch carrying food (or faeces).

F_{coe}♀^{m} — A female chaffinch carrying nest material.

F_{coe}^{*2E3N} — An occupied nest of chaffinches, with two eggs (E) and three nestlings (N); * shows the location. Do not mark unoccupied nests, which are not of territorial significance by themselves.

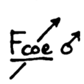
$P_{maj}^{⊠ 10E}$ — Great Tit *Parus major* nesting in a specially provided site. Please remember to use this special symbol for a nest in a nest box.

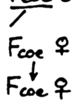
F_{coe}^{*P} — Chaffinch nest with a parent bird incubating or warming young.

F_{coe}juv — A chaffinch fledgling

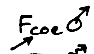
·F_{coe} fam — Juvenile chaffinches with parent(s) in attendance.

Movements of birds can be indicated by an arrow using the following conventions:

 A calling male chaffinch flying over (seen only in flight).

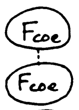
 A female chaffinch moving between perches. The solid line indicates that it was definitely the same bird.

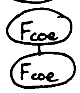
 A singing chaffinch perched, then flying away (not seen to land).

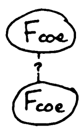
 A male chaffinch flying in and landing (first seen in flight).

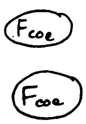
 A Siskin *Carduelis spinus* circling above the forest.

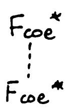
The following conventions indicate which registrations relate to different, and which to the same, individual birds. Their proper use will be essential for the accurate assessment of clusters.

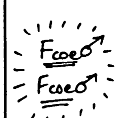
 Two chaffinches in song at the same time, i.e. definitely different birds. The hatched line indicates a simultaneous sighting/hearing of song and is of great value in separating territories.

 The solid line indicates that the registrations definitely refer to the same bird.

 The question-marked solid line indicates that the sightings/songs probably relate to the same bird. This convention is of particular use when your census route brings you back past an area already covered – it is possible to mark new positions of (probably the same) birds as those recorded before, without risk of double-recording. If you record birds without using the question-marked solid line, overestimation of territories will result.

 No line joining the registrations – there is no assumption as to whether the records concern different birds, but, depending on the pattern of other registrations, they may be treated as if only one bird were involved (a question-marked dotted line indicates that the sightings/songs were almost certainly of different birds).

 Two chaffinch nests occupied simultaneously, and thus belonging to different pairs. Only adjacent nests need to be marked in this way. Where they are marked without a line, it will be assumed that they were first and second broods, or a replacement nest following an earlier failure.

 An aggressive encounter between two chaffinches; may be accompanied by notes on vocalisations.

code. The symbols from Box 9.1 are also incorporated on the species map. This is repeated for each of the visits until a map containing all of the registrations from all of the visits has been produced for each species.

The symbols on the species' maps should form clusters around which non-overlapping rings representing approximate territory boundaries can be drawn. Conventionally, at least two registrations are needed to define a cluster if there were 5–7 visits or three if there were 8–10 visits. To avoid including temporary migrants, records in the cluster must be from at least ten days apart. Simultaneous registrations indicate different individuals and should never be incorporated into the same cluster unless they are thought to be two adults of a pair. Records of nests can be counted as a cluster even in the absence of sufficient records of the adults.

Dealing with edge clusters, those that overlap the plot boundary, is problematical, and several analytical methods have been used. Treat all edge territories as belonging to the plot; include them if more than half of the registrations within the cluster lie in the plot; or use the proportion of a cluster's registrations that lie within the plot to calculate a fraction of a territory. The first method will overestimate densities.

Clusters can be difficult to differentiate and may overlap. For inconspicuous species, there may be few registrations per cluster and no simultaneous registrations. Thus, despite the existence of standard guidelines (IBCC 1969; Marchant 1983; Marchant *et al.* 1990; Bibby *et al.* 2000), analysis of species' maps can be subjective and requires experience, as well as time.

Though map analysis is generally undertaken at the end of the season, if it were undertaken during the season, fieldwork could be targeted at clarifying confusing situations. The species' maps could even be taken into the field.

Advantages and disadvantages

Territory mapping is very time-consuming and can thus be expensive and inefficient as a monitoring tool. The time commitment to cover one site using this method usually limits the total number of plots that can be covered. The alternative of covering more sites less intensively may be attractive if the aim is representative monitoring. At first sight, this would appear to be an accurate and precise method, but this is not always the case and one needs to be aware of the underlying assumptions being made. It is not suitable for species that are colonial or semi-colonial, for those that live in loose groups or whose territories are large relative to the study area, for species that sing for brief periods, or for species with complex mating systems. It can be used only when birds are territorial, and thus is largely suitable only for breeding birds, though migrant species may set up individual, rather than pair, territories on their wintering grounds (e.g. Rappole & Warner (1980) and Kelsey (1989), see 'Response to playback'). It does, however, yield a map of bird distributions that can be particularly useful for analysing fine-scale bird-habitat associations or in the management of an individual site. Because of the great amount of time spent in the field, the method is better buffered against environmental variation (e.g. weather and timing of visits in relation to a species' breeding cycle) than are other less time-consuming techniques, such as use of point counts and line transects. It allows density to be estimated directly (although it provides no measure of precision) and, despite its drawbacks, is still the favoured method for determining population sizes of territorial breeding species on moderate-sized plots of land in temperate regions. Mapping methods can also usefully be combined with nest finding, radiotelemetry, mist nesting etc. in research projects. Mapping has seldom been used in the tropics, largely because breeding is more asynchronous and many species have complex social behaviours.

Biases

In some species, unpaired birds sing more. For example, unpaired male ovenbirds *Seiurus aurocapillus* and Kentucky warblers *oporonis formosus* sing 3.5 and 5.4 times more often than paired males, respectively (Gibbs & Wenny 1993). In the same study, all unpaired males were detected but only 50% of paired male ovenbirds and 65% of paired male Kentucky warblers were located over ten visits. Male sedge warblers *Acrocephalus schoenobaenus* cease to sing as soon as they have attracted a mate, whereas males of the cogeneric reed warbler *Acrocephalus scirpaceus* continue to sing once mated (Catchpole 1973). These differences in behaviour can make it unclear whether the breeding population is being censused.

The method assumes that birds live in pairs in fixed, discrete and non-overlapping ranges, which is often not the case (e.g. polygynous species, polyterritorial species). Despite standard guidelines for map interpretation, there is nevertheless a good degree of subjectivity involved and this can lead to variation, which makes comparison between studies difficult. The method can be unreliable at high densities, if birds are not readily visible, if registrations are plotted inaccurately, or if it is difficult to obtain many simultaneous registrations.

Transects

There are two types of transect most commonly used in bird surveying; line transects and point counts (or point transects). Both are based on recording birds along a predefined route within a predefined survey unit. In the case of line transects, bird recording occurs continually, whereas for point transects it occurs at regular intervals along the route and for a given duration at each point. There are variations on this theme whereby birds are recorded to an exact distance (variable distance) or within bands (fixed width) from the transect point or line. While there are some important differences between the line and point transects, there are many practical and theoretical similarities.

Line and point transects are the preferred survey methods in many situations. They are highly adaptable and can be used in terrestrial and marine systems. They can be used to survey individual species, or groups of species. They are efficient in terms of the quantity of data collected per unit of effort expended, and for this reason they are particularly suited to monitoring projects. Both can be used to examine bird–habitat relationships (though generally in less detail than territory mapping), and both can be used to derive relative and absolute measures of bird abundance. Transects can usefully be supplemented and, to some degree, verified in combination with other count methods such as sound recording, mist netting and playback (e.g. Haselmayer & Quinn (2000) and Whitman *et al*. (1997), see ‘Response to playback’).

There are several issues to consider when using transects in the field. The recommended walking speed is particularly important for line transects, as are the counting instructions. A further important consideration is whether to use full distance estimation, i.e. estimating distances from the centre of the point count or from the transect line, to all birds heard or seen, or to use estimation within distance bands or belts. In the latter case, you need to decide on the specific distance bands. It is preferable to record some measure of the distance to each bird seen or heard because this provides a useful measure of bird detectability and allows species-by-species density estimation. Modern methods, known as *distance sampling* (i.e. employment of a variable circular plot or variable-width line transects), are used to analyse such data (Buckland *et al*. (2001); see ‘Correcting for differences in detection probabilities’). Ideally, it is best to record the exact distance to birds, but, failing this, distance bands or belts can be used. As range-finders become increasingly affordable, they open the way for simple and accurate distance estimation, especially for single-species surveys.

The aim of transects is to record all birds identified by sight or sound with an estimate of distance when first detected. Distances should be estimated perpendicular to the transect line (rather than the distance from the bird to the observer), or from the point-count station. Birds that are seen flying over the census area (aerial species) are recorded separately because they cannot be included in standard density estimation. For such mobile species, it is best to make an estimate of their numbers along each section of transect, or at each point. If birds fly away as you are counting, record them from the point you first saw them. It is recommended that birds flushed as you approach a point-count station should be recorded from that point and included in the point-count totals (but you must make this plain in the write-up). Try to avoid double-counting the same individual birds at a point count or within a transect section by using careful observation and common sense. It is, however, correct to record what are likely to be the same individual birds when they are detected from subsequent point counts or transect routes. For surveys of breeding birds, between two and four visits to a site are recommended each season, depending on manpower, resources and specific objectives.

Line transects

Line transects are used for birds of extensive open habitats, e.g. shrub-steppe and moorland, offshore seabirds and waterbirds. This is a highly adaptable and efficient method.

Method

Line transects are undertaken by observers moving along a predetermined fixed route and recording the birds they see or hear on either side of that route. Line transects can be walked or driven on land, sailed at sea, or flown in the air. Because the observer needs to be able to move freely through the land, sea or air, transects are most suitable for large areas of continuous open habitat; but the method has proved highly adaptable.

First, the transect route(s) need to be chosen. Ensuring that their location is as random as possible is crucial to the success of the study. If, for example, a route were to follow a path, a hedge, a stream or a road, the results obtained could be markedly biased by the influence that these linear features might have on bird populations. A similar example would be of transect counts of fish-eating seabirds made from fishing trawlers that are, like the seabirds, actively seeking out fish stocks. The location of such transects could not be considered to be random, and would bias (probably inflate) any estimates made from the counts for particular species. The difficulty of randomly allocating routes due to access restrictions is a disadvantage of line transects. The Breeding Bird Survey in the United Kingdom (Gregory & Baillie 1998, 2004; Gregory 2000; Gregory *et al.* 2004; Raven *et al*. 2003; http://www.bto.org/survey/bbs.htm) uses line transects located on a north–south or east–west axis within randomly allocated 1-km × 1-km grid squares

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of the National Grid. In reality, few transects are able to follow the idealised route and some bias towards field boundaries, paths and roads may be inevitable. Birds are recorded in three distance bands from the transect line (0–25 m, 25–100 m, >100 m), or as in flight. There are three visits to each square each year: one to record land use and set up the counting route; and two to count the birds early in the morning, one early in the breeding season and one late. A similar model has been followed in the Republic of Ireland, Poland and Bulgaria. A transect could even be square or rectangular to ensure that the observer ends up at the starting point. Where maps are insufficient to plan a route precisely, it is a good idea to walk along compass bearings (Koskimies & Väisänen 1991), and generally to use a compass or GPS to aid navigation. Triangular line transects in forest, 2 km in length, have been used to survey capercaillie, *Tetrao urogallus*, in Scotland (Wilkinson *et al*. 2002).

The total length of transect route will vary depending upon the study in question. Practical considerations (e.g. time available to spend in field, size of the area to be surveyed, study species or group of species) may well be most important. Ideally, split the total length down into several shorter lengths. These could either continue one on from the other or be wholly independent of one another. The latter may be more useful for analytical purposes since the separate lengths of transect can be considered statistically independent. In Finland, breeding birds are surveyed along rectangular transects with a total length of about 5 km (Koskimies & Väisänen 1991). In the UK Breeding Birds Survey, each of two 1-km transects is further subdivided into five 200-m lengths for more geographically precise recording of birds and habitats. The total length of transect will depend on your objectives and local conditions.

If several different transects are to be undertaken on a plot, they need to be sufficiently far apart to sample the birds appropriately. Sensible distances might be 150–200 m in closed habitats, but 250–500 m in open habitats, depending on your specific objectives. The distance between transects should be greater in open habitats because birds are more visible over greater distances and are more likely to flee greater distances from an observer.

Once the transect routes have been planned it is then necessary to decide how many visits are to be made to each route and what distance estimation is to be used. As for point counts (see below) it is sensible to repeat each transect one or more times to maximise the chance of recording all species since bird activity often varies across seasons (either because the species is absent, or because it becomes unobtrusive at certain times). Two counts per nesting season is usually the minimum for monitoring studies.

Methods for estimating density are very similar to those used with point counts (see Chapter 1 for details) and various approaches have been advocated (Järvinen & Väisänen 1975; Burnham *et al*. 1980; Bibby *et al*. 2000; Emlen 1977; Buckland *et al*. 2001). Simple indices of the number of birds recorded per unit length of transect obtained by counting birds, either up to an unlimited distance, or to a single fixed distance on either side of the transect, are unlikely to be reliable because birds are inevitably missed. Increasingly sophisticated methods under the banner of distance sampling are now commonly applied to transect data for birds and the necessary software is available freely (see ‘Correcting for differences in detection probabilities’).

In practice it may be sensible to map all bird records onto a schematic representation of the transect in your notebook, or onto a recording sheet. It might also help if distance bands were drawn onto this, too. Recording the birds in this manner means that a variety of different techniques can ultimately be used to analyse the data. If birds are recorded in separate distance bands, check that the distances can be reliably estimated. Try to standardise the rate of movement along the transect route; walking too fast misses birds, but walking too slowly may result in double-counting. A walking rate of 2 km per hour is reasonable in open habitats, though 1 km per hour would be more realistic in forest.

Line transects at sea

Away from nesting colonies, seabirds are frequently surveyed by transect from a ship (Tasker *et al*. 1984; Komdeur *et al*. 1992; Briggs *et al*. 1995; Bibby *et al*. 2000). Seabirds present particular problems because they are often recorded in flight, and their speed of flight in relation to the speed of the ship through the water and direction of flight relative to that of the ship influence the results markedly. In addition, some birds are attracted to boats, whereas others avoid them, and general viewing conditions are often difficult against the sea surface. The sophisticated methods used on land can generally not be replicated at sea, so surveys tend to focus on indices of relative abundance and have caveats attached. By standardising the count methods, it is at least possible to draw comparisons between different areas and different studies.

Two simple, standard methods for transects at sea have been advocated (Tasker *et al*. 1984; Webb & Durinck 1992). The first involves counts to one side of the ship during a standard time period in a 300-m band (which is subdivided into 0–50-m, 50–100-m, 100–200-m and 200–300-m bands) or over 300 m. Birds are recorded perpendicular to the direction of the ship's course. By recording birds in distance bands, it is possible to generate detection functions and then apply adjustments specific to species and sea states. Frequently, two observers record the seabirds with counts every 10 min. The distance covered is calculated from the average ship speed in relation to the recording width and bird 'densities' are reported. The second method is the 'snapshot' approach in which observers estimate the number of flying birds and sitting birds in an imaginary box, for example, 300 m at right angles to the ship and as far ahead as all birds can reasonably be seen and identified. By taking a series of snapshots of this kind, it is possible to estimate the number of seabirds per unit area of sea. Validation of such figures from either method is in reality extremely difficult.

Line transects from the air

Waterfowl, some colonial species and seabirds are sometimes counted from the air by flying along transects of known length, width and direction (Komdeur *et al*. 1992). Though the use of a plane can be expensive, the speed of the plane, compared with that of a ship, does mean that the chances of double-counting the same birds, and thus overestimating density, are reduced. The flushing action of the plane can be helpful in some circumstances, although harmful disturbance must be avoided.

The width of the transect will vary with the particular application, but an overall width of about 200 m (100 m on either side of the plane) is sensible. The plane should be flown at a fixed and

Table 9.2. *A comparison of line and point transects*

Line transects	Point transects
Suits extensive, open and uniform habitats	Suits dense habitats such as forest and scrub
Suits more mobile, large or conspicuous species and those that are easily flushed out	Suits more cryptic, shy and skulking species
Suits populations at lower density and more species-poor habitats	Suits populations at higher density and more species-rich habitats
Covers the ground quickly and efficiently, recording many birds	Time is *lost* moving between points, but counts give time to spot and identify shy birds
Double-counting of birds is a minor issue, since the observer is continually on the move	Double counting of birds is a concern within the counting period – especially for longer counts
Birds are less likely to be attracted to the observer	Birds may be attracted to the presence of observers at counting stations
Suited to situations where access is quite good and terrain easily worked	Suited to situations where access is restricted and difficult terrain
Can be used for bird-habitat studies	Better suited to bird-habitat studies
Errors in distance estimation have a smaller influence on density estimates (because the area sampled increases linearly from the transect line)	Errors in distance estimation can have a larger influence on density estimates (because the area sampled increases geometrically from the transect point)

reasonably low (e.g. 50–100 m) altitude and at a moderate to low speed (e.g. 150 km per hour). In general, bird identification is more of an issue for aerial transects than for ship-based ones, and larger species are more readily surveyed. Identification becomes difficult if the plane is too high; and birds pass below too swiftly if it is too low. In practice, flight speeds may be too fast to count every individual bird and quick estimates of flock size are often needed. Bird density can be calculated from the number of birds counted and the overall area of transect covered (from its width, the speed of the plane and the time taken to complete the transect). The main disadvantages of the method are the expense, dependence on suitable flying and observation conditions, and restriction to larger, more visible species.

Advantages and disadvantages of line transects

Line transects can be undertaken at any time of year, on land, on sea or in the air. Line and point transects each have their own strengths and weaknesses (Table 9.2) and it is important that the methods are matched carefully with the survey objectives. Line transects are suited to large areas of homogeneous habitat, and are particularly useful where bird populations occur at low density. Because most birds are detected by song or call, a high level of observer experience is required. Estimates of density can be calculated using distance-sampling techniques. The area sampled by a line transect increases linearly away from the transect line; thus errors in detecting birds close to the observer and in distance estimation are less likely to bias density estimation than is the case with point counts. Random allocation of transect routes can be particularly difficult in some habitats and in some terrain. Because the observer is continually on the move, identification can be difficult and cryptic birds can easily be missed. The high costs of transects at sea can be reduced by observing from ships involved in other activities (though this may introduce some biases). Transects from the air are sometimes too quick to allow precise counts and the identification of some species, their age and sex.

Biases

Density estimation makes a number of assumptions; for example, it assumes that birds on the transect line are not missed (e.g. from walking too fast); that birds do not move before being detected (e.g. in response to the observer); that they are not counted twice along the same transect (walking too slow); that distance is estimated without error; and that all observations are independent events (e.g. one bird is not detected because of the alarm calls of another). In practice, many of these assumptions will not be met and all may lead to bias. Because of the short length of time spent in the field, line transects can be markedly influenced by weather conditions. Ideally, counts should not be carried out in strong winds, rain or cold weather.

Point counts or point transects

These methods are used for highly visible or vocal species, often passerines, in a wide variety of habitats.

Method

A point count is a count undertaken from a fixed location for a fixed time. It can be undertaken at any time of year, and is not restricted to the breeding season. Point counts can be used to provide estimates of the relative abundance of each species or, if coupled with distance estimation, can yield absolute densities, too (Buckland *et al*. 2001).

Point-count stations (the position from which the count is made) should be laid out within the study plot either in a regular/systematic manner (e.g. on a grid) or in a random manner and stratified as appropriate. The stations should not be too close together since some individuals would be counted at more than one counting station, which could spuriously inflate the sample size and influence the results. A sensible minimum distance is 200 m. If the distance between points is too great, however, too much time will be wasted travelling between the counting stations. A reasonably large number of point counts (more than 20) will be needed from each study plot; point counting is thus not a suitable technique for small study areas. Twenty counts can readily be made in a morning starting soon after dawn. An advantage of point counts over line transects is that it is often easier to approach and gain access to individual points than to establish transect lines, particularly when access and the terrain are problematic.

Wait for a set time, say a minute, before beginning to count at each station in order to allow the birds to settle down following your arrival. Count for a fixed time at each station. Ideally, this should be either 5 or 10 min, the actual duration depending on habitat and the bird communities present. If counts are too short, individuals are likely to be overlooked; if they are too long, some birds may be double-counted. Record all birds seen or heard. Endeavour to count each individual only once at each station. Most registrations will occur in the first few minutes, thus counting for too long can be inefficient. The time saved by counting for a shorter period can be used to count at more points, or to cut down the total time spent in the field. In areas with a very rich bird fauna or where species are hard to detect or identify, for example, in a tropical rainforest, it may be necessary to count for longer than 10 min.

In habitats with high densities of birds, it is easy to confuse different individuals, or to be uncertain whether you have already recorded a particular individual or not. A simple way of resolving this is to record their approximate positions in a notebook. This can be divided into four quarters, and birds recorded in these quarters (e.g. left and to the front, right and behind, etc.) marked accordingly by a species code. If you are counting in several different distance bands (see below), these could also be drawn as concentric circles around your central position.

If all that is required is an index of abundance, then count up to an unlimited distance, or only within an arbitrary range such as 30 m from the observer. However, such crude indices are generally not recommended and much can be gained by a little more effort. In practice, there are three ways of incorporating distance estimation into point counts to enable detectability to be assessed and density to be calculated. The simplest is to have two counting bands, and to record birds up to a fixed distance (e.g. 30 m in a forest, or 50 m in a more open habitat) and beyond that distance separately. Simple formulae (based on the possible manner in which detectability falls off with distance) can then be used to calculate the density of each species (see Chapter 3, Bibby *et al*. (1985) and (2000) and Buckland *et al*. (2001)). However, by recording birds in several distance bands, or to exact distances, a range of more sophisticated methods can be tested and applied (Buckland *et al*. 2001); such approaches are highly recommended and are much more efficient (Diefenbach *et al*. 2003).

It is often advisable to undertake at least two separate counts at each counting station, one in the first half of the season and one in the second. This will not only ensure that both early and late breeders are recorded during the counts, but will, in part, also take into account seasonal variation in bird activity, since a species, though present, may be more detectable during one part of the season than during another; equally, summer migrants may arrive only part way through the season. In general, the maximum plot count for each species should be used in analyses of density. This increases the chance that all birds are detected at the centre of the count area, which is an important assumption in density estimation (see below). The maximum value need not be used if only relative indices are required, rather a mean value can be used. If several counts are made at each counting station, it can sometimes be difficult to relocate the precise counting station on subsequent visits. It is thus necessary to use a GPS or mark the locations of counting stations in a reasonably obvious manner (e.g. brightly coloured tape wrapped around a post or vegetation), particularly in habitats in which the vegetation is likely to grow rapidly between visits.

The North American Breeding Bird Survey (Robbins *et al*. 1986; Sauer *et al.* 2001; http://www.mbr-pwrc.usgs.gov/bbs/) uses 50 3-min counts at intervals of 0.8 km along randomly selected roadside routes. Birds are counted once at the height of the breeding season, starting

30 min after sunrise, and all birds heard and seen within 0.4 km of the road are recorded at each stop. Each route takes about 4–4$\frac{1}{2}$ h. No distance estimation is involved, thus all species are measured in terms of a relative index. Though it has gathered an enormous range of information (2000 routes are counted each year and used to monitor about 230 species), the roadside nature of the scheme has led to problems in interpretation since habitat change along roads is unlikely to be representative of habitat change throughout North America as a whole. Such potential problems should always be considered if the census technique is to be used as the basis of a long-term monitoring scheme.

Advantages and disadvantages

Point counts are widely used to census songbirds. Line and point transects are compared with each other in Table 9.2. Point counts have been used, for example, to census waders, waterfowl and nocturnal birds in Finland (Koskimes & Väisänen 1991), parrots and hornbills in Indonesia (Marsden 1999) and the endemic bullfinch on the Azores (Bibby *et al*. 2000). Because most birds are detected by song or call, a high level of observers experience is required of observers. Counting stations are relatively easy to allocate randomly, which is not always the case for territory-mapping plots or line transects. Recording time is lost in moving between counting stations. Point counts are more suitable than transects where habitat is patchy, though much less so in open habitats where birds are likely to flee from the observer. Point counts are unsuitable for species that are easily disturbed or those that respond strongly to the presence of an observer. They are, however, very efficient for gathering large amounts of data quickly. Point counts can be used outside the breeding season.

Biases

Estimation of density assumes that all birds at the centre of the count area (i.e. where the observer stands) are recorded. This will not be the case if birds flee from the observer, or if the species is particularly skulking. Because the area sampled by a point count increases geometrically with distance from the observer, small errors in detecting birds close to the observer can seriously bias density estimates. Overestimates will occur if birds are attracted to the observer (Hilton *et al*. 2002). Where birds are highly mobile, the same bird may be recorded twice. Because of the short length of time spent in the field, point counts can be markedly influenced by weather conditions. Ideally, counts should not be carried out in strong winds, rain or cold weather.

Correcting for differences in detection probabilities

Method

Having carried out a survey of a species in a particular habitat, we often wish to compare our results with those of other similar studies. This is often easier said than done because to do so using the raw, or unadjusted, counts, you must assume that the probability of detecting birds is the same in each study. It is, however, unavoidable that some birds present in your study area will go undetected regardless of how well the survey is carried out. 'Detectability' is a key concept in wildlife surveys and needs to be assessed carefully. A comparison of unadjusted counts will be valid only if the numbers represent a constant proportion of the actual population present across space and time. This assumption is at best questionable and has been a matter of much debate (Buckland *et al*. 2001; Rosenstock *et al*. 2002; Thompson 2002).

The solution is to adjust counts to take account of detectability, for which various methods have been proposed (Thompson 2002). For example, the 'double-observer' approach uses counts from primary and secondary observers, who alternate roles, to model detection probabilities and adjust the counts (Nichols *et al*. 2000). The 'double-sampling' approach uses the findings from an intensive census at a subsample of sites to correct the unadjusted counts from a larger sample of sites (Bart & Earnst 2002). The 'removal model' assesses the detection probabilities of various species during the period of a point count and adjusts the counts accordingly (Farnsworth *et al*. 2002). Finally, 'distance sampling' models the decline in the detectability of species with increasing distance from an observer and corrects the counts appropriately.

Distance sampling is a specialised way of estimating bird densities from transect data and assessing the degree to which our ability to detect birds differs in various habitats and at various times (Buckland *et al*. 2001; Rosenstock *et al*. 2002). The software and further information to undertake these analyses are freely available at http://www.ruwpa.st-and.ac.uk/software.html. Distance sampling takes account of the fact that the number of birds we see or hear declines with distance from the observer. The shape of this decline, the distance function, differs among species, among observers and, importantly, among habitats. Birds in open grassland are detectable over much greater distances than are those in dense forest – even when they occur at the same densities. Distance sampling models the 'distance function' and estimates density taking into account both the birds that were observed and those that were present but were not detected.

Advantages and disadvantages

Distance sampling provides an efficient and simple way of estimating bird density from field data and corrects for differences in bird detectability under various circumstances (e.g. in different habitats in the same habitat experiencing successional change). It allows for differences in conspicuousness between habitats and species (though not observers), enabling comparisons to be made between species, across habitats and at different times. These methods are strongly recommended. Density estimates improve with the number of birds recorded – a minimum of about 80 records is recommended. Such methods, however, demand a high degree of accuracy in distance estimation by observers and a series of statistical assumptions to be met. Some, if not many, of the underlying assumptions are likely to be broken in the field and it is often unclear how much bias has been introduced.

Biases

Distance sampling and related methods rely on a series of assumptions, which need careful evaluation in the field; and positive steps should be taken to lessen their effects (Buckland *et al*.

2001). The key assumptions of distance methods are that all the birds actually on the transect line or at the counting station are recorded (for cryptic and shy species this might not be true); that transect lines are randomly or systematically located; that birds do not move in response to the observer prior to detection; that distances are measured without error; and that the detection curve has a shoulder, i.e. detection rates are higher closer to the observer or transect line but fall away with distance (Buckland *et al*. 2001).

Capture techniques

Because most birds are visible and vocal, survey methods generally rely on observers seeing or hearing them. Species that live in dense understorey or forest canopy and are rarely seen or heard, however, can be censused by catching them in mist nets. Two separate approaches are used; capture–mark–recapture (also known as mark–release–recapture, MRR) or catch per unit effort. The former allows estimation of population size the latter produces population indices.

Capture methods can be time-consuming and require substantial training to develop the skills necessary to catch, handle and mark birds safely. In many countries, a licence is needed before these techniques can be used. As a method of surveying birds, the return is poor in relation to the effort required, but there are other reasons to catch birds, for example to measure demographic parameters. Information on methods of capture and marking is given in Gosler (2004).

Catch per unit effort

This approach is used mainly for passerines, particularly of woodland, scrub and reed beds, but also for some riverine, dense-undergrowth and canopy species

Method

By placing standard lengths and types of mist nets in standard locations, for standard time periods under similar conditions, this method can be used to monitor changes in population level. Several schemes use capture per unit effort as a monitoring tool, the best known being the UK Constant Effort Sites (CES) scheme (Peach *et al*. 1996; http://www.bto.org/ringing/ringinfo/ces/index.htm), which has been adopted by an increasing number of European countries. The (Monitoring Avian Productivity and Survival (MAPS) programme (Desante *et al*. 1993, 1999) is a similar initiative in North America.

These schemes differ from all the methods discussed so far in that demographic, as well as long-term population, information is collected. Thus, rather than simply documenting year-on-year changes in population level, these methods can help interpret such changes by highlighting whether productivity and survival are possible causes of population change.

The MAPS programme provides very specific detail on methods for participants (DeSante *et al*. 1993). Sites are chosen to fulfil the following requirements: they are at least 9 ha in size (though preferably up to 20 ha); contain a reasonable breeding population of birds; are away from areas where transient and migrant birds tend to congregate; and are in areas where active habitat management ensures that the habitat is held in lower successional stages. The number and length of nets set depends on the workforce available, though these parameters should remain constant from year to year. In the UK, where one or two people are working the site it is recommended that ten 12-m, 30-mm-mesh, four-tier, black, tethered, nylon mist nets are set uniformly in a 7–8-ha netting area within the whole plot, thus giving a density of about 1.25–1.5 nets per hectare. Nets are placed where capture efficiency is likely to be maximised, for example near water, along rides or at the edge of woodland. Nets must be set in exactly the same position each year, and are operated for six morning hours per day beginning at sunrise, for 12 days each, for periods about 10 days apart, from early May to late August. Netting starts when most spring migrants have already passed through and stops when autumn migrants begin to appear. No baits or playbacks are used to attract birds to the nets. All birds caught, including retraps, are identified, aged and sexed (see e.g. Pyle *et al*. (1987), Svensson (1992) and Baker (1993)) and all unringed birds ringed (banded).

It is essential to standardise catching time and the number of nets in a site. Simply calculating birds per 10 m of net per hour is insufficient, since doubling the number of nets in a site will not necessarily double the number of birds caught. For the same reason, catching for twice as long will not double the number of birds caught, particularly since this would mean more netting outside the period of peak activity.

Care must even be taken to standardise the mesh of the nets. Species Weighing below 16 g are caught more frequently in 30-mm- than in 36-mm-mesh mist nets, whereas the reverse is true for those weighing above 26 g (Pardieck & Waide 1992). Thus, studies should not compare captures made with different mesh sizes.

Constant-effort ringing is often used to study birds of woodland and scrub, but is also good for surveying skulking rainforest-undergrowth species. It has also been used to monitor riverine species and was shown to correlate well with actual abundances of these species (Ormerod *et al*. 1988). It can also be used for canopy species, though, in this case, nets need to be raised many metres above the ground using pulleys or telescopic aluminium poles (Meyers and Pardieck 1993). A gunsling can be used for firing a line up to 45 m into the canopy and then using a pulley to pull up a mist net (Munn 1993).

Although MAPS and CES use mist nets, any accepted capture technique can be used, provided that effort is standardised (same number of traps, places, time periods, etc.).

The information obtained from such schemes has several uses. First, changes in the size of the adult population can be calculated. This can either be done in terms of a simple index based on the number of adult birds caught, in which case between-year comparisons are based on the number of individuals caught during the season irrespective of how many times each was caught, or it can be done using absolute population levels calculated from capture–recapture methods (see below and Chapter 3). Second, indices of post-fledging productivity can be calculated from the ratio of juveniles to adults caught late in the breeding season. Finally, adult survival-rates can be calculated from between-year retraps of ringed birds (Buckland & Baillie 1987; Peach *et al*. 1990; White & Burnham 1999). Because capture probability does not vary between years, survival-rate analyses are greatly simplified by constant-effort ringing. Such estimates are bound to be minimum because adults that survived between years, but did not return to the same site, are assumed to have died. Increasingly sophisticated methods have been developed to calculate survival rates (Clobert *et al*. 1987; Pollock *et al*. 1990; Lebreton *et al*. 1992; White & Burnham 1999; Nichols *et al*. 2004). First-year survivorship (the survival rate of young birds) cannot be so readily calculated, as the young birds often do not return to their natal site to breed.

Advantages and disadvantages

Unlike most other census methods, capture per unit effort provides information on productivity and survival. Constant-effort schemes are an excellent way of directing the efforts of numerous ringers who would otherwise ring in non-standardised and less useful ways. Long periods of training followed by application for a license are necessary before any ringing can be undertaken in some countries, and expensive specialist equipment is required. This makes it an unattractive method in many circumstances. In addition, it is time-consuming, sites are often chosen rather than randomly allocated, and habitat succession at sites can confuse the long-term picture. In consequence, it is not the most appropriate method for monitoring population levels and is usually able to cover only a very limited set of species. It can, however, be useful for censusing species that live in habitats within which observation is difficult (e.g. dense undergrowth, forest canopy and reed-beds). The method is best for species with high probabilities of retraping (e.g. warblers).

Biases

Because of the constraints on finding somewhere suitable to perform constant-effort ringing, sites are rarely randomly allocated and thus between-year changes might not faithfully represent changes on a larger, e.g. regional or national, scale. Any change in methods between years, for example change in location, number and length of nets and their mesh size, could lead to bias, as could successional change to the habitats, which is likely in the typical range of habitats chosen. Some individuals of some species may become 'trap-shy' and thus will actively avoid being recaught.

Capture–mark–recapture

In principle this method can be used for a wide range of species, though in practice the method is rarely used as a census technique.

Method

If birds are caught and individually marked, for example with rings (bands), then the population size can be estimated from the ratio of marked to unmarked birds subsequently recaptured or resighted. This can readily be explained by example. Assume that 100 birds of a particular species were caught at a site, marked and released, and, a week later, 50 of the same species were caught (or seen), 25 of which had been marked on the first day. If the proportion of birds caught on the second date that were marked (25/50) is the same as that in the whole population, then the size of the population at that site is 200.

An array of models (see Chapter 1) has been developed to analyse data from capture–mark–recapture studies. The simplest, the Lincoln index (or Petersen method), assumes one capture and one recapture (or resighting) event only, and that the population is closed. The calculations are essentially those described above. Models that are more complex allow for multiple capture (resighting) events and for open populations. The latter types of model, generally known as Jolly–Seber models, provide information both on population size and on survival rates.

Though colour rings (bands) are the most common method of marking, several other techniques, such as the use of wing tags, neck collars, colour dyes and radio transmitters, are also available (see e.g. Bibby *et al*. (2000) and Gosler (2004)).

Advantages and disadvantages

In practice, capture–mark–recapture is rarely used to estimate population sizes of birds. For many species, it is difficult to catch a large enough sample and there is a host of sources of error. Since most species of bird are readily observable, other techniques are usually preferred. For some species, however, particularly skulking ones and those living in the forest canopy, it may be the only practical method.

Biases

Estimating population sizes using capture–mark–recapture requires that numerous assumptions are not broken. It assumes that birds mix freely within the population; that the population is closed and no birds enter or leave through births, deaths or movements; that marking does not affect the probability of recapture (or resighting); that marked birds have the same probability of survival as unmarked birds; and that marks do not fall off or become less visible. Although many of these assumptions will be broken, it is possible to minimise their influence on the results. If the first and second capture dates are close together, the study site well defined and the study undertaken outside the breeding and migration periods, then the population will more approximate a closed one and population estimates will be more reasonable.

Counting nests in colonies

This method is used for colonial nesters, particularly seabirds and herons.

Method

About one-eighth of bird species nest in colonies and, as a consequence, are particularly easy to census during the breeding season, when that season is reasonably well defined. The technique adopted depends upon whether the colony is on a cliff face, or whether the species nests on the ground, in burrows, trees or bushes. Each is treated in turn below, and each method relies on discriminating occupied from unoccupied nests. Birkhead & Nettleship (1980), Lloyd *et al*. (1991), Gilbert *et al*. (1998), Mitchell *et al*. (2004) and Steinkamp *et al*. (2003)

provide details of methods for counting colonial seabirds, the latter also including colonial waterbirds. Two comprehensive manuals of methods for censusing seabirds, one for Britain and Ireland (Walsh *et al*. 1995), the other for Gough Island (Cuthbert & Sommer 2004), are also available.

Many colonial nesting species breed synchronously (although not all; and asynchronous breeding creates particular problems). This can be advantageous for censusing, since a high proportion of breeding birds will be at the colony during the same period. The best time to count is generally from midway through incubation to early in the nestling stage (Bullock & Gomersall 1981; Hatch & Hatch 1989). Any earlier and some clutches might not have been started; any later and some pairs may already have lost chicks and deserted the nest site, both leading to underestimates of the total breeding population. Other colonial species have a more protracted breeding season, sometimes with high rates of nest failure, e.g. the greater flamingo *Phoenicopterus rubber* (Green & Hirons 1988). For these, population estimation can be more difficult since at any time part of the population might be elsewhere, and the birds present during one visit might not necessarily be those present during another. Under such circumstances, individual marking of birds may be necessary.

Cliffs

Ideally, count from a position slightly above but opposite the colony. Do not count from immediately above the colony, since many nests will be missed. Several ornithologists have died studying seabirds and it is important to ensure that the counting position and access route to it are safe. Count pairs of birds or occupied nest-sites (or at least apparently occupied nest-sites). For some species that nest at very high densities (e.g. guillemots, *Uria aalge*), however, pairs of birds are difficult to count because this requires identification of all sites with eggs, young or incubating adults; this can take hours of observation. For such species, counts of individual birds are more effective. Subdivide large colonies into smaller units for ease of counting. Photographs can be used to divide the cliff into counting units and to provide a permanent record of them. Colony attendance can vary both with season and diurnally and should be taken into account in deciding when to count.

For some highly visible colonial nesters, particularly those that, like the gannet *Morus bassanus*, build substantial nests, it may be simpler to photograph the colony and to count nests directly from the photograph, or by projecting an image onto a large screen and counting from that. This method is particularly useful where there is no suitable position to count from, yet a photograph could be taken (e.g. from a boat or from the air). For some species, photography may be unsuitable since black and white seabirds are readily confused with guano and shadows.

Burrows

Burrow-nesting seabirds are particularly difficult to census, many of them return to land after dark, and burrows may be unoccupied or occupied by more than one pair. They are best censused by sampling, using random or stratified random quadrats or line transects (e.g. Brooke (1990), Gibbons & Vaughan (1998), Ratcliffe *et al*. (1998) and Mitchell *et al*. (2004); see also Chapter 2) and then counting the number of burrows that appear occupied. Circular sampling plots are easy to use in practice, since a fixed length of rope tied to a stake will give a fixed size of plot. A rope and stake are also easy to carry into the field. Occupied burrows can often be recognised by a range of features such as feathers, excavated earth, droppings, broken eggshells and smell (especially when young are present) or by planting matches or toothpicks around the entrance to the burrow and seeing whether these get knocked over, but beware pre-breeding birds that are prospecting for nest sites. An endoscope (optical fibrescope) or miniature nest camera on a flexible pole can also be used to examine the nest contents, though if the burrow contains too many bends this may be time-consuming or impossible. It is often useful to play recordings of the call; if a response is elicited then the burrow is occupied, though not all birds will necessarily respond (see 'Response to playback', below). Digging down to the nest to expose the nest chamber is discouraged. For nocturnal species, it may be useful to play recordings of the call to elicit a response (James & Robertson 1985; Ratcliffe *et al*. 1998; Mitchell *et al*. 2004). As digital nest-camera technology and recording improves, it is increasingly possible to use remote triggering and digital recording to monitor nest burrows in an unobtrusive and highly efficient manner.

One perennial problem with censusing burrow-nesting species is that it is necessary to distinguish the burrows of various species and to exclude those of mammals. This is not always straightforward. The simplest way of overcoming this is to survey in places, or at times of year, when only the species under study is present. This will clearly not always be practical, and should the use of endoscopy, nest cameras or playback prove impossible, it may be necessary to develop more sophisticated techniques, such as that of Alexander & Perrins (1980), which is based on mark–recapture.

Colonies of ground-nesting species

Many species of seabirds, e.g. gulls, terns, penguins and albatrosses, nest in colonies on the ground. If the colony is small (fewer than 200 pairs) and can easily be viewed, then the number of nests may be counted directly. For larger colonies, it is probably sensible to subdivide the colony and count each section separately. Old nests, which can readily be identified by the lack of a white coat of faeces, should not be included in the counts.

Counts should be carried out at the time of year when adults are most likely to be on the nest (usually from mid-incubation to soon after hatching) and during the time of day when attendance is most stable. This will probably vary between species and colonies, but, as a rule, avoid early morning and evenings.

Particularly extensive colonies are probably best censused using line transects or quadrats (e.g. Thompson and Rothery (1991); see Chapter 3). To do this, first map the colony boundaries and calculate the overall area of the colony. When using transects, define their location, mark them on the ground with string, walk their length and count all occupied nests up to a set distance (e.g. 1 m) from the transect line. Do not count the same nest twice. Alternatively, if using quadrats locate them at random within the colony, or at equal distances along a transect, and count all occupied nests within each quadrat. It is simple to calculate the colony size from the total area of the colony and the total number of occupied nests in, and area of, all transects or quadrats. Rather than simply counting all nests within fixed-width transects, all nests seen from the transect could be counted, their distance from the transect line measured and distance-sampling methods (see above and Chapter 3) used to estimate densities and thus total numbers of nests.

Any technique that forces adults off their nests is traumatic both for birds and for the observer. It is essential to ensure that disturbance is kept to a minimum and adults should not be kept off the nest for more than 30 min, ideally less. Colonies should not be disturbed when it is very wet, cold or hot for fear of causing egg and chick losses. Care should be taken to ensure that chicks do not run off, predators do not take advantage of the disturbance and eggs and young are not trampled. Such techniques are probably best not used near public areas.

Rather than walking through colonies to count nests, a more rapid and less invasive technique for small colonies is the flush count (Steinkamp *et al*. 2003). In this approach, all birds in the colony are flushed into the air with a loud noise and all flying birds counted. Using this method, the colony size can be estimated only if the relationship between flying birds and breeding pairs is known. For Arctic terns *Sterna paradisaea* three flushed birds correspond to two breeding pairs (Bullock & Gomersall 1981; Whilde 1985; Bibby *et al*. 2000), though this relationship will vary among species. An obvious concern with this approach is disturbance and nest abandonment at times when birds are particularly sensitive (e.g. during colony settlement early in a breeding season).

Tree colonies

Many herons, egrets, storks and spoonbills nest in dense colonies in trees, though species from several other groups (e.g. crows and weaver birds) do so as well. For those which nest in deciduous trees reasonably early in the year, nests are best counted before the leaves have completely emerged, or else the nests will become obscured. Occupied nests can often be identified by the presence of fresh nesting material, droppings in the nest, or underneath, and incubating or attendant adults or chicks calling in the nest. Alternatively, it may be necessary to use a mirror or miniature video camera on the end of a long telescopic pole to see into the nest cup. Many herons, egrets, storks and spoonbills are sensitive to disturbance and for these species it is probably not a good idea to visit until the colony is well established, once egg-laying has commenced. Even then, extreme care should be taken to ensure minimal disturbance.

Fortunately, many tree-nesting species are highly visible from a distance, so, provided that a suitable vantage point can be found, sensible nest counts are reasonably straightforward. Observation from custom-built tower hides is often best. Where a suitable ground-based vantage point cannot be found, aerial counts can be undertaken, finances permitting. Aerial counts of great blue herons *Ardea herodias* recorded 87% of the ground total while aerial photographs recorded 83% (Gibbs *et al*. 1988); Aerial methods were considered less disruptive than ground counts, were precise and were highly repeatable. The least disruptive method used, however, was a ground count of used nests after the breeding season.

Advantages and disadvantages of counting nests in colonies

The biggest advantage of this method is that counts are undertaken at a time of year when the species is highly clumped and thus can be counted in a very cost-effective manner. At other times of year these species may well be spread over a very much larger area and are consequently very difficult to census. The disadvantages are that it is suitable only for breeding birds and that care has to be taken to keep disturbance to a minimum and to count all nests present.

Biases

Colony attendance can vary both diurnally and throughout the nesting season and this must be taken into account. Poor vantage points for counting can lead to unknown biases and probable un-recording.

Counting roosts

This method is used for communally roosting species, particularly waders, many wildfowl, parrots and some passerines.

Method

Many species of birds roost communally either during the night or, among coastal species, at high tide when their feeding grounds are covered. Birds are highly clumped at roosts and thus can be efficiently censused at this time. Many species roost only in the non-breeding season, though some species (e.g. colonial corvids such as the jackdaw *Corvus monedula*) roost during the breeding season as well; in this case males go to roost whilst females incubate.

When roosts are small and easily viewed, birds can be counted at the roost. When they are large or hidden, for example in trees or on rooftops, it is best to count flocks of birds (see ‘Counting flocks’, below) entering or leaving the roost. This is particularly the case at dusk when flocks of birds coming to roost may be visible against the sky, but are invisible once on the ground or in the trees.

For some estuarine species where alternative feeding areas such as salt marsh are available once the mudflats have been covered by the incoming tide, accurate counts can be obtained during very high tides when the sea covers all potential feeding sites. Waders are best counted at high-tide roosts during the 2 h either side of the highest spring tide of the month. If counting over a large area encompassing several roosts, count all roosts simultaneously, since individuals may move between roost sites. Pithon and Dytham (1999) used teams of volunteers to census ring-necked parakeets *Psittacula krameri* using simultaneous counts at all known roosts.

Roosts can be counted only once located. However, since many roost sites are traditional they are often well known. Unknown roost sites can be located by following the flight paths of flocks of birds as dusk, or high tide, approaches. Some coastal species, however, can roost on agricultural land up to 1 km inland.

Advantages and disadvantages

This is by far the easiest way of counting many species that are widely dispersed at other times, and is particularly useful outside the breeding season.

Biases

Some roosts are enormous and contain several million birds (e.g. of starlings *Sturnus vulgaris* and quelea *Quelea quelea*). As when counting flocks (see below), numbers of birds in large roosts are probably underestimated, especially if the species is small.

Counting flocks

This technique is used for flocking species, particularly waders, wildfowl and some passerines.

Method

Where the flock is of no more than a few hundred birds, all can be counted directly from a suitable vantage point through binoculars or a telescope. This is easy with large birds but becomes progressively more difficult with larger numbers and smaller birds at greater distances.

For small flocks, say fewer than 500 birds, count individual birds. With large numbers of birds, or with mobile flocks, however, count in tens, twenties or even greater numbers rather than counting individual birds, and estimate what proportion of the flock each represents. Use landmarks to divide large flocks on the ground into smaller groups. When flocks are particularly dense, try to count them from above if possible. However, take care not to disturb the birds, by keeping at a distance and counting from a concealed location. Try to ensure that the sun is behind you when counting, since this will improve your view of the flock, allowing you to discriminate among species and to make a more accurate census.

Advantages and disadvantages

This method is of most use outside the breeding season. Unlike roosts, the location of flocks is often not traditional and may respond to short-term changes in food resources. Flocks may be composed of several species, so it is necessary to get close enough to ensure that you can count each species separately without disturbing the flock. When searching an area systematically for flocks the data obtained can be markedly non-normal in distribution (e.g. many areas with no birds, and thus zero counts, and a few areas with very large counts); such data can present problems during statistical analyses.

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Biases

Prater (1979) has shown that observers generally overestimate sizes of small flocks (a few hundred birds) and underestimate sizes of large flocks (a few thousand birds), and that there is a high degree of between-observer variability. Rapold *et al*. (1985) also document large observer errors in the estimation of flock sizes. To help overcome this, obtain repeated counts of a flock and, where possible, get others to count the same flock, too, for comparison. Flocks tend to bunch in the centre so that different parts of the flock covering similar areas will not contain the same number of birds.

Counting migrants

This method is used for migrating raptors, storks, pelicans and some passerines.

Method

Diurnal migrants

Several species of large diurnal migrants pass through bottlenecks on their migration routes. Raptors and storks on migration in Europe and the Middle East concentrate at narrow sea crossings, and birds at many of the best-known sites, such as the Straits of Gibraltar and the Bosphorus (Turkey), are routinely counted. During the autumn in North America, many hawks pass through migration funnels along the barrier islands off the coast and over ridgetops in the Appalachians and down through central America. Because these species are often widely dispersed at other times of year, often over huge areas with sparse human populations, counting birds at bottlenecks, particularly when they are limited in number, can be an extremely efficient census method (Meyburg & Chancellor 1994).

Though the most complete counts are made over the entire migration period, 80%–90% of some raptor species pass through a bottleneck during a 2–3-week time window, the dates of which are often well known. Teams of observers position themselves at vantage points (often high ground, with a wide field of view) 6–8 km apart across the breadth of the flyway. The number of teams will depend on the breadth of the flyway, though 6–8 km is about the optimal distance to avoid different teams counting the same birds. Each team should have a few observers, including someone skilled in raptor identification, and another member to take notes. Bildstein & Zalles (1995) give further detail on raptor-counting methods, but essentially this is done by observers methodically scanning the horizon, then moving their binoculars up one field of view, and repeating this several times. The number of gliding birds (not those circling in thermals) passing per hour is counted. It is useful if one observer counts to the north, one to the south and one overhead. Ideally, the teams should communicate with radio transmitters to avoid duplicate counting. Where numbers become too great to count, it may be sensible to photograph the passing flock, project the image onto a screen, and count the dots (Smith 1985). However, this can be slow and the same birds may be duplicated on different images. Well-coordinated raptor counts, repeated from year to year, are used to monitor raptors in North America (Lewis & Gould 2000).

Nocturnal migrant songbirds

A large proportion of migrants travel at night and some nocturnal migrant songbirds call to one another to keep in touch. These contact calls are generally specific to the species, though it is often hard to hear them against a background of other noise. Using sensitive microphones and customised software it is possible to distinguish automatically among species and to count the number of each species passing overhead at night (Evans 1994; Evans & Rosenberg 2000; http://www.birds.cornell.edu/brp). Currently the technology does not count birds that fly above 1000 m and, for monitoring purposes, it assumes that a constant proportion of each species calls as they fly; whether or not this is the case is unknown.

An alternative approach to studying nocturnal migrants is to observe them through a telescope as their silhouettes pass across the Moon's disc at night (Lowery & Newman 1966; Alerstam 1990). With this Moon-watching method, birds within the narrow cone of sky between the observer and the Moon can be seen and counted. Migration intensity can be determined by calculation. Though the method requires cloud-free weather, the smallest songbirds can be detected at a distance of 2 km with a 20 × telescope.

Radar has been used to ascertain migration routes as well as to calculate the size and speed of migrating flocks, though rarely their specific identity. It has even been used to estimate seabird numbers (Burger 1997). Useful summaries of the uses of radar in ornithology are given in Eastwood (1967) and Alerstam (1990); however, since the method requires access to extremely sophisticated equipment it is beyond the reach of most ornithologists.

Advantages and disadvantages

A large proportion of the population of some migrants passes through bottlenecks, thus allowing a cost-efficient method of counting these species. Identification of species can be difficult, particularly for high-flying and nocturnal migrants. Large numbers of well-coordinated personnel are needed to count migrating raptors.

Biases

Weather conditions can cause raptor streams to change position, and thus flight paths can be missed. Differing levels of observer experience can lead to bias through misidentification. Double counting by observers who are spaced out to count over a broad front can lead to overestimates of population size. At mid-day, some raptors may migrate at heights invisible to the naked eye and, in general, the uncertainty over heights at which individual species migrate makes calculations of migration intensity difficult. Some migration bottlenecks may have been overlooked.

Indirect methods of censusing

Indirect methods are used for censusing wildfowl and gamebirds (droppings) and to detect the presence of elusive, nocturnal, ground-living species (footprints).

A variety of indirect methods can be used to detect the presence, and in some cases abundance, of species; two are considered here – measurements of droppings and footprints.

Dropping counts

Method

Determining the distribution of feeding wildfowl can be very time-consuming since they often feed in flocks that frequently move between sites. In some instances, daily observations are needed to determine which sites a flock visits. A simple way of overcoming this is to count the density of droppings at each site (Owen 1971). A single count can give a relative measure, but a much more accurate measure is obtained if plots are cleared on a regular basis.

In order to do this it is first necessary to determine how long the droppings last before they disintegrate and become either indistinguishable one from another, or completely unidentifiable. Fresh droppings can be marked with bamboo stakes and then revisited over a period of days to determine how long they last prior to disintegration. Inevitably, they will disintegrate much more quickly in the rain and when subjected to trampling. Bamboo stakes are then placed at random locations (20 stakes gives a good sample if the species is reasonably common) throughout the feeding site. All droppings within a given radius of each bamboo stake are then removed. The simplest way to measure this radius in the field is to use a length of string tied to the bamboo stake. If a spoon is tied to the other end, it can be used to 'flick' the droppings off the circular plot.

The area is then revisited at an interval such that all droppings produced in the interim period will still be visible, and the numbers present in the set radius around each of the randomly allocated stakes are counted. The mean number of droppings produced per unit area per day can then be calculated from the number of droppings counted, the number of days between clearing and counting, and the area of each circular sample plot. The whole procedure can then be repeated if required.

These data provide only a relative measure of the extent to which various sites are used, though they can be converted to the number of bird-days by estimating the dropping rate of the species. This involves watching an individual bird's bottom for a period of 10 or 15 min. If the bird turns out of sight or the view becomes blocked, switch observations to another individual. Intake rate may vary with position in the flock; thus, to determine a mean dropping rate, observations of birds throughout the flock should be made.

Gamebirds also have persistent and recognisable droppings. This is particularly useful for surveying elusive forest pheasants. Recording the presence/absence of droppings during a timed search and counting the number of droppings found along transects are frequently used methods.

Advantages and disadvantages

This is a very useful way of censusing elusive forest pheasants and determining site usage by wildfowl remotely. Some sites may be visited by several species, and distinguishing among their droppings may be difficult.

Biases

Heavy rain and trampling can cause droppings to disintegrate, which makes counting more difficult.

Footprints and tracking strips

Method

This method has been used to detect the presence of the ground-dwelling Jerdon's courser *Rhinoptilus bitorquatus*. Because it is nocturnal and lives in a densely wooded habitat, the species is very elusive and its presence was detected from footprints left in tracking strips (Jeganathan *et al*. 2002). These tracking strips were 5-m lengths of fine-grained soil about 2 cm deep. Birds that ran across these strips left tracks of footprints, and, to find out which species left which tracks, automatic cameras were placed at the ends of some. By measuring the shape of the footprints, either from casts or photographs, the distinctive tracks of Jerdon's courser were determined, allowing them to be separated from those of several similar species in the area. In areas where the species was known to occur, its tracks were recorded on about one in 30 nights. Calculations suggested that, if a grid of 15 strips were checked for about a month, Jerdon's courser would be very likely to be detected if present.

Advantages and disadvantages

This is a time-consuming method. It requires the preparation of tracking strips and consideration of the best type of substrate for capturing footprints; this may well require trial-and-error assessments of the soil types locally available. It is necessary to distinguish among the tracks of various, sometimes closely related, species with similar tracks. To do this it is important to determine which species left which track and this is best done with automatic cameras, fired when a bird walks across the strip. Inclement weather can destroy tracking strips, as can cattle or sheep, so strips may require frequent checking. It is difficult to estimate numbers of birds rather than their simple presence. The method is, however, non-disruptive – observers are not present when birds are active – and may be the only method to detect the presence of such cryptic species.

Biases

Misidentification of tracks, particularly among closely related species, could lead to errors in detecting whether a species is present or not.

Response to playback

This approach is used for many species that cannot easily be seen or heard in their breeding or non-breeding habitat.

Method

Some species of birds are notoriously difficult to see or hear, but will respond to a recording of their song or call. Examples of such species are those that have a skulking behaviour; those that live in dense habitats at certain times of the year; those that are nocturnal or crepuscular; and those that nest down burrows. Recordings of the songs and calls of many species are now available commercially, and can be copied onto tape or digital media. Ideally, use a tape loop or digital equivalent, so the song will continue to be broadcast until the player is switched off. If you are using tape playback, and a tape loop is not available, start recording at the beginning of the tape, so that it can easily be wound back to the start of the recording. The song can be broadcast from a hand-held loudspeaker or from one mounted on a vehicle. It is often sensible to combine passive recording with playback to increase the chance of detecting birds (frequently half the time is given over to passive recording and half to playback and listening for a response). One problem with the use of playbacks is that some individuals or species may habituate themselves (cease to respond) to the playback if it is used too frequently.

Playback can be used alongside other census methods, for example, during territory mapping or transects. Wotton *et al*. (2002) used tape playback alongside a transect method to increase their chances of detecting ring ouzels, *Turdus torquatus*, in a survey of the population in the British uplands. In this open and rocky terrain ouzels can be surprisingly difficult to detect. Playback accounted for about a third of all territories located, suggesting that it was successful in eliciting responses, but the response rate varied both seasonally and geographically. The new method set a baseline against which future surveys could be compared, but fell short of establishing a full calibration of response rates against known numbers. Similarly, a combination of playback and point-count observations has been proposed as a standard survey protocol for burrowing owls, *Athene cunicularia*, in North America (Haug & Didiuk 1993; Conway & Simon 2003). The method has also proved effective in assessing populations of North American wood warblers (*Parulini*) on their wintering grounds in Central America (Holmes *et al*. 1989; Lynch *et al*. 1985; Sliwa & Sherrry 1992; Graves 1996). At this time of year, although these birds often establish territories, they do so in dense and sometimes remote habitats and can be highly inconspicuous. Playback greatly increases the probability of detecting a species when it is present and, if used in a standardised manner, allows the population to be monitored.

The results from census work involving playback, however, need careful interpretation. If the aim is simply to determine whether a given species is present in an area, then playback may simply increase the chance of finding it, as described above. If, however, the aim is to estimate the population size or to produce a population index, then more care is needed. To generate a reliable population index the probability of birds responding to playback needs to be held constant. This can be helped, for example, by standardising the manner in which the call is played (same volume, recording, playback length, time of day, season, etc.) and ensuring that the call is not played to any one individual too frequently, causing it to habituate and respond less frequently. Playback has been used widely for monitoring populations of marsh birds, owls and raptors (Fuller & Mosher 1981; Mosher *et al*. 1990; Lor & Malecki 2002; Newton *et al.* 2002; Conway 2003). Detailed studies of black rails, *Laterallus jamaicensis*, in North America, however, illustrate some of the difficulties in using this technique to estimate population size and monitor populations (Legare *et al*. 1999; Conway *et al*. 2004). Response to playback varies with the sex of the bird, month, year and temperature (Legare *et al*. 1999) and yet vocal surveys provide the only practical way to census these birds and standardised procedures have been proposed for monitoring purposes (Conway *et al*. 2004).

Estimating absolute population size from playback is more complex because the probability of the average bird in the population responding to playback needs to be estimated. Detailed additional work will often be required to learn more about when and where birds will response and at what rates. The most recent census of seabirds in Britain and Ireland, for example, relied heavily on tape playback for three species of burrow-nesting procellariformes: storm petrels, *Hydrobates pelagicus*; Leach's petrels, *Oceanodroma leucorhoa*; and Manx shearwater, *Puffinus puffinus* (Mitchell *et al*. 2004). Additional calibration work was undertaken to estimate the response rate, which can vary between the sexes, within and among colonies, and even across years (Ratcliffe *et al*. 1998; Mitchell *et al*. 2004).

Advantages and disadvantages

Skulking, secretive and nocturnal species that would otherwise be overlooked can be located and population indices or population estimates produced. Careful and highly standardised use of playback is essential. Great attention needs to be paid to survey protocols and the methods need to be published in full to allow others to replicate them in the future and make comparisons. Some species and individuals may rapidly habituate themselves to playback. Variation in response rate needs careful assessment and will often require research that is more intensive.

Biases

Care should be taken to ensure that playbacks are broadcast for set durations, at a standard volume and under set conditions (e.g. time of day, weather), otherwise responses will vary. Ensure that the precise use of playbacks is noted, otherwise it may be impossible to repeat the survey. This has particularly been the case when playback has been used with constant-effort mist netting; sometimes tapes have been used, sometimes not, and use has often gone unrecorded. Such variation makes comparison of the results very difficult.

Vocal individuality

This approach is used for rare species that are difficult to see or capture in their preferred habitats.

Method

The songs and calls of many bird species are individually unique and often identifiable, if not by ear, then from a sonogram analysis, allowing them to be used for monitoring (Saunders & Wooller 1988). Sound recordings of birds are widely available, for example, from the British Library's sound archive (http://www.bl.uk/collections/sound-archive/wild.html), or from similar sources, and constitute a highly useful resource. Acoustically distinct calls of this kind have considerable potential in monitoring and conservation, particularly for birds that occur in dense vegetation or are otherwise difficult to observe, but this potential has not always been realised (McGregor *et al.* 2000). The method involves recording songs or calls with a directional microphone and examining sound spectrograms using freely available software. Spectrograms from an individual bird are often recognisable by eye and discrimination can be formalised using statistical techniques. The songs or calls of individuals are recorded onto tape or digital medium, preferably with a directional microphone, and sound spectrograms produced using readily available computer software such as RAVEN (http://www.birds.cornell.edu/brp/raven/Raven.html). The spectrograms of individuals can then be visually separated, either by a panel of observers or by the more time-consuming, but more rigorous, approach of measuring the duration and frequency of each component of the spectrogram, and using discriminant function analysis to distinguish among individuals (Gilbert *et al.* 1994).

Work on European bitterns, *Botaurus stellaris*, denizens of dense reed-beds, has shown that their booming calls are individually distinct. This has allowed their numbers to be tracked precisely and year-to-year survival to be estimated (Gilbert *et al.* 2002). Knowledge gained using this method greatly increased the researchers' understanding of bittern behaviour and it is hard to see how this could have been achieved using other methods. In a study of the corncrake, *Crex crex*, which is highly cryptic, and calls from rank and dense habitat mainly at night, information gained from vocalisations increased census estimates in some areas by 20%–30% (Peake & McGregor 2001). This study also showed that males called less frequently than had previously been thought. The churring call of the male European nightjar *Caprimulgus europaeus*, a mainly nocturnal and mobile species, has also been shown to differ among individuals (Rebbeck *et al.* 2001). The pulse rate of calls and the phase lengths together allow the identification of the great majority of males. Interestingly, males were shown to move some distance within a breeding season, but they returned to the same territory year after year. In each case, quantitative rules were developed to help discriminate one bird from another, but this is not always straightforward and, in some cases, ambiguity remains. One can also apply capture–mark–recapture methods to resightings based on vocalisations to estimate population size. In contrast to the successful studies described above, while the calls of black-throated diver, *Gavia arctica*, were found to be distinct, their calls proved to be too infrequent and too difficult to record to make the method viable (McGregor *et al.* 2000).

Advantages and disadvantages

This is sometimes the only possible method and produces minimal disturbance. It is often advisable to pilot the method before embarking on a full study because there is no guarantee that it will work in all situations. It is non-intrusive; this might be particularly useful in studying rare and endangered species. The disadvantages are that it requires a good deal of hard work to collect high-quality recording of birds that often live at low densities across widely scattered sites and to analyse and distinguish among calls. Ideally, one also needs an independent means of identification, such as marking or radio tracking, to corroborate the findings. It requires specialist and quite expensive equipment; it often only tells us about breeding males; and it can be very time-consuming unless the analysis is automated (Rebbeck *et al*. 2001). For some species, the calls of individuals may vary between years, even though they are consistent within years.

Biases

Only calling or singing birds (mostly males) can be censused by this method. Females, immature males, non-breeding males and possibly males at low densities may well be missed since they may vocalise less frequently.

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