Seabird monitoring handbook for Britain and Ireland

A compilation of methods for survey and monitoring of breeding seabirds

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J.J.D. Greenwood	overall text
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S. Murray	gannet
I.C.T. Nisbet	terns
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R.M. Sellers	cormorant
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S. Wanless	gannet, shag

Future updates

Revised texts for individual species or species-groups may be published in future if substantial improvements in methodology become available. Any revised versions will be notified in the annual report on *Seabird numbers and breeding success in Britain and Ireland*, and in the Seabird Group Newsletter. Methods for storm petrel *Hydrobates pelagicus* and Leach's petrel *Oceanodroma leucorhoa* are in preparation.

Copyright waiver

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Introduction

This handbook attempts to summarise current seabird counting and monitoring techniques, relevant to British and Irish colonies, in a single source. The layout is intended to be suitable for use in the field, presenting step-by-step procedures for each species for censusing/monitoring populations and for assessing productivity (chicks fledged per breeding pair).

Techniques for counting and monitoring breeding seabirds have advanced considerably in the last twenty years. In 1969-70, the Seabird Group's *Operation Seafarer* survey was the first attempt to count and catalogue the coastal seabird populations of the whole of Britain and Ireland (Cramp *et al.* 1974). Attention was drawn at the time to shortcomings in the methods available for some species. Subsequently, much effort has gone into developing census and monitoring methods further, with the result that for most species practical and reasonably accurate techniques are now available (e.g. Birkhead & Nettleship 1980; Evans 1980; Harris 1989a; Lloyd *et al.* 1991). Some methods have, as yet, failed to transfer into general field use. For many species a range of methods or census units, which give results not always easily comparable, have been employed at different colonies.

Here, we have aimed to summarise methods of use to reserve wardens, volunteer fieldworkers and others wishing to collect basic information on breeding numbers, population changes, and breeding success. The information obtainable using the methods described is intended to be appropriate and sufficiently accurate for general conservation monitoring purposes. By this, we mean that the statutory and other conservation organisations should be able to use the results in:
a) identifying the most important concentrations of breeding seabirds (and justifying their protection under law if necessary);
b) estimating national or regional populations of breeding seabirds, in order to place individual colonies in context;
c) assessing whether or not local, regional or national populations of breeding seabirds show any important changes in either the short term or the long term;
d) assessing geographical or temporal changes in basic breeding success;
e) looking at the relationships between breeding success, population size, and the results of other studies of population or environmental parameters (e.g. seabird survival rates, seabird diet, predation, fish stocks), to assess, for example, why seabird numbers have changed, how might they change in future, or what factors influence breeding success.

The methods included are not aimed at researchers wishing to carry out highly specialised studies requiring highly accurate results, and there usually is a degree of compromise between accuracy and practicality. Throughout the manual, the emphasis is on *practical* methods, and we have omitted some methods which (though highly accurate) are too labour-intensive or time-consuming for general monitoring use. For some 'difficult' species or colony-types (e.g. burrow-nesting puffins), the methods described are necessarily rather detailed. For some species, several alternative methods are described, to allow for different circumstances (e.g. time available).

The organisations involved in producing this manual are all interested in collating information on breeding numbers, trends, and breeding success of British and Irish seabirds. Whole-colony counts, in particular, are collated for the Seabird Colony Register, a computer database currently maintained by JNCC and the Seabird Group, and for the RSPB's tern database. Further details of the Seabird Colony Register are given in *Appendix 2.* Virtually all coastal seabird colonies in Britain and Ireland were counted during 1985-87 (Lloyd *et al.* 1991), and regular counts continue at many of these colonies. Since 1989, an annual report summarising breeding success and population changes for coastal seabirds has been produced by JNCC, RSPB, and the Shetland Oil Terminal Environmental Advisory Group (Walsh *et al.* 1990-94). Much of the census or monitoring work is carried out by these organisations, or funded through external contracts. We are also very dependent, however, on the good efforts of many other organisations, including the statutory nature conservation agencies in Britain (Scottish Natural Heritage, English Nature, and the Countryside Council for Wales), other conservation and research bodies, and a network of volunteer counters. Through this manual, we would like to maximise the usefulness of the results obtained from all these sources, for the benefit of seabird conservation in these islands.

We hope that fieldworkers will find this a clear and practical guide. It is likely to be upgraded periodically to keep pace with developments in technique, and updates are likely to be provided for individual species. When sending results of counts or monitoring to JNCC and RSPB, or at any other time, please feel free to comment on and suggest improvements to any aspect of the handbook, from layout to the practicality of the various techniques.

Format of the handbook

Some general issues are discussed under the introductory headings below, and some general guidance on sampling and census methods is given in the next main section (*General methods*). These may assist with planning of monitoring activities. Further background on methods for individual species or species-groups is given in the relevant species sections, followed by step-by-step outlines of each recommended method.

In conjunction with the relevant species sections, we strongly recommend that users of this handbook read the sub-sections on *Licensing of certain activities* and *Safety,* the section on *General methods* (sample plots and randomisation; general techniques for counting cliff colonies), and *Appendix 2* (Seabird Colony Register). A guide to some of the terminology used is given in *Appendix 1*.

Scope of the handbook

The methods presented here deal only with assessment of population sizes, population changes, and the numbers of chicks produced by breeding pairs.

It is also important to monitor other population parameters such as adult survival rates, diet, rate of food-delivery to chicks, or growth-rates of chicks. Such work is funded by JNCC, RSPB, and others at a limited number of geographically dispersed colonies. The methods required for monitoring survival rates, in particular, are too labour-intensive for widespread use. A future edition of this handbook may cover such methods. In the meantime, guidance on relevant methods is available from the compilers.

Time-scales for monitoring

For seabirds, it is important to have counts or estimates for both local and wider populations as baselines from which to measure change, or from which to identify important breeding areas for site-conservation. It is worth emphasising that an accurate count, or good estimate, of a colony is always worth attempting, even if there is little prospect of a repeat count in the near future. Where resources are limited, it may be necessary to decide whether it is more important to do a one-off count of a colony or to re-count a colony that can be visited more regularly. The decision taken will depend on such factors as the relative importance of the colonies, likely threats to a colony (perhaps requiring up to date counts to justify protection), or time since previous counts. Further guidance on priorities may also be sought from the compilers of this handbook.

A very rapid survey of a colony may allow little more than an assessment of the order of magnitude of the colony (e.g. 1-10 pairs, 100-1000 pairs). For some species (notably shearwaters and petrels), even this may prove difficult and there may be no easy way to estimate numbers more precisely. A rapid assessment of colony size may provide some basis for deciding whether a more detailed count should be a priority.

Large-scale, infrequent surveys (e.g. counts of seabirds on the entire coast of Britain and Ireland in 1969-70 and 1985-88, summarised by Lloyd *et al.* 1991) inevitably include some colony counts of low precision. Nevertheless, major long-term changes (or regional variations in direction or degree of change) may be revealed. For example, many gannet colonies are remote, large, and difficult to count, and counts at intervals of 10 years have been the only practical method of monitoring the gannet population as a whole. This has nevertheless documented a widespread and continuing increase in numbers this century. However, more accurate detection of the timing, magnitude, and direction of population changes requires more frequent, and more precise, counts of a sample of the population.

For widespread monitoring of some species or colonies (e.g. gannets, shearwaters, petrels) counts every 5-10 years are probably a realistic target to aim for under present circumstances. Individual colonies may be counted more often (we suggest every 1-5 years), depending on availability of suitable methods, fieldworkers, and other logistic support. For other species, annual counts are optimal, at least on a local or sample scale. Most existing schemes operate at one- to three-yearly intervals. The danger of infrequent counts is that trends in the intervening period are not clear, and major declines might not be detected for many years. However, less frequent counts can be useful in allowing coverage of a larger study-area, for example through coverage of different colonies or regions every second or third year, if resources are limited.

One of the reasons for monitoring seabird breeding success is to detect or reflect changes in environmental conditions that might not be revealed by population monitoring alone (or not until too late). Productivity monitoring is also important for building population models, which are important in understanding the causes and mechanisms of population change, predicting future changes, and attempting to reverse adverse changes. It is important to assess productivity each year if possible. Less frequent assessments are much less useful, except in that they contribute to our understanding of the normal range of variation.

Geographical scales for monitoring

The methods outlined in this manual are appropriate to designing and implementing monitoring schemes for given colonies, lengths of coastline, or defined regions. They do not deal explicitly with the design of monitoring schemes on a wider scale, for example covering Britain as a whole. When wider schemes are being established, techniques of random selection of sampling locations are still appropriate (see *General methods*), if statistically representative samples are sought. In practice, however, wider sampling must usually build on sampling locations already in place, or on the availability of fieldworkers.

Within a given colony, region, or other defined area or coastline, where comprehensive, wide-scale monitoring or survey is not possible, consideration should always be given to obtaining a representative sample of the population.

For colonies or species for which accurate or frequent complete counts are not practicable, counts of sample plots may be seen as having two distinct aims: (i) detection and quantification of population changes in 'representative' samples; or (ii) extrapolation from sample counts to whole-colony estimates. In practice, some sampling schemes are used to achieve both aims, particularly for burrow-nesting seabirds where direct counts of whole colonies are rarely possible. For cliff-nesting seabirds, sample counts are generally used only for assessment of rates of population change, while whole-colony figures are derived from cruder or less frequent counts.

For species such as guillemot and razorbill, detailed monitoring of population changes requires replicated counts within each count-year. The time required to replicate counts usually means that only sample plots of these species can be monitored. For species not requiring 5-10 repeat counts in a given year (e.g. shag, kittiwake), more time may be available to survey long stretches of coast, the resulting counts providing the basis for population monitoring.

See *General methods* for further details on the use of sample plots.

Recommended dates for counting particular species

Optimum periods (usually a range of several weeks) for counts are suggested under the relevant species headings. These suggestions are derived from a combination of detailed studies of individual species, and general experience gained from survey work in recent decades. Much relevant information is summarised by Cramp *et al*. 1974, Cramp & Simmons 1977, Cramp 1983, 1985, and Lloyd *et al*. 1991.

For most species, however, little detailed information is readily available on geographical variation in the average timing of the breeding season within Britain and Ireland. (Changes from year to year can also occur, and are mentioned for some species.) Latitudinal variation might be expected in some cases, with populations in the south of England breeding earlier than in the north of Scotland, but cannot be assumed. In the methods for a few species, we try to make some allowance for latitudinal variation.

The species that show most evidence of geographical variation in timing of breeding within these islands appear to be cormorant, shag, some of the large gulls (especially great black-backed), and puffin. Most of these species *tend* to breed earlier in the south of their British and Irish range, sometimes differing by one or several weeks from those in northern Scotland. Both cormorants and shags also show marked annual changes in timing, however, and cormorants can show very local variation in timing of breeding.

In general, the ranges of dates recommended should allow useful information to be collected during wide-scale surveys. For many species, recommendations on the timing of counts derive largely from work at Scottish colonies (which hold the bulk of Britain's seabirds). Where more detailed population monitoring is to be undertaken in a particular region, particularly in southern Britain or Ireland, it is advisable to investigate the local timing of breeding.

The compilers of this handbook would appreciate being sent any relevant information on timing of breeding seasons.

Statistics

The methods described often require the calculation of means, standard errors, and/or standard deviations, if results are to be presented in a standard way in reports or if assessments of the statistical significance of differences or trends are needed. A scientific calculator is very useful for basic calculations, while various statistical packages available on computer allow more detailed or rapid calculations.

However, we strongly recommend that raw data are always provided when results are submitted, for example to JNCC or RSPB. This allows someone else to do the calculations if necessary, or to check yours if you are uncertain. Having the raw data available may also be important if further, more detailed, analyses are required.

For those interested in understanding statistical thinking and concepts further, Rowntree (1981) is an excellent and well-written non-mathematical introduction. Other useful references include Bailey (1981) and Fowler & Cohen (1986). We have provided some basic information below.

Mean, standard deviation, standard error, and confidence limits

Standard deviation (SD) is a measure of the variability shown by a set of data, for example counts of guillemots in a study-plot in a particular year. It describes how tightly results from different plots or different counts are grouped around the *mean*. If all values are very similar to the mean for the population, the standard deviation will be low; if individual values are highly variable, the standard deviation will be high.

Standard error (SE), properly termed the standard error of the mean, is a measure of the chance that the mean of a particular sample will be much bigger or smaller than the mean of the whole population. Standard error is calculated by dividing the standard deviation by the square root of the sample size (e.g. number of counts). In effect, the standard error indicates what degree of trust we can place in the sample mean. For example, a low standard deviation, based on counts of a study-plot on five separate days in June, might suggest that there was little daily variation in guillemot numbers in that plot. The same standard deviation, derived from ten counts (thus a smaller sample error), would be a more reliable indication that variability was low. The standard error can be used to place confidence limits on the mean.

Licensing of certain activities

All seabird species in Britain and Ireland are subject to general protection against disturbance at the nest. Where relevant, observers should ensure that they hold relevant general licences (e.g. ringing permits). In addition, several seabird species are subject to stronger protection (under respective British and Irish wildlife acts): Leach's petrel, roseate tern, little tern, and (in Ireland) Sandwich tern. (Very scarce or irregular breeders, including Mediterranean gull *Larus melanocephalus*, little gull *L. minutus*, and black tern *Chlidonias niger*, are also subject to special protection.)

For these 'scheduled' species, disturbance at the nest (including handling or close observation of nest contents or chicks) must be licensed by the appropriate authority: Scottish Natural Heritage, Countryside Council for Wales, English Nature, the Department of the Environment for Northern Ireland, or, in the Republic of Ireland, the National Parks and Wildlife Service.

Safety

General

Seabirds often breed in remote locations, frequently on cliffs or offshore islands. Several fieldworkers have been injured or killed in recent decades, in the UK and elsewhere, while engaged in work at seabird colonies. We have no wish to add to their number. *The safety of observers is of paramount importance, and may require deviations from ideal best practice.*

Most safety rules are common sense. If in doubt as to the safety of a particular action, always err on the side of caution. In particular, avoid choosing study-plots that cannot be observed from a safe vantage point and avoid entering areas of the colony where the ground crumbles underfoot, particularly near cliff edges. Be aware that some vantage points may become unsafe during windier conditions or if the ground is wet.

If working alone, leave a detailed note with someone regarding your intended movements, including planned start and finishing times. Wear boots or other stout footwear with a good tread on the sole, although walking on wet rocks or vegetation may still be dangerous. Particularly care is needed if working in a shearwater or petrel colony at night. If cliff descent is essential (which is rare), *obtain appropriate training* in use of a rope and other safety equipment and *never climb alone*. Careful judgement is required where a vantage point can only be reached by descending a grassy or other slope; a safety rope, and other precautions, may be needed.

Wear (or carry) adequate clothing to protect against cold and wet. Inclement conditions produce poor quality records anyway, so if the weather is bad it is usually best to stop work and wait for better conditions. This applies even more so if fieldwork involves disturbing seabirds at their nest-sites. At the other extreme, ensure you are protected against prolonged exposure to the sun.

Boats

The main risks are exposure and falling overboard. The boat itself should be operated by an experienced, trained boat-handler, and *single-handed counts from a boat should never be attempted*. Preferably, have a minimum of three people: boatman, counter, and an extra recorder. Life jackets should be worn at all times, with suitable waterproofs and clothing to protect against cold and wet. Take safety flares, a compass, ropes, and any other equipment potentially of use in an emergency. There is little point in trying to make counts other than in calm weather, but if caught in rough seas a safety line connecting each passenger to the boat (as short a length as practical) is advisable. Leave word of your route and when you expect to return.

Lyme disease

The common seabird tick, *Ixodes uriae,* has recently been found to carry Lyme disease (Olsen *et al.* 1993), and may be encountered by fieldworkers at colonies. Other tick species in Britain are already well known to harbour the disease, and may occur in cliff-top vegetation. We urge fieldworkers to pay serious attention to the risk of infection.

In the UK, Lyme disease was identified only recently. Many doctors are not experienced at diagnosing the condition. It is thought to take some time (possibly 24 hours) for the pathogen to transfer from tick to host, so, if bitten, remove the tick with care as soon as possible. (The mouth-parts may remain, but it is better to risk this than the disease.) If, later, you get flu-like symptoms (usually but not always preceded by a red, ring-shaped rash around the bite), *it is important that you get medical attention.*
Without such treatment, *severe* symptoms may follow.

General methods

Sample plots and randomisation

The size of many seabird colonies, and sometimes the geographical spread of species breeding in small, scattered groups, often makes counting or monitoring all birds or breeding attempts impractical. The usual approach to this problem is to study a sample of the colony or colonies, and to use results from this sample to infer, for example, how the population of a species in the colony as a whole is changing, or how successfully birds are breeding in the colony. Estimates of numbers in sample areas can also be extrapolated to provide an estimate of numbers for the whole colony , provided good information on colony area is available. In the case of colonies on cliffs, sample plots have mainly been used for statistical assessment of breeding output and of detailed population changes. Whole-colony estimates for cliff colonies are usually best derived from less frequent, complete counts (despite problems of accuracy). Estimating colony size based on sample plots is most useful for 'ground' or 'slope' colonies, where whole-colony counts would be impossible or very time-consuming.

The techniques for assessing breeding success described in this handbook often involve mapping or marking of individual nest-sites, and thus are generally applied to sample plots within seabird colonies. The main exceptions to this are methods used for terns, which often breed in small colonies and for which, in practice, whole-colony assessments of breeding output are generally made.

The pattern of sampling

Sample plots for seabird work have generally, in the past, been selected *haphazardly* or for the *convenience* with which birds can be observed or the sites visited. This has serious drawbacks. Virtually all detailed studies of seabirds have shown marked differences in density and breeding productivity between different parts of the colony. Non-random sampling is likely to bias plot selection so that the sample does not reflect the population as a whole, as 'convenient' plots may be at the edge of the colony, where breeding density is often low. Constraints imposed by the need for safety, both of the observer and of breeding seabirds, cannot be avoided, however.

Randomisation of plot selection, which can be used to select areas of a colony, whole colonies from an area, or sections of coastline, is a valid technique for obtaining an unbiased, statistically representative sample of a population.

Ideally, all birds or breeding sites in the colony should have an equal probability of inclusion within a sample plot/quadrat. In practice, some may have to be excluded. Reasons for exclusion include safety considerations, excessive disturbance to the birds, and areas that are poorly visible (on cliffs) or otherwise difficult to study (e.g. some boulder / scree areas at 'ground' colonies). Although this compromises strict randomness, any effect is usually negligible so long as most areas of the colony are included in the potential sample of plots. Once potential plots have been identified, the crucial point is to select study-plots by non-subjective means.

A disadvantage of fully random sampling is that the resultant plots or quadrat positions may be clumped (and two or more plots may abut each other) while other parts of the colony may be under-represented. One solution to this is to use instead *stratified random sampling*, which many ecologists and statisticians consider to be the best sampling technique for ecological studies (Southwood 1978). The technique can involve dividing a study area (e.g. a colony) into either a number of sections or areas of equal size, and randomly selecting a fixed number of plots or quadrat positions inside each subdivision. Alternatively, a colony is divided into different areas (possibly of unequal size) on the basis of habitat or known differences in density of breeding birds. Within each area, plots or quadrat positions are then selected randomly, the number of plots being proportional to the size of area. The latter approach is used in counting burrow-nesting puffins on Dun, St Kilda (Harris & Rothery 1988).

Stratified random sampling improves the precision of sample results, by treating each defined area of the colony as if it is a separate colony, before the results are combined. This is of particular advantage in cases where density varies markedly, as in the case of some puffin colonies (cf. section on *puffin methods*).

Another approach is to use *systematic sampling* of a colony, whereby study-plots or quadrats are placed at fixed, regular intervals throughout a colony, usually of ground-nesting or burrow-nesting species (e.g. Anker-Nilssen & Rostad 1993). In this technique, plots / quadrats may be placed, for example, either along transect lines criss-crossing (or radiating from the centre of) a colony, or the colony is divided into grid-squares of equal size, with plots positioned at the centre-points of the squares. (Preferably, the origin or starting point, from which fixed positions are measured, would be chosen randomly.) Opinions vary as to whether or not the resulting data can be analysed statistically. For plots positioned at the centre-points of a regular grid-pattern, Milne (1959) found that, if data were analysed as if they were derived from random positions, the resulting statistics were "at least as good, if not rather better" than those drawn from random samples. For burrowing seabirds, Savard & Smith (1985) found that burrow density in systematically placed quadrats was less variable than in randomly placed quadrats, i.e. the precision of results was higher. Other advantages of systematic sampling are that is easier and quicker to carry out than random selecting, and that it can provide information on
colony-extent at the same time as nest- or burrow-densities are being assessed (e.g. Anker-Nilssen & Rostad 1993; Tasker *et al.* 1988).

A theoretical disadvantage of a systematic pattern of sampling is that if a seabird species is already distributed in a systematic or 'regular' pattern throughout a colony, the two patterns might happen to coincide and, for example, sample areas might coincide mainly with regularly spaced low-density areas. Such a pattern might be obvious already, or become so when the data are analysed (Milne 1959), but there remains a danger that an unrecognised systematic pattern might bias the data in a more subtle way.

Figures 1-4 present simplified examples of random, stratified random and systematic placing of study plots.

Techniques for selecting plots at random

Depending on the type of colony (see *Situation of plot* below), plots can be selected from among either predefined potential plots (e.g. of sections of cliff: *Figure 4*) or from quadrat or transect positions marked on a map grid (*Figure 3*). Avoid biased attempts at randomisation, like sticking pins in a map or picking positions mentally 'at random'.

The most convenient way to select from predefined potential plots is to number each, and then select random plots using a table of random numbers or the random number function available on some calculators (see *Figures 1-2*), or by drawing the numbers from a hat.

For colonies on flat ground or slopes, superimpose a grid onto a map of the colony extent. Number the individual grid-squares or transects. Transects or grid-squares can then be chosen as for predefined plots (above). If quadrats are to be used, each grid-square should preferably be of similar dimensions, to ensure that each potential quadrat-position has an equal chance of being selected. For example, if circular quadrats are used, grid-squares on the map should have sides equivalent to twice the radius of a quadrat (see *Figure 3*). If transects are to be used, divide the mapped areas into long strips each the width of one transect (*Figure 3*).

The crucial factor is that every suitable plot, transect or quadrat position on a map or grid should have an equal chance of selection under the procedure set up, and the subjective biases of the observer should be eliminated as far as possible. Human minds are not capable of randomness, perhaps especially when they are attempting to achieve it! Your result may not 'look' random, but so long as the method is not biased, do not be fooled. Whatever you do, don't 'adjust' the results!

Always document how you selected and positioned plots. If in any doubt about what to do, ask advice. It is better to delay the start of a monitoring scheme, and get it right, than to discover flaws in the design of the scheme some years later.

When selecting plots randomly, it is always useful to select a few extra plots just in case (and retain details for future reference). Then, if one of the selected plots is found to be unusable, it can be replaced by the next randomly selected plot in sequence, to maintain adequate sample sizes.

Once a random sampling scheme has been established, it is possible to compensate for major expansion of breeding seabirds beyond the previously defined boundaries of a colony. Without such compensation, rates of population change detected by existing plots may no longer be valid. In such cases, a suitable approach would be to treat the 'new' breeding area as a separate subcolony and to allocate sample plots in proportion to its relative area (stratified random sampling). For example, if the area occupied by breeding puffins is found to have increased by 20% after several years, increase the total number of plots by 20% through random positioning within the new 'subcolony'.

For productivity monitoring, if the number of pairs breeding in a plot falls below a useful size, further plots may be needed to maintain sample sizes in the colony as a whole. Provided that some attempt is made to assess productivity of a representative sample of a colony, preferably by random or systematic positioning of plots, it is not strictly necessary to retain precisely the same plots and boundaries from year to year. Different random selections of plots in different years should, in theory, provide equally valid estimates of average breeding success in a colony. In practice, retaining the same plots (perhaps with slight adjustments) usually proves convenient, and may improve the precision with which changes in breeding success are detected.

In the same way, sample plots used to determine *densities* of breeding seabirds in a proportion of the colony, for example for extrapolation to a whole-colony estimate, need not be retained between surveys, provided that they have been selected randomly or are otherwise considered representative of the colony. Where plots are being used to quantify population *changes*, however, retention of the same plots allows more precise assessment of changes from year to year (e.g. Harris & Rothery 1988). Study-plots used for population monitoring at cliff colonies form a special case, as the primary aim is usually detection and quantification of change (rather than density-estimation and extrapolation). For such plots, comparisons between one year and the next must be based on *precisely* the same plots, with the same boundaries. Over a period of years, however, the number or boundaries of plots can be gradually changed, provided that precisely the same plots are used in comparisons between consecutive years.

Situation of plot: flat ground or slopes

For colonies on flat ground or slopes, quadrats of a standard area are best selected by random or systematic positioning on a map grid (*Figure 3*). To do this, the first step is to determine the extent of the breeding area as accurately as possible, and to sketch this onto an existing Ordnance Survey map or (less accurately) a map drawn in the field (with measured distances). A similar approach can also be taken to positioning of transects (*Figure 3*). Where the colony is divided obviously into areas of markedly different density, often associated with differences in vegetation or substrate, greater accuracy is obtained by treating each area as if as a separate subcolony (*stratified random sampling*: see above and *Figure 3*).

Situation of plot: cliffs

Plots on *cliffs* should be selected, so far as possible, as relatively discrete groups of birds or nests, occupying a section of cliff that can be defined precisely without reference to the birds or nests. Ledges, cracks, and fissures in rocks, or other natural features that can be used to mark boundaries, are best. In practice, many groups of nests or birds will have to be divided along some arbitrary (but consistent) line to produce plots of an appropriate size. In some plots, sections of the boundary will have to follow imaginary lines between two landscape features, although this should be avoided where possible. Plot boundaries should not go across or through a ledge that holds guillemots, unless there is some feature such as a wide fissure or obstacle to prevent birds moving back and forth along the ledge (Jones 1978). On cliffs, all potential plots should be defined (relatively roughly) in advance, then the actual study-plots selected (*Figure 4*). Again, random, stratified random or systematic positioning are preferable to haphazard positioning. In the case of a cliff colony, it may be convenient to stratify (subdivide) the colony into similar lengths of cliffs, or into stretches holding similar numbers of birds.

Additional guidelines for cliff colonies (from Jones 1979, and Birkhead & Nettleship 1980), which should be followed in identifying suitable plots from which to choose, include:

a) The position from which a plot is viewed should be safe (and acceptable as such to other observers), even in wet or moderately windy conditions.
b) The count position should not be so close to the plot as to cause disturbance (interfering with breeding success and with the count), e.g. when the observer appears on the skyline.
b) Individual birds or nests (as relevant to the species) should be easily distinguishable using binoculars or, if necessary, a telescope (cf. section on *General techniques*).

c) The angle at which a plot can be viewed should be as near a right angle as is possible; if the angle of view is too small, e.g. looking up or along at a plot, birds or nests are likely to be hidden by cliff-features or by each other (*Figure 5*).

If the plot is selected for monitoring, the boundary must be *precisely* delineated. Much the best way to do this is to photograph the plot in good light, and, using a transparent overlay or writing directly onto a large print, draw the exact boundary very carefully, as a fine dark line. Do not simply circumscribe birds or nests by drawing a line around them, as, if a plot is 'full', further expansion may not be detected. Where possible, draw boundaries that allow room for expansion, by including some unoccupied habitat. The defined boundary should be strictly adhered to from then on. An accurate and detailed sketch map may also be used, but is much more prone to misinterpretation and ambiguities. Especially for productivity monitoring, prints should be large (A4 size). Black-&-white photographs are generally preferable to colour.

To maintain plot sizes at cliff colonies within acceptable limits (for ease of checking), it is perfectly allowable to split a cliff-face into several smaller sections, each treated as a separate potential plot. When plots are selected randomly, it may well happen that several of the plots will be contiguous, with some common borders. Since each has been selected randomly, such plots should continue to be treated as separate plots for statistical purposes.

Number and size of plots

The *number and size of plots* involve trade-offs between statistical efficiency and practicality. The larger the number of plots and the larger their size (other things being equal), the better the sample is likely to be statistically as a reflection of the total population. More, smaller plots are preferable to fewer, larger ones. Above a certain population size or density, a given plot may take a disproportionately long time to count and become more prone to inaccuracy. Too many plots (and perhaps counting positions) may reduce the time available for other monitoring. However, the larger the proportion of a colony covered, the greater the chance of results being representative of the whole population. Always record what proportion of (a) the total and (b) the 'monitorable' population is present in the sample.

Individual species accounts suggest the optimal size, type, and numbers of plots for each. For example, population plots of 100-500 individual guillemots can be found easily in most colonies, whereas smaller plot-totals are usually appropriate for razorbills.

In practice, when plots are initially established, occupied parts of colonies on cliffs are often divided into potential plots of unequal size, depending on the density of birds. For example, a small area of cliff with high numbers of birds may need to be divided into several manageable plots (using definable features of the cliff-face), whereas a large cliff-face with few birds may be treated as a single plot (provided it can be counted accurately as a whole). There is no easy solution to the problem of dense masses of birds (particularly guillemot) which cannot be split into manageable groups for accurate counting. Such parts of the colony may have to be excluded from detailed monitoring

In some very large colonies, it can be very time-consuming or impracticable to divide all the visible areas into potential plots, before selecting plots using the fully randomised method. In such a case, stratified random sampling (see *The pattern of sampling* above) becomes particularly useful: divide the colony into a number of larger areas (whole cliff-faces, stacks, etc.), roughly equal in extent, and select a certain number of plots randomly from within each of the larger areas.

Ideally, when plots are being selected at a colony for population monitoring, *all* parts of the colony with suitable habitat, whether or not breeding seabirds are present, should be included in the pool of potential plots. Thus, for example, fifteen plots selected randomly from a length of cliff might comprise ten plots with moderate or large numbers of guillemots, two plots with very few guillemots and three plots with none. If the sample size provided by occupied plots is considered too small, random selection of plots continues until an adequate sample total is reached.

In practice, this approach has not been taken at any British colonies. There are several difficulties that may be encountered, such as how to decide what is a suitable size for an empty plot. Assessing the potential suitability of a portion of habitat for a species may also be subjective. The presence of other species may provide clues, but a cliff with breeding fulmars will not necessarily be suitable for guillemots and a section of cliff devoid of any seabirds does not necessarily mean that suitable ledges are not present. A further potential problem is that, if the area occupied by a species were to expand markedly, a formerly empty plot might end up holding too many birds to count accurately in the time available. However, it is worth considering inclusion of 'empty' (and certainly low-density) areas when establishing schemes based on sample plots. The alternative, currently used in many schemes, is to map and count whole colonies periodically; this may detect, but not adequately quantify, colony expansion.

Documenting the positions and boundaries of plots

Precise documentation of the positions and boundaries is particularly important for plots where population changes are to be measured.

In the case of population-monitoring plots on *cliffs*, it is critical that viewing angles and boundaries are precisely the same on each date and in each year. Less care may be needed if plots are to be used only for monitoring of productivity, although it is still important that angles of view remain constant in any one year, to avoid missing particular nests or chicks on some dates. As described earlier (*Situation of plots*), precise boundaries of cliff plots should be marked on black-&-white photographs. Colour photographs are generally less useful, but can be helpful for some colonies (e.g. where parts of the cliff-face are vegetated).

Count-positions on cliff-tops should be marked, as accurately as possible, onto Ordnance Survey or other good maps of the coastline. Plots should be photographed from several angles with an observer (or telescope and tripod) in place. Preferably, the position itself should also be physically marked using a stake or a mark painted or etched on rock. If plots are used for productivity monitoring only, based on individually mapped nest-sites, it is less critical that precisely the same viewing position be used each year. However, within a given year it is usually important to ensure that the same viewing position is used on different dates, to avoid confusion between adjacent nest-sites (some of which may be hidden from some angles).

It is important also to document the locations of cliff plots on large-scale maps, to aid location of the plots by different observers. This applies equally to plots used for monitoring of populations and those used for monitoring breeding success. Photographs of plot boundaries will show the plot as viewed from count position, providing a further check if an observer is uncertain of the correct position. A more general photographic view, showing the location of each plot within broader areas of cliff, will also help with this (and with locating the plot itself).

For *colonies on level or sloping ground*, positions of transects or quadrats should be mapped as accurately as possible, showing distances and directions necessary for location of the plots. It is always useful to retain a copy of the original grid-map used to position the plots, for example to aid selection of further plots. A photographic record of the colony boundaries (and other features of the colony) can also be useful. Aerial photographs will be best (if available), but some photographic documentation may be possible on the ground or from suitable vantage points.

If repeat counts of plots within a 'ground' colony are planned, some permanent markers within the colony are advisable. In the case of transects, both the starting and finishing 'corners' should be marked; additional markers at intervals along the boundaries are also helpful but less important. Positions of circular quadrats can be indicated by a central marker. The most widely used markers are wooden posts, driven well into the ground. Posts should preferably be weather-sealed in some way (charring the base of a wooden post in a fire is effective). Numbering of markers may not strictly be necessary for transects (or small numbers of quadrats), but is helpful for large numbers of quadrats. For long-term schemes, stainless steel 'badges' with numbers stamped or etched on them may be the most suitable labels. Some markers may become dislodged through weathering of the soil or disturbance (e.g. by burrowing seabirds). Be aware too that, where human interference is a possibility, some markers may have been moved to (or dislodged ones replaced in) the wrong positions. Any major discrepancy from the original documentation of quadrats positions should be noted.

For any type of colony, relevant photographs and maps should always be available for use in the field, for example by wardens. Additional copies (along with photographic negatives) should be stored safely at other locations, such as regional and national headquarters of relevant organisations.

(i) random numbers with first two digits ≤ 50			(ii) selected random plot-numbers	(iii) 'spare' random plot-numbers
.976	.**12**5	.**02**4	**49**	**4**
.**49**4	.**21**5	.**04**5	**8**	**2**
.909	.**33**8	.930	**3**	**16**
.674	.**39**5	.823	**14**	**30**
.**08**1	.**21**2	.**16**9	**5**	**38**
.**03**2	.**25**3	.**30**8	**21**	**48**
.**14**6	.553	.**38**4	**12**	**16**
.**05**3	.**33**7	.**48**7	**33**	
.**21**9	.918	.**16**1	**39**	
.835	.**04**2	.814	**25**	

Figure 1 Unrestricted random sampling: use of the 'random number' function of a scientific calculator to select 10 plots randomly from 50 potential plots. Cf. *Figure 4.*

Steps are as follows:

a) Generate random numbers by pressing the random number button, and write these down in sequence. Highlight the numbers that fall within the required range (i.e. ≤ 50 in this example); use the first two decimal places (or last two digits) only, if necessary.

b) Select the first ten numbers within the required range (excluding any repeats).

c) Select a further five or ten numbers as 'spares', in case it becomes necessary to replace any plots that might subsequently be re-classified as unsuitable (e.g. too dangerous), or in order to allow for future improvements in the monitoring coverage of a colony.

d) If necessary, repeat step (a) and select appropriate numbers until the required sample size is reached.

(i) random numbers with first digit ≤ 5

.**5**79	.**4**76	.**4**45	.074
.**2**57	.**4**07	.713	.**4**37
.063	.689	.927	.**3**84
.877	.**3**37	.807	.883
.**5**61	.**5**75	.**2**36	.**2**53
.631	.693	.017	.**1**20
.**3**10	.**3**72	.**4**13	
.895	.**1**25	.**5**89	
.**5**33	.876	.**5**21	
.**3**37	.664	.956	

(ii) selected random plot numbers		(iii) 'spare' random plot numbers
5	A	**3**
2	B	**1**
5	C	**4**
3	D	**2**
5	E	**4**
3	F	**5**
4	G	**5**
4	H	**3**
3	I	**2**
5	J	**1**

Figure 2 Stratified random sampling: use of the 'random number' function of a scientific calculator to select single plots randomly within each of ten colony sections (A-J). Cf. *Figure 4.*

Steps are as follows:

a) Generate random numbers by pressing the random number button and write these down in sequence. Highlight the numbers that fall within the required range (i.e. ≤ 5 in this example); use the first decimal place (or last digit) only, if necessary.

b) Select the first ten numbers within the required range (repeats are allowed in this example, as only one plot is needed per colony section).

c) Select a further ten numbers as 'spares', in case it becomes necessary to replace any plots that might subsequently be re-classified as unsuitable (e.g. too dangerous), or to allow for future improvements in the monitoring coverage of a colony. Match these numbers against those initially selected under (a); i.e. the 11th number is a 'spare' for the 1st number (excluding any repeats here).

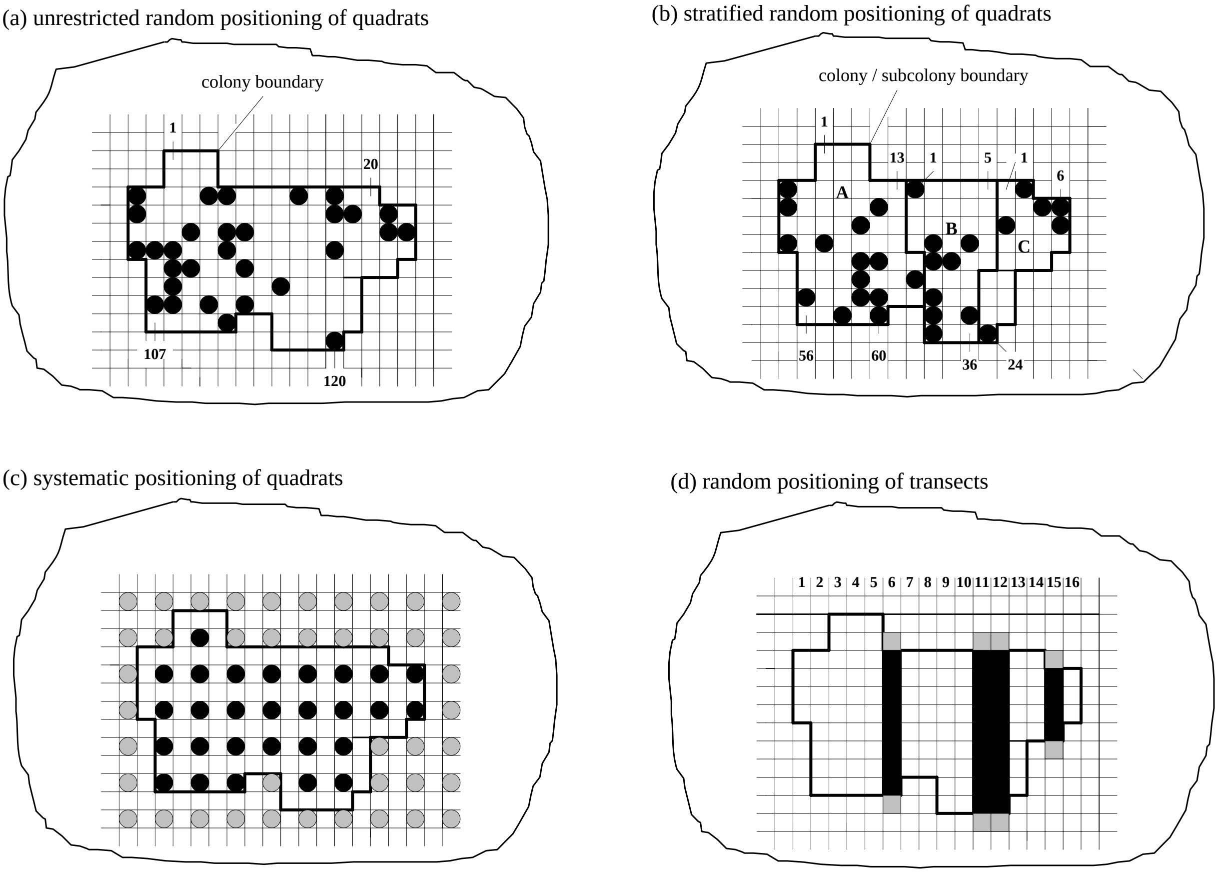


Figure 3 Techniques for positioning sample quadrats or transects in a colony of ground-nesting or burrow-nesting seabirds. In this simplified example, a preliminary survey has mapped the boundary of a gull colony on the summit of an island. A pattern of grid-lines has been overlaid on the map, splitting the colony into 120 grid-squares, each measuring 20 m x 20 m. Nests are to be counted in a sample of 25-30 circular quadrats each of area 300 m^2 (radius 9.77 m), placed centrally within grid-squares, or in transects covering a similar area.

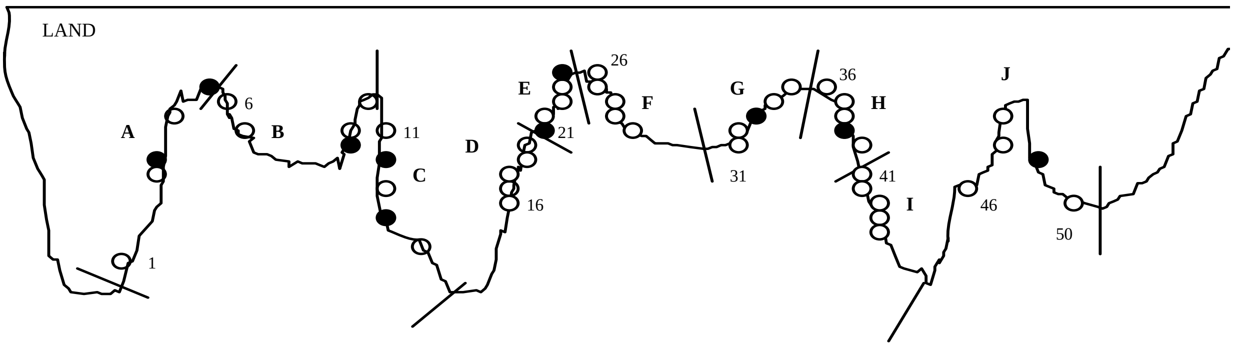
(a) *Unrestricted random (quadrats)*: 30 quadrats are positioned randomly within the colony as a whole. A series of random numbers is obtained, for example using an electronic calculator (cf. *Figure 1*). The first 30 numbers (excluding repeats) within the range 1 - 120 are chosen and the relevant grid-squares are marked on the map.

(b) *Stratified random (quadrats)*: Three major subdivisions, differing markedly in nest-density, have been identified, and the high-density (A), medium- density (B) and low-density (C) subdivisions make up *c*50%, 30% and 20% of the colony, respectively. 30 quadrats are positioned randomly within the three colony subdivisions, in proportion to the relative area of each subdivision (i.e. 15 quadrats randomly within A, 9 within B, and 6 within C). Squares are numbered separately within each subdivision (A = 60 squares, B = 36 squares, C = 24 squares). Random numbers are obtained as described under (a), except that this is done separately for each subdivision, i.e. 15 numbers chosen for A, 9 for B, and 6 for D.

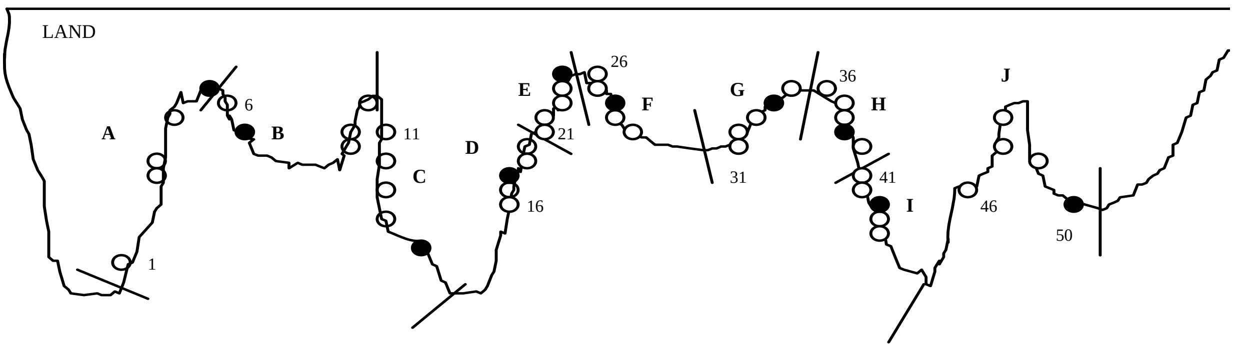
(c) *Systematic (quadrats):* Quadrats are placed at fixed positions within the colony (in this example, at intervals of two grid-squares from the approximate centre of the colony). Preferably, the 'starting point' would be selected randomly. Here, 28 quadrats fall within the colony boundary; 'empty' quadrats outside boundary could be checked rapidly in future years to look for any major increases in the extent of the colony.

(d) *Unrestricted random (transects)*: Transects are positioned randomly within the colony as a whole. A series of random numbers is obtained as described in (a) above. The first 3-6 numbers (excluding repeats) within the range 1-16 (the number of potential transects across the long axis of the colony) are chosen, until a maximum of 30 occupied grid-squares is included.

(a) Unrestricted random positioning



(b) Stratified random positioning



(c) Systematic positioning

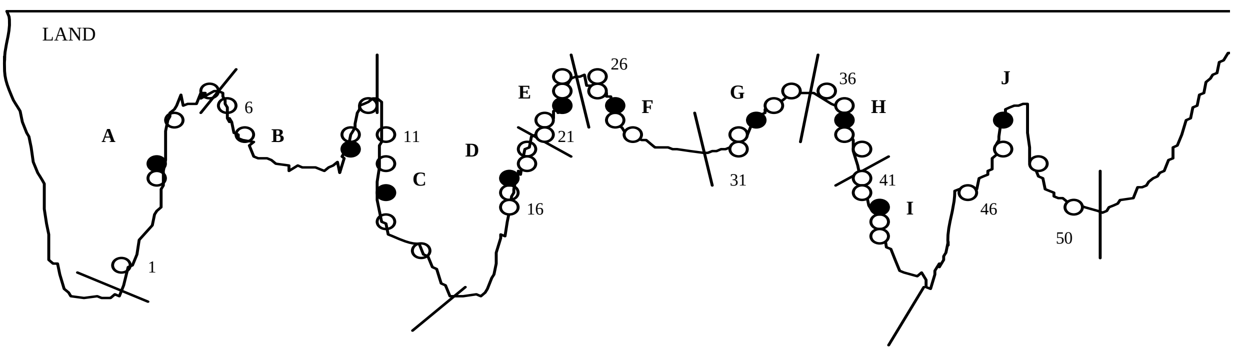


Figure 4 Techniques for positioning sample plots along a seabird cliff. In this hypothetical example, a preliminary survey has identified 50 suitable, potential plots, and ten larger sections (major divisions), each holding similar numbers of birds. Plots are to be counted on five to ten dates annually, and, in the time available on each date, ten study-plots can be counted.

a) *Unrestricted random positioning*: ten plots positioned randomly along the coastline as a whole (regardless of the major divisions). See *Table 1* for selection of these plot numbers.

b) *Stratified random positioning*: one plot positioned randomly within each of the ten major divisions. See *Table 2* for selection of these plot numbers.

c) *Systematic positioning*: one plot at a fixed position (e.g. middle plot) within each of the ten major divisions.

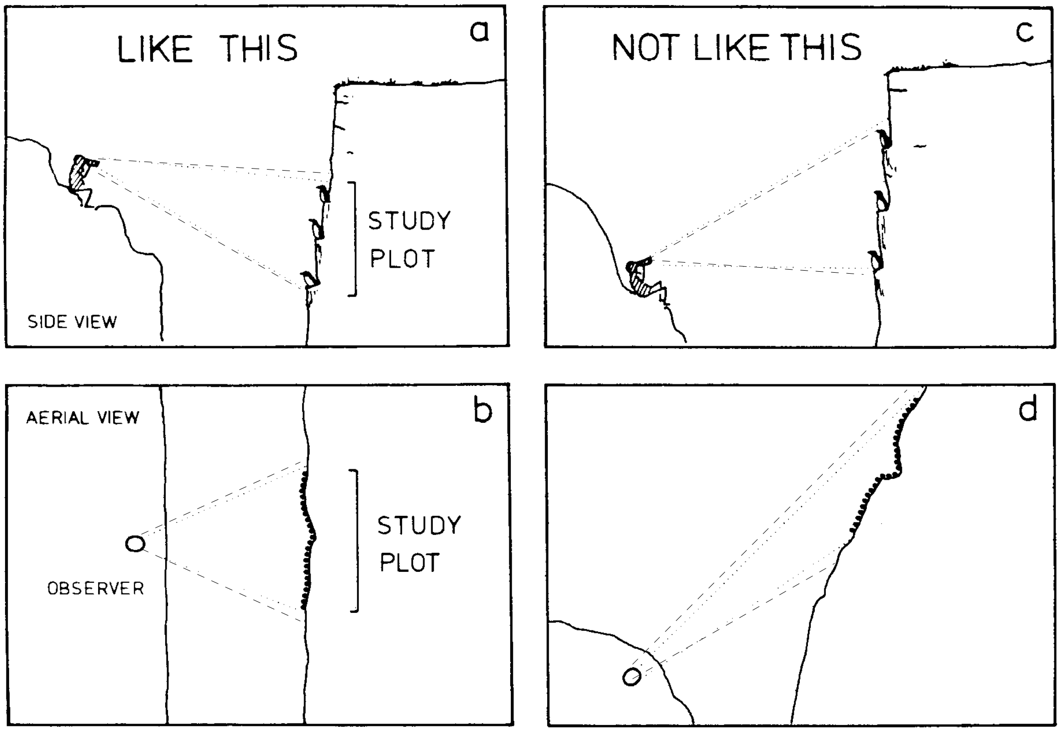


Figure 5 Correct positioning of observer for viewing and counting at cliff study-plots (from Birkhead & Nettleship 1980, reproduced with permission of the Canadian Wildlife Service):
a) side view - should be slightly above breeding birds;
b) aerial view - observer should be directly opposite study plot.

General techniques for counting cliff colonies

Whole-colony counts

Some of the advice given in sub-section on *Plot counts* below is also relevant here. See also the section on *Counts from the sea, from the air or from photographs*.

Make sure that colony boundaries used for counts are the same as in previous counts, or can be directly related to previous boundaries. This information may be available in Seabird Colony Register files, and in reports on previous counts at a colony. Always refer to available documentation of previous counts at a colony, especially if you have not counted it previously.

Before attempting a count, it is essential to gain some familiarity with the colony. Visit the colony with someone who has counted it previously and can provide advice. This will help in identifying count positions, or difficult sections to count, and in estimating the time required for the count. It will also help improve accuracy of counts, and reduce the time required. The latter can be important, as optimum count-dates for most species span only a two- to four-week interval, poor weather may prevent fieldwork on some days; and other colonies may need to be counted in the same period.

Make use of all suitable, safe, potential vantage points. Document their positions if possible, for example by marking them on 1: 10,000 Ordnance Survey maps of the relevant coastline, and by photographing (or, less accurately, sketching) cliff-faces as viewed from the vantage points.

Photographs of count positions with an observer *in situ* are also useful. Deposit copies of maps/photos with relevant organisations / offices.

The accuracy with which a colony is will depend on any physical difficulties involved, and on the time allocated. Where time is limited, it may be necessary to prioritise colonies or species to be counted, to optimise the usefulness of the data collected. Arriving at a balance of priorities for whole-colony counts can be difficult, but is worth attempting when planning (or reviewing) fieldwork activities. For example, the optimum approach may be to concentrate on obtaining accurate, regular counts of fewer colonies or species, and to survey a wider spread of colonies or species less frequently.

Quantifying the degree of inaccuracy involved in a whole-colony count is usually difficult, even where all seabirds can be safely viewed from land. Replicate counts of the colony or parts of the colony can provide useful supporting information. This can be important, particularly if a whole-colony (or section) count differs markedly from previous counts. If several observers take part in a count, it is particularly useful for them to cross-check some of their counts.

Plot counts

Before counting seabirds in study plots, it is important to be completely familiar with the precise boundaries of the plots or, at least, to be able to make accurate use of the photographs on which plot boundaries are delineated. This will help ensure that you don't make simple mistakes when identifying the parts of cliff to be included. If possible, someone who has previous experience of the plots (preferably someone who has counted them in previous years) should guide you through them, clarifying any uncertainties about boundaries (e.g. 'is this nest in or out?'). If you need to, add further annotations to the boundary photograph as a reminder (with your initials and date, in case you make a mistake which might mislead other observers).

Even when you are familiar with the precise boundaries of each plot, it is easy to make mistakes once you are actually counting a plot, especially when focusing on small parts of the plot at a time if using a telescope. You may start scanning the correctly defined corner or edge of a plot only to find that you have overshot the far boundary (or not reached it). Practice-counts of each plot before the main counting period begins are *essential*, and will help you identify the best pattern or direction of scans for counting a particular plot. For example, some plots may have obvious ledges or other horizontal cliff features that allow scanning back and forth while gradually moving up or down through the plot. Other plots might require counts of several discrete sub-sections, with further checks for more scattered birds or nests in between.

Birds or nests in study-plots should be counted as accurately as possible, as the use of sample plot counts is intended to increase the precision with which population changes can be detected. Plot counts should never be hurried (although greater speed will come with practice and experience, including familiarity with the plots). Do *not* simply estimate numbers or attempt to count rapidly in groups of five or ten birds or nests (although this may be acceptable for a whole-colony count if time is limited). If you find it difficult to count a particular plot (especially of guillemots), for example if birds are so dense that you lose track, attempt several counts, and report the individual counts and their average. Occasionally, even this may prove impossible, and if you need to resort to a rougher estimate, such as one based on tens of birds, or if you are totally confused, please note this when reporting your data. In some cases, it may be that a plot is no longer (or was never) suitable for accurate counting, and its use may need to be discontinued.

Many study-plots can be counted using binoculars only (10x magnification is recommended, and no higher unless a supporting tripod is used). One advantage of being able to use binoculars is that the wide field of view makes it less easy to become 'lost' while scanning through a large plot. If you have any difficult in picking out individual birds or nests clearly when using binoculars, for example if a plot is too distant or a ledge is too crowded, you should use a telescope, firmly mounted on a tripod, instead. The most suitable magnifications are 25x-30x (a wide-angle lens is best, for improved field of view); at higher magnifications, there is usually a significant loss of clarity and of light-gathering power. Some species in a plot (e.g. densely-crowded guillemots, or razorbills part-hidden in small crevices) may need to be counted using a telescope whereas others (e.g. fulmars) may be more easily counted using binoculars. Even within the same plot, some dense ledges may need the use of a telescope.

If you are counting individual birds (e.g. guillemots) in a study-plot, birds arriving or departing during the count may cause confusion. In such cases, ignore any birds which land behind or which take off ahead of the immediate position you have reached in your count, i.e. only count birds present at the 'correct' position as you scan from bird to bird.

Where population monitoring of a particular species (especially guillemot, razorbill, and fulmar) is based on replicated counts of sample plots within a cliff colony, it is important that all study-plots are counted on each date. If this is not done, it becomes much more difficult to combine the plot data for statistical assessments of change. Year-to-year population changes in individual plots can be assessed regardless of whether or not the same numbers of counts are available for each plot, but trends shown by individual plots are likely to be of little importance. It is the assessment of change in all plots combined that is crucial.

Counts from the sea, from the air, or from photographs

The use of photographic methods to count seabirds has been tested for a number of species but, in most cases, accuracy has been found to be low (e.g. Harris & Lloyd 1977). However, photographic counts of large species nesting on discrete sites have proved effective; it is the standard method for many gannet colonies (Wanless 1986), and has proved effective for counting breeding cormorants at some colonies (Reynolds & Booth 1987). Photographs are also an invaluable permanent record of the boundaries and/or density of seabird colonies in a particular year.

Counts from the sea are often needed, especially where the terrain is such that most of the birds are not visible from the cliff-top. It is important, when combining land- and boat-based counts, to record counts accurately onto large-scale maps, to avoid duplication and to highlight hidden sections.

If boat-based counts are not possible, but sections of a colony are thought to be hidden, please note this. If possible, attempt estimates from the cliff-top, based on apparent amount of 'dead ground', numbers on visible sections, or on experience of previous boat-based counts. Express such estimates as a range of figures. However, in reporting these estimates be very clear that their reliability is unknown and that they may not be directly comparable with other counts. Such estimates may also be made before attempting boat counts, as some degree of check on both methods.

Accurate counts from a boat are difficult. Calm weather, ideally flat calm, is needed. Views from too close in or at oblique angles to the breeding ledges on a cliff can produce serious under-counts. Nests may be difficult to see clearly (or their state of construction may not be obvious, which is important in some counting methods). In general, sea counts magnify the problems associated with counting, for example, densely-packed guillemot ledges or seabirds breeding over large areas of apparently featureless cliff. However, boat counts are useful for checking caves, covering lengths of sparsely populated coast (e.g. for black guillemots, shags, and, in some regions, kittiwakes), and checking rapidly for new colonies.

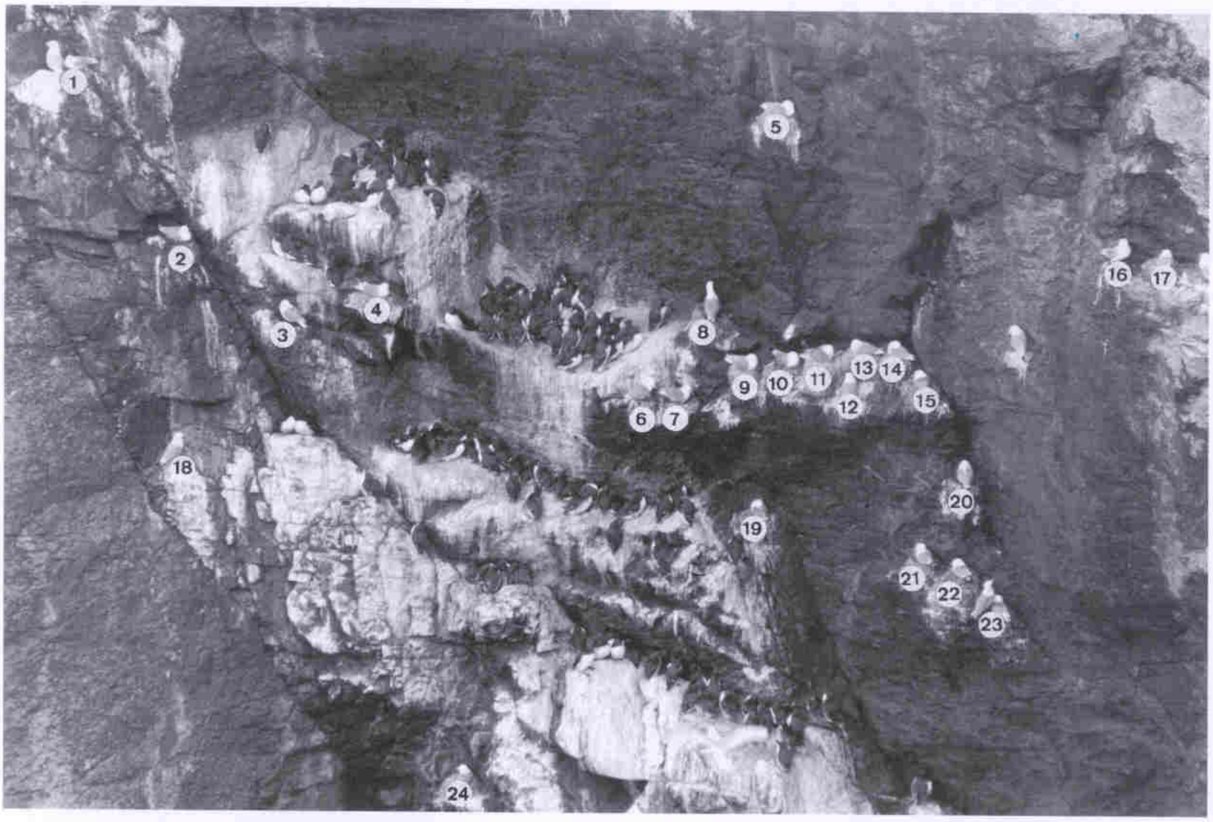


Plate 1 Example of a study-plot used for monitoring breeding success: kittiwakes on St Kilda, north-west Scotland. The enlarged sub-section shows positions of 24 pairs which constructed nests during a season. Copyright: P.M. Walsh.

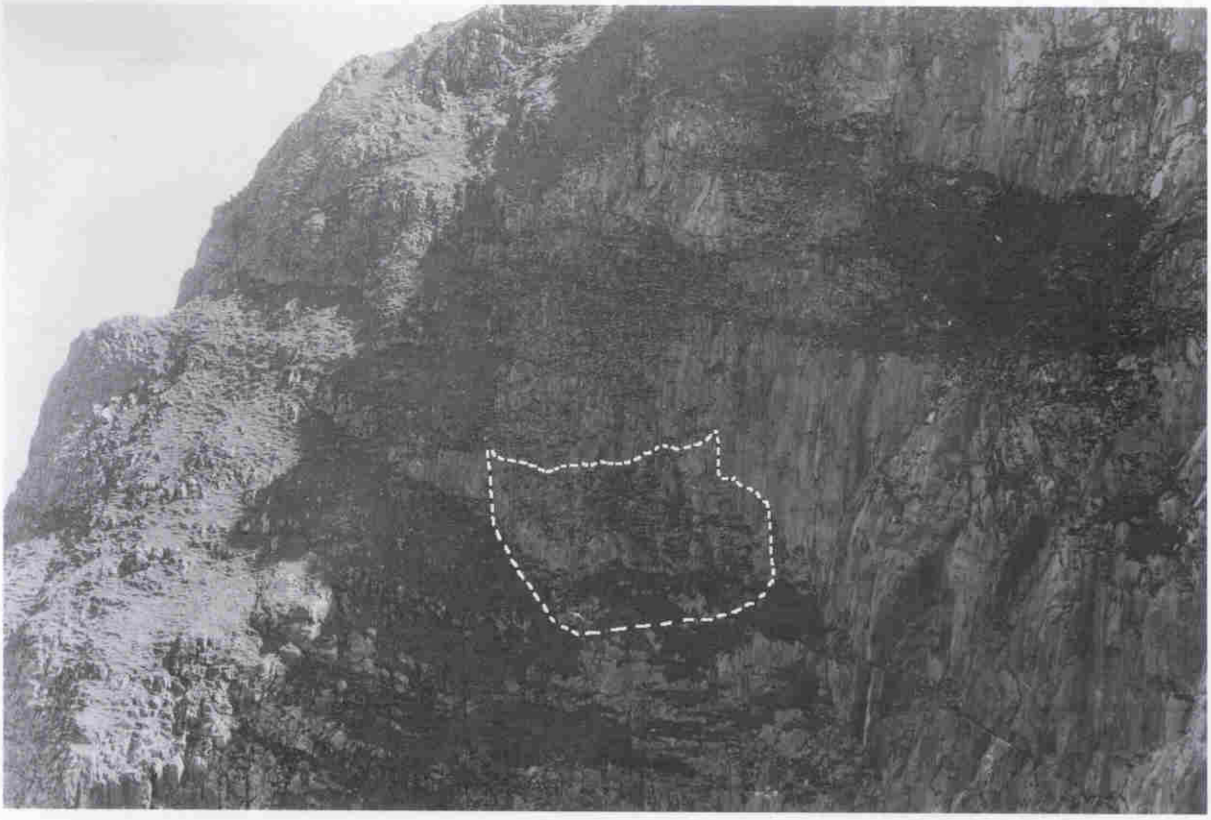


Plate 2 Example of a study-plot used for monitoring breeding numbers: fulmars on St Kilda. This plot holds, on average, >200 apparently occupied sites. Copyright: P.M. Walsh.

Fulmar *Fulmarus glacialis*

Census / population-monitoring methods

During intensive studies of fulmar reproduction or behaviour, the number of pairs breeding becomes apparent from repeated checks. However, this approach is generally too labour-intensive for censusing or population monitoring.

Censusing fulmars involves counting the number of apparently occupied sites (AOS) in the period between late May and early July (ideally in June). The limitations of this method are that many sites are occupied temporarily by individuals or pairs that do not breed, and the relatively extended breeding season means that a number of occupied sites where birds have failed, or where breeding has not begun, will be missed. (Generally, however, egg-laying will be completed by the start of June.)

For more detailed population monitoring, this error can be reduced by mapping sites two or three times over a period of ten days in late May / early June (when the bulk of pairs have usually laid), counting only sites where eggs are seen (rarely the case) or which are occupied on all occasions. For practical reasons, this can only be done for small colonies, or for study plots in larger colonies. A good compromise (which to some degree allows for day-to-day variation in numbers of AOS) is to use the mean of several counts during June.

Fulmars nest in a wide variety of situations, including cliff-ledges, broken rocks, slopes, buildings, sand dunes, entrances to rabbit burrows, and flat ground at the base of walls, and can nest on crags some distance inland. Some individual colonies in northern and western Scotland are very large, holding thousands of pairs. Other colonies (particularly farther south) are often small and scattered, or there may be long stretches of coast occupied at low density and with little obvious separation into 'colonies'. Monitoring of such low-density populations should be based on long stretches of coast if time and resources permit. Whole-colony (or whole-area) counts are generally to be recommended, but more accurate monitoring may require the use of sample plots (if repeat counts of the whole of a large colony or long stretch of coast are not practical).

Detailed population monitoring should preferably be based on annual counts, but counts at 2-5 year intervals can provide useful information on trends. Two broad methods are outlined below, preceded by a general method for whole-colony counts.

Census units

The generally recommended unit is the *apparently occupied site* (AOS). A site is counted as occupied only when a bird appears to be sitting tightly on a reasonably horizontal area judged large enough to hold an egg. Two birds on such a site, apparently paired, count as one site. (This should exclude birds which are sitting or crouching on sloping sections of cliff.)

Many AOS will look obviously suitable (e.g. depressions/pockets in turf or soil on a cliff or slope), but other occupied, reasonably horizontal sites, where an egg *could* be present, should not be excluded.

Whole-colony census method

1. Define clearly the boundaries of the census area, whether a stretch of coast (or inland area) or a colony. The area should be consistent from year to year. Within colonies, subdivide counts into sections clearly definable on Ordnance Survey maps and, if necessary, sketch individual cliff-faces to show smaller subdivisions for ease of counting. Where larger areas or lengths of coast are being counted, check all suitable habitat for signs of newly established colonies.

2. Counts should be made in June. (Opinions vary as to whether early or late June is preferable, and the possibility that the timing of the breeding season varies latitudinally within Britain and Ireland has not been investigated.) Counts in late May and early July are better than nothing. Counts should take place between 0900 and 1730 BST (0800-1630 GMT) (Dott 1975). Note weather conditions at the time of each count, and avoid counts during winds stronger than Beaufort force 4 or during heavy or continuous rain. (In windy conditions, many non-breeders or failed breeders may leave the cliffs, although incubating birds should not be affected; however, a variable proportion of the former may remain, and the overall count may not be comparable with counts in calmer conditions elsewhere or in other years.)

3. Count all AOS and, if possible, also count total numbers of birds ashore, in case this may shed light on attendance patterns.

4. Keep a note of (and map) any parts of a colony that might not be visible from land. Try to estimate (minimum-maximum) the number of AOS likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population).

5. If possible, make one or more repeat counts over a two- to four-week period in June, and *report each count*, along with the mean count (± standard deviation). Do not include any May or July figures in mean counts.

Population-monitoring method 1 (replicated plot-counts)

1. This is probably the best practical method in most cases. The basic method is as for whole colony counts (above), except as amended below.

2. Make at least five (preferably ten) repeat counts in June during suitable weather conditions. Where possible, count the whole colony.

3. If the colony or stretch of coast has too many fulmars to allow repeat counts of all AOS, select as many sample plots (preferably *c.* 10) as can be covered in the time available and count these. Suitable plots might contain 50-200 AOS (or 10-100 AOS in low-density colonies, e.g. most coasts south of northern Scotland). Aim to include in selected plots about 10-30% of the total population. Plots should if possible be selected randomly or otherwise dispersed through the colony (see *General methods*). The exact boundaries of plots should be clearly marked on photographs (or *detailed* drawings if photographs cannot be arranged in time.) If possible, plots should cover the full height of a cliff. If this is not possible (i.e. if cliff-height or fulmar-density is too high), the plots should be selected from a series of potential plots which include the full range of positions relative to cliff-height.

4. Report counts for each individual plot on each date, and for the whole sample on each date, as well as the mean and standard deviation for each plot and for the total.

Population-monitoring method 2 (nest-site mapping)

This method provides a better indication of actual breeding numbers, but involves considerable extra effort. It can be conveniently combined with the main method for productivity monitoring.

1. Where possible count the whole colony. Otherwise, choose sample plots of 50-200 AOS (or 10-100 AOS in low-density colonies, e.g. in southern Britain), as many as can be covered in the time available. See *Method 1* and *General methods* for other details of plot selection.

2. Where plots are used, mark boundaries unambiguously on maps or photographs and mark the location of every nest-site (or potential nest-site) occupied.

3. Visit the colony/stretch of coastline/plots three times 3-4 days apart in late May/early June, by which time most eggs will have been laid. For each potential nest-site record on a check-sheet what you think the bird is doing. For instance, record 'egg seen' (noticeable only if a bird stands up briefly), 'no egg present' or 'apparently incubating'. Do not flush birds or eggs may be lost. The main problem with fulmars is to decide how many pairs are actually breeding. The best estimate is the number of nests where an egg was seen plus sites where a bird appeared to be incubating on all three checks.

4. When plotting positions of sitting birds on each date, it is very easy to miss a few birds if sufficient care is not taken, particularly if some birds are only partly visible, for example in well worn niches on turf / clay cliffs. It is worth coding any 'difficult' sites differently on photo overlays, as a reminder to check carefully on subsequent visits.

5. It may also be worth checking, on each date, whether or not 'extra' sitting birds become visible if the viewing position is changed. If so, mark such birds on the photo overlay and also give them a different code. These birds may be included in your sample *provided* they are thoroughly checked for on each visit *and* in subsequent years - for the latter, the plot photo and instructions for locating the viewing position will need to be annotated accordingly. Otherwise, if you happen to notice that some birds are visible only from additional viewing positions, they may be ignored (since, unless visible on

all three dates from the main count-position, they will not form part of the population sample based on this method.)

6. Record the number of sites at which eggs were seen or had adults sitting on all three visits (a) for each plot, and (b) in total.

Productivity-monitoring methods

Productivity monitoring using sample plots is reasonably straightforward. The methods outlined below are designed to reduce errors caused by day-to-day variations in numbers of apparently occupied sites (AOS) and, as far as possible, to distinguish actual breeding sites from other AOS. These methods can be combined conveniently with population monitoring by using the same sample plots for both measures. Particular care must be taken not to flush incubating fulmars; this can easily happen where birds nest on the ground or on low or accessible cliffs and may cause failure of the breeding attempt.

Productivity-monitoring method 1 (nest-site mapping)

1. The method involves mapping sites on photographs or drawings (Harris 1989a). See *Appendix 4* for sample data sheets which can be used to record details of individual nests.

2. If the colony is small enough, check all the visible nest-sites.

3. If the colony is large, sample plots must be chosen, and the higher the proportion of the population included the better. For fulmars, a plot containing 30-50 nest-sites is a suitable size, although it may be necessary to use smaller plots at some colonies, especially away from the larger Scottish colonies. If possible, select at least three study plots (preferably five or more), or enough to total several hundred pairs.

4. Plots should if possible be selected randomly or otherwise dispersed through the colony (see *General methods*). Suitable plots to choose from are those which can be viewed safely and without disturbing breeding fulmars. If the cliffs are not too high, the plots should span from the cliff-top to the sea. Whatever method you use, document exactly how you made your choice. If you are constrained to checking only specific plots for any reason (safety, time, only places not to disturb birds or the public), say so.

5. It is not necessary to use the same plots or precise plot boundaries each season if you are comparing breeding output between years. However, if the plots are also being used for population monitoring, the same plots (and precise boundaries) must be retained.

6. Photograph the chosen plots and make large (A4) black-&-white prints. Tape on a transparent overlay, showing plot boundaries, and mark and number nest-sites. For clarity, use a superfine permanent marker, and place dot on the exact position of a site and a number beside it. The use of sketch maps is not recommended as sites are easily confused. Even with photographs, care is needed when 'matching up' nest-sites between dates. Be aware too that growth of vegetation may have obscured some sites later in season.

7. Visit the area three times 3-4 days apart in late May/early June, by which time most eggs will have been laid (if this is not possible, visit two or three times, 5-10 days apart, between late May and mid June). For each potential AOS, record on a check-sheet what you think the bird is doing. (Alternatively, mark directly onto overlay). For instance, record 'egg seen', 'no egg present' or 'apparently incubating'. Do not flush birds or eggs will be lost. The sample size for breeding success will be sites where an egg is seen or a bird appeared to be incubating on all three checks (or on two consecutive checks if visits are made 5-10 days apart).

8. When plotting positions of sitting birds on each date, it is very easy to miss a few birds if sufficient care is not taken, particularly if some birds are only partly visible, for example in well worn niches on turf / clay cliffs. It is worth coding any 'difficult' sites differently on photo overlays, as a reminder to check carefully on subsequent visits.

9. It may also be worth checking, on each date, whether or not 'extra' sitting birds become visible if the viewing position is changed. If so, mark such birds on the photo overlay and also give them a different code. These birds may be included in your sample *provided* they are thoroughly checked for on each visit *and* in subsequent years - for the latter, the plot photo and instructions for locating the viewing position will need to be annotated accordingly. Otherwise, if you happen to notice that some birds are visible only from additional viewing positions, they may be ignored (since, unless visible on all three dates from the main count-position, they will not form part of the population sample based on this method).

10. Check each numbered site again in early to mid August for the presence or absence of a chick. Assume that all large young (including downy young about adult size) fledge. Keep a note of any medium-sized or small downy chicks present, and if possible check them two or more weeks later.

11. For each plot, express the results as the mean number of young fledging per regularly occupied site.

12. Report results in detail (i.e. at least for each plot). The colony production should be expressed as the average of the plot means ($\pm$SE). (However, results from very small plots, say <10 pairs, may have to be combined.)

Productivity monitoring method 2 (repeated counts of AOS)

1. The method has some similarities to *Method 1*, but does not involve mapping of sites. It is less time-consuming, but is more likely to overestimate breeding numbers (as non-breeders are more likely to be included).

2. Small colonies, at least those parts visible from safe vantage points, can be covered in their entirety. For larger colonies, or longer stretches of coast, select plots as in *Method 1*. Each plot should contain 50-200 AOS (or 10-100 AOS in low-density colonies, e.g. most coasts south of northern Scotland).

3. If plots are used, mark plot boundaries on good quality photographs (or, less ideally, detailed sketch maps).

4. Visit the area on three or more days in June and count the number of AOS - one or two fulmars occupying a site capable of holding the fulmar's single egg. Counts should be made between 0900 and 1730 BST (0800-1630 GMT) and should not be made during winds stronger than Beaufort force 4 or during heavy or continuous rain.

5. Calculate the average number of AOS. Visit the area again in mid August (*c.* 10th-20th) and count the number of chicks. Assume that all large young (including downy young of adult size) fledge, but keep a note of smaller young too (check these a few weeks later if possible).

6. For each plot, divide the estimated number of young fledging by the average June count of AOS. Unless most plots are small (say, <20 AOS), avoid pooling results from plots; if there are significant differences between plots the colony production is more appropriately calculated as the average of the plot means ($\pm$SE).

Plate F.1 Large fulmar chicks, retaining (top) all, (middle) some, and (bottom) no down. When counting 'fledgable' fulmar chicks in August, the majority of chicks should preferably be at the partly downy stage. Copyright: P.M. Walsh (top, middle) and J. Vaughan (bottom).

Manx shearwater *Puffinus puffinus*

Census / population-monitoring methods

Manx shearwaters are a notoriously difficult species to count owing to their nocturnal and burrow-nesting habits, and the variety of terrain - turf, scree, under rocks and gorse bushes, and on low islets and mountains - in which they nest. Much research has gone into devising suitable methods, some specific to particular colonies. *Method 1* relies on counting apparently occupied burrows in randomly selected quadrats. One difficulty is that burrow occupation is often not clearly marked, so that different observers may differ considerably in their judgements. There is also potential for confusion with other burrow-nesting species (including puffins, and rabbits *Oryctolagus cuniculus*) where they occur together. Further work (or collation of available experience) is needed before problems of burrow identity can be solved routinely.

Compare with other ways of assessing burrow occupancy, the use of tape-playback of male shearwater calls at burrow entrances (*Method 2*) is less subject to observer bias. In comparison with exhaustive methods involving opening burrows (which we would discourage), the tape-playback method is fairly accurate and much quicker (James & Robertson 1985). Potential confusion with burrows of other species, such as puffins, is also eliminated.

The methods given here should, between them, be applicable at many colonies, although greater difficulties arise with colonies or subcolonies among boulders. Counts of burrows within quadrats can be used to monitor population trends, or extrapolated to a whole-colony count where the total area of the colony is known. Errors in assessing colony area can be large, in some cases. For example, Furness (1990) recommended that further aerial photography and ground-based survey would be necessary for accurate mapping of the mountain-top colony on Rum, western Scotland.

A third method, which has been used on the islands of Skomer and Skokholm in Wales (Corkhill 1973; Perrins 1968; Alexander & Perrins 1980), can produce an estimate of the number of chicks fledging (and, by extrapolation, numbers of breeding pairs). The method is very labour-intensive and involves ringing large numbers of well-grown chicks and recapturing them during fledging. As with mark/recapture techniques in general, it is difficult to assess the reliability of the technique, but it may be useful for obtaining rough estimates for colonies where large-scale ringing is routinely undertaken. Further details are not included here, but are available from the compilers.

Census units

The census unit is the *apparently occupied site (AOS*), the nest-site in this species being a burrow or crevice. Burrow occupancy is judged on the basis of physical signs (as in *Method 1*) or on the basis of birds responding to tapes (*Method 2*).

Census method 1 (sample quadrats)

1. The method of random selection of quadrat sites is adapted from methods used for puffins by Harris & Rothery (1988). It is not usable where shearwaters occur in mixed colonies with puffins or sizeable populations of rabbits. (If there are lots of rabbits, it may be possible, with experience, to identify shearwater burrows late in the season by their entrance 'profile', with basal grooves where the legs have scrabbled: C.M. Perrins, pers. comm.) Nest-sites among boulders or scree, where entrances cannot easily be distinguished, also present major problems (see point *8*).

2. Sampling should be carried out during the early incubation period (early incubation to early nestling stage, early May to early July, is acceptable).

3. Define the limits of the area occupied by shearwater burrows on a map (a sketch map if necessary), and measure its area as accurately as possible.

4. Select *randomly* a number of positions on the map of the colony, as described under *General methods*. If the colony is divided obviously into areas of markedly different density, often associated with differences in vegetation or substrate (e.g. turf, walls, gorse), greater accuracy is obtained by treating each area as a separate subcolony (*stratified random sampling*). A reasonable number of quadrats is about 30. Some selected quadrats may not be usable for safety reasons or because there is a greater danger of collapsing burrows than elsewhere. If so, select an alternative quadrat by random methods.

5. The best alternative to random positioning of quadrats is *systematic* positioning, whereby quadrats are placed at fixed intervals through the colony (see *General methods*). We do not recommend haphazard positioning of plots, or positioning on the basis of subjective judgements of representativeness.

6. Place quadrats at the selected points *regardless of whether or not there are burrows present*, even if the whole area is bare rock. The location of the point should be fixed by measuring angles and distances from fixed points, such as rock outcrops or other structures. These points may be permanently staked and used each year, or new points can be selected annually.

7. The shape and size of quadrats is not important so long as the average quadrat contains some burrows. Circular quadrats of around 20 m^2 or 30 m^2 are convenient. A rope of 2.52 m length (for 20 m^2) or 2.96 m (30 m^2) can be rotated around a fixed stake and the number of occupied burrows within the radius counted. A burrow judged to have more than half of its entrance within the quadrat should be counted.

8. Count all apparently occupied sites/burrows (AOS) whose entrances lie mostly or completely within the quadrat. These are characterised by, for example, recent signs of digging (often the most obvious indication), fresh droppings, eggshell remains at entrance, or one or more shearwater body-feathers. (As with puffins, more burrows may show signs of digging than are actually laid in, but this is acceptable for monitoring/survey purposes.) Detecting shearwater burrows by smell is generally difficult.

9. To obtain an estimate of the total population, first calculate the mean number of apparently occupied burrows (AOS) in each quadrat (sum of estimates for each quadrat divided by the number of quadrats taken). Divide this by the area of each quadrat (typically 20 m^2 or 30 m^2). Multiply the mean density by the total area of the colony (in m^2) for the final figure.

10. *N.B.:* Where different areas of the colony have been sampled separately (point *4*, above), this calculation should be performed for each area separately and the results summed.

11. At colonies where some or all of the population breeds among scree or boulders, the above procedure is not possible. As a *very* rough way of assessing the relative proportions occupying the different habitats, it may be possible to compare shearwater 'activity' soon after sunset (assuming that most birds then will be breeders). The number of birds seen landing, and departing, over a given time and area as the observer walks around should be noted. Preferably, this should be done by the same observer on the same night, within a short period, although this presents logistical problems if the different habitats are widely separated. Visits to different habitats, at the same time on different, randomly selected nights in similar weather conditions, within the same two-week period may be a suitable compromise. (Limited use of the tape-playback method may be possible in such habitats: *Method 2*, point *13*).

Census method 2 (tape-playback in sample quadrats)

1. This method was developed by James and Robertson (1985); Smart (1985) validated the technique and proposed some minor adjustments adopted here. The method requires a high-quality tape recording (15 seconds duration) of the male Manx shearwater call. This can be obtained from commercially available recordings or the compilers of this handbook.

2. Sampling should be carried out during the day during the mid to late incubation period (late May to early June), but before any chicks have hatched. (Chicks are left unattended by day once about a week old: Brooke 1990.) Counts should be made during the day, when fewer non-breeding immatures or prospecting birds will be present in burrows.

3-7. As *Method 1*.

8. The base figure for occupied burrows is the number of burrows from which there is a response to a recording of male calls played at natural volume within 0.3 m of the burrow entrance for a maximum of 15 seconds. Ensure that all burrows within the quadrat are checked, but beware of counting responses from the same bird more than once if several entrances lead to the same nest chamber.

9. From earlier work on Manx shearwaters, a correction factor for the probability of response from an incubating male and the proportion of incubating birds which are male was derived by Brooke (1978). This figure was 1.98 (female shearwaters never responded to male calls, whereas males almost always did). Thus, if 50 birds (presumed males) responded to tapes, the estimated breeding (at least, burrow-occupying) total was (50 x 1.98) = 99 pairs. The conversion factor may vary among colonies, but only this single estimate is available at present.

10. For each quadrat, as an approximation, multiply the number of responses by 2 to give an estimated number of occupied burrows. (This assumes that each occupied burrow has only one entrance, and that each entrance leads to only one nest chamber.)

11. To obtain an estimate of the total population, first calculate the mean estimate of occupied burrows in each quadrat (sum of estimates for each quadrat divided by the number of quadrats taken). Divide this by the area of each quadrat (typically 20 m^2 or 30 m^2). Multiply the number obtained by the total area of the colony for the final figure.

12. Where different areas of the colony have been sampled separately (*Method 1*, point *4*), this calculation should be performed for each area separately and the results summed.

13. In colonies or subcolonies where shearwaters nest among boulders or scree, the tape playback method is less useful, as there are so many potential nest-site entrances to check (many of which will be virtually inaccessible). A *minimum* estimate of numbers of occupied burrows might be obtained by playing the call at a loud volume at the centre of each quadrat for periods of 15 seconds, with 15-second gaps to listen for responses, over a period of several minutes. Preferably, the tape would be played at several positions within the quadrat. For more quantitative assessments, further work would be needed to determine the level of effort (loudness, duration and number of positions for tape-playback) required at a particular colony. Alternatively, it might be possible to assess the *relative* breeding densities in rocky versus turf habitats by walking at a fixed pace through both habitats (preferably along random transects), playing male Manx shearwater calls at loud volume a metre above the ground, and noting the number of birds audibly responding per unit time. In difficult habitats, adaptations of the tape-playback method are probably more useful in arriving at whole-colony population estimates (based on sample quadrats and extrapolation to area of habitat) than for detailed monitoring of population change.

Productivity-monitoring method

Productivity monitoring is relatively straightforward, using the procedure developed by Harris (1989a) for puffins.

1. The method involves feeling down burrows with a bamboo or stick. It is not appropriate for areas where puffins also nest.

2. Check a series of burrows, dispersed through the colony, soon after the peak of laying (usually early to mid May). Try for a sample of 100+ burrows. Because breeding success can vary markedly with burrow-quality (Thompson & Furness 1991), it is important not to be biased towards burrows which are easy to check (shallow). Very deep burrows may prove impossible to study using this technique, however. If such burrows are encountered, add a note on their relative numbers (compared with burrows where presence or absence of an egg could be confirmed), to highlight the possibility that results may not be representative of a colony.

3. Select a series of sticks 15-60 cm long. Take the longest, lie on the ground and push the stick and your arm down the burrow. Any incubating shearwater will move off the egg which can usually be felt with the stick on the floor of the nest-chamber. If the stick is too long to go around a bend in the burrow, try again with a shorter one. Be careful not to break the egg. Any burrow where an egg is felt is then staked (but not necessarily numbered), bearing in mind that the vegetation may well grow quite tall and you will want to find the burrow again. These checks are best made when the ground and burrow floor (and ground) are dry.

4. During daylight (to minimise the possibility of encountering adults in burrows), re-check the burrows in early to mid August, when most chicks will be large (but before fledging begins in late August). It is usually easy to determine if the nest has been successful, either by feeling the chick or searching for moulted down among the nest-lining. If puffins also occur in the colony, check the shape of the bill by touch, or remove the chick, to confirm it is a shearwater.

5. Success is expressed as the number of chicks present divided by the total number of burrows refound where presence or absence of a chick was determined.

Gannet *Morus bassanus*

Census / population-monitoring methods

Although Gannets are conspicuous and their nests are generally large and obvious, major censusing problems may arise from the remoteness or size of some colonies. There has also been much confusion over the best count methods. Counts of individuals, of 'pairs', of apparently occupied nests and of apparently occupied sites have all been used, sometimes in conjunction with correction factors for time of year and time of day. This confusion has led to difficulties in comparing counts both within and between colonies.

In general, fieldworkers have found that apparently occupied sites (AOS) constitute the most convenient and comparable units for counting gannets given the variety of methods (direct counting from land or the sea, photographs from land, sea or air) which may be involved (Nelson 1983, Wanless 1987). Whole-colony counts made directly (*Method 1*) or from photographs (*Method 2*) are recommended where possible, especially as many colonies are expanding and expansion tends to be by increased area rather than density. Sample plots are usually of little use for this species (e.g. Murray & Wanless 1992). In photographic counts, it is usually impossible to distinguish actual nests with any certainty. Counts of apparently occupied nests (AONs) at colonies accessible to land- or boat-based counting will, however, reduce some of the variation in counts caused by changes in numbers of adult-plumaged non-breeders.

At many colonies, 'clubs' of immature- and adult-plumage non-breeders are discrete from breeding areas, so that areas for AOS counts can be identified easily. However, at some colonies (e.g. Hermaness, Shetland), non-breeders are scattered among breeders, which can cause considerable difficulties unless AONs are counted (see Murray 1992).

It may prove impractical to count some colonies more often than every 5-10 years, because of logistical difficulties. More frequent counts would highlight trends in more detail, but are most feasible at the accessible, particularly wardened, colonies.

Table G.1 Gannet colonies at which standard count-sections have been defined. Some additional details for other colonies are given in Wanless (1987)

Colony	Reference / source
St Kilda (Western Isles)	Murray (1981), Boyd (1961)
Hermaness (Shetland)	Murray (1992)
Noss (Shetland)	Murray & Wanless (1992)
Fair Isle (Shetland)	Riddiford & Harvey (1992)
Sule Stack (Orkney)	Fisher & Vevers (1943), Wanless (1987)
Troup Head (Banff & Buchan)	Walsh (1993)
Ortac, Alderney (Channel Islands)	Hill (1989)
Les Etacs, Alderney (Channel Islands)	Hill (1989)

Census units

The generally recommended unit is the *apparently occupied site (AOS)*, i.e. a site occupied by one or two adult gannets irrespective of whether or not any nesting material is present, so long as the site appears suitable for breeding. Sites with unattended chicks are included. The main advantage of this unit is its usefulness in counting gannets from aerial or other photographs of colonies, although care is needed to ensure that single gannets on adjacent AOS are not confused with pairs of gannets on single AOS. The regular spacing of AOS helps, and it is important that photographs are of good quality, with birds on AOS as sharply defined as possible.

At colonies which can be counted directly from land or sea, especially where large numbers of non-breeding birds are present, counts of *apparently occupied nests (AON)* may be more appropriate (some observers may find assessment of AOS confusing at close range). For gannets, an AON is counted if one or two adults with nest material (however flimsy), or a large chick (which may not be on an obvious nest), are present. Counts of well-built nests are sometimes made, but judging these is more subjective (and may become more difficult as the season progresses and nests become flattened or lose material). Attempts to use correction factors to convert counts of adult birds to 'pairs' or AOS are not recommended, as too many unconfirmed assumptions are involved and the results will be of doubtful accuracy.

Census method 1 (field counts)

1. This procedure is modified from that adopted for the 1984-85 North Atlantic gannet survey (Wanless 1987).

2. The preferred months for counts are June or July; however counts between mid May and mid August may be useful. Counts should be made between 0900 and 1600 BST, but again a count outside this range is better than none at all (though counts of AOS should be interpreted with caution as numbers of non-breeders ashore may change).

3. Counts can be made in any weather but obviously the more benign the conditions the easier (and more accurate) the count. Counts should be replicated, ideally by two counters at the same time.

4. Divide the colony into clearly defined subgroups, based on natural features of the site. Also note any unoccupied sections. The locations of these groups should be shown on Ordnance Survey maps, along with the best position for counting each subgroup. Boundaries of these subgroups should be marked on photographs, or on accurate sketches. For many gannetries, such subdivisions and count-positions have been established during earlier studies and will be on file with JNCC, RSPB, Scottish Natural Heritage or other bodies. See *Table G.1* for details.

5. If nest material (even of small or partly constructed nests, no matter how flimsy) can be safely distinguished in all parts of the colony, count AONs. Otherwise, count apparently occupied sites (AOS).

6. If comparison needs to be made with a previous count of a different census unit, try to count both AONs and AOS at the same time. In subsequent years, the new count unit (usually AONs) should be the priority.

7. Keep a note of (and map) any parts of a colony that might not be visible from land. Try to estimate (minimum-maximum) the number of sites or nests likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population).

8. Report the replicate and mean counts of AOS/AONs for each subgroup of the colony, and for the colony as a whole. If single counts only have been done, this should be noted. Note how each subgroup was counted (e.g. from land, from sea, or combination).

9. If possible, repeat the whole count several weeks later (e.g. in July), and report both sets of counts. If both counts are considered to have been accurate, use the higher overall count (to allow for real, seasonal variation) as the best estimate of the population. However, if counting accuracy is believed to have been low (or is uncertain), the average count is a more appropriate figure to use (with range).

10. If time allows, counts of individual adults and immatures in non-breeding 'club' areas may also be useful.

Census method 2 (counts from photographs)

1. This procedure follows that adopted for the 1984-85 gannet survey (Wanless 1987) for counts made from photographs taken from the air, from a boat, or from land.

2. The preferred month for counts are June or July; however counts for mid May to mid August are better than none at all. Photographs should be taken between 0900 and 1600 BST, but again photographs taken outside the preferred range are better than none at all.

3. Photograph the colony, or parts of it, at as close a range as possible, *provided* birds in the colony are not disturbed (especially by aircraft) and provided you can distinguish any areas of overlap between photos. Where gannets are nesting in a large, unbroken area with few obvious physical features (e.g. Grassholm, Dyfed), a single, sharp photograph is preferable to several larger-scale photographs covering smaller areas of the slope. If possible, visit the colony on foot or check from a

boat to identify and delimit non-breeding areas of the colony. This will help in interpretation of the photos later. (Many non-breeders may leave the colony on the approach of the plane, however.)

4. Good quality, large prints are essential; black-and-white photographs are ideal. Alternatively, project a transparency on to white paper fixed securely to a solid surface such as a wall.

5. If possible, divide the colony into clearly defined subgroups for the purposes of counting. The boundaries of these groups should be marked clearly on large-scale maps or on photographs. For many gannetries, such divisions have been established during earlier studies and will be on file with JNCC, RSPB, SNH, or other bodies (cf. *Table G.1*). These divisions should be retained where possible.

6. Count all AOS. Where a number of photographs are used (particularly if taken from different vantage points), it is important to avoid double-counting parts of the colony. This is best achieved by marking subgroup boundaries on the print or projection. On a transparent overlay or on a projection, cross off AOS with fine, coloured markers, in contiguous groups of 200-300 at a time. (Use varied colours for each group in case you have to start again, and note the numbers in each group as you do them.) Also try to identify, and count separately, the number of individuals of any age in club (non-breeding) areas of the colony.

7. Ideally, have one or two other people repeat your count. If not, make at least one repeat count yourself.

8. Report all replicate counts for each subgroup of the colony and the whole colony, and also the mean counts (± standard deviation). Also report numbers of individuals in clubs if counted. Document, on maps or photographs, the extent of the colony and of non-breeding areas for future reference.

Productivity-monitoring methods

Measuring productivity in gannets is relatively simple, and should ideally be based on repeated checks of individual nests within plots dispersed through the colony (similar to the method recommended for shags: *Method 1*). However, many gannetries are not visited sufficiently often to permit such an approach; in such cases, *Method 2* should be applied.

See *Appendix 4* for sample data sheets, which can be used to record details of individual nests.

Productivity-monitoring method 1 (mapped nests)

1. The method is based, with amendments, on that developed for shags and kittiwakes by Harris (1989a). It involves visiting the colony every 7-10 days from mid-incubation (late April to mid May depending on the colony: see Nelson 1978), to check the progress of breeding at individually plotted nest-sites until the young are fully feathered.

2. As with all monitoring, the aim is to reduce the chances that the samples you choose are atypical of the colony as a whole. If the colony is small, check all the visible nests. Most colonies will be too large for this, but nevertheless, the higher the proportion of the population checked the better.

3. If the colony is large, sample plots must be chosen. A plot containing 50-100 nests is considered a reasonable size for this species. Select as many plots as can be efficiently covered, preferably five or more. If possible, these plots should be selected randomly (see *General methods*). If non-random

plots are used, it is important that they be dispersed through the colony and include centre and edge areas and different heights of cliffs.

4. Whatever you do, document exactly how you made your choice. If you are constrained to check only specific plots for some reason (e.g. safety, time, only places not to disturb birds or the public), record this.

5. It is not necessary to use the same plots each season.

6. Photograph the selected plots, preferably when birds are at their nests, and make large (A4) black-&-white prints. Tape over a transparent overlay. Mark on the position of nests and number them. Alternatively, sketch the colony, but this is likely to cause confusion during later checks, especially among denser groups of nests.

7. Visit the area every 7-10 days after your first visit and for each nest record its state (e.g. few sticks, complete platform), contents (if visible - do not flush sitting birds), and whether an adult appears to be incubating or brooding. Chicks can fledge from 12 weeks old, so count disappeared birds which could have reached 12 weeks old during the 7-10 days before being revisited as having fledged (see *Table G.2* for a guide to ageing of chicks).

8. Express your results as the total number of young fledged divided by the number of nests where birds appeared to be incubating at some stage in the season. Record the reasons for any losses if known (e.g. predation; egg did not hatch; chick died in nest).

9. Do not pool results from plots as if there are significant differences between plots the best estimate of colony production is the mean ($\pm$SE) of the figures for individual plots. Also quote figures for each plot.

Productivity-monitoring method 2 (comparison of nest- and chick-counts)

1. This method is for use when time is limited. Select study-plots as in *Method 1*. Again, try to cover as many nests as is safe and practicable; in small colonies this may be all nests.

2. Count nests during late incubation/early nestling period (mid to late May), depending on the colony. Count any nest with an adult apparently incubating or brooding, or with an unattended chick, as a breeding attempt. Keep a separate count of other occupied, well-built nests in which eggs may not yet have been laid or which may already have failed. Map or photograph nest positions if possible.

3. Check again shortly before the first chicks fledge. Dates around 10-15 August are generally suitable. A search should also be made for additional breeding attempts, chicks should be counted and (if possible) the apparent age of each chick should be noted. See *Table G.2* for a guide to ageing of chicks.

4. If possible, follow up youngest chicks on a later visit or visits (say two weeks later) to improve the estimate. Birds can fledge from 12 weeks old, so, where repeat visits are made, count disappeared birds which could have reached 12 weeks old between counts as fledged. If you can make only a single visit in the fledging period, treat the total number of all live chicks as the a maximum estimate of fledging success. Survival of gannet chicks is generally high, so that the number of chicks present in mid August will provide a useful index of productivity.

5. Productivity is expressed as the number of chicks which potentially fledged divided by the number of nests where an egg or apparent incubation was recorded. Bear in mind that a figure based on only

one count of chicks may be a substantial overestimate, and that figures for other years or colonies may not be directly comparable.

Table G.2 Guide to ageing gannet chicks (adapted from Nelson 1978 and Wanless 1987)

Age	Description
Newly hatched	Black and naked, egg-tooth obvious.
Week 1	Fairly black, with sparse, hair-like down; very wobbly (normally brooded constantly by adult).
Week 2	Partly covered with down; larger than parents' feet; head and neck bare; movements well coordinated.
Week 3	Body and wings covered in white down, but lacks luxuriantly fluffy look of 4 week old; cannot be covered by parent.
Week 4	Down long and fluffy; two-thirds adult size, taking up most of the nest.
Week 5	Still fluffy; approaches adult size; pin primary and tail feathers show black through the down.
Week 6	Fluffy, but scapulars, wings, and tail-feathers clear of down; looks bigger than parent.
Week 7	Mantle and back a mixture of white down and black feathers; breast, underparts, head and neck covered in long white down.
Week 8	Mainly black above; down disappearing from forehead, mantle/back, and tail.
Week 9	Down starts to go from ventral surface, but still thick on flanks, belly, and parts of neck; looks scruffy.
Week 10	Some down on nape, flanks, and back.
Week 11	Only wisps of down remain, on nape and flanks.
Week 12	Complete juvenile plumage.

Gannet colony count data sheet

Observer name:

Address:

Gannetry:

Date of count: Time....................

*Census unit: (tick as appropriate) Apparently occupied site / Nest / Other (specify)..................

Count method: (tick as appropriate) Field count from land / Field count from sea / From photo from land / From photo from air / Other (specify)................

Weather and sea conditions:

*Problems:

*Comments:

Subgroup (if used; refer to map)	Method	Accurate count	Estimate
Total			

**Counting unit:*
1. Apparently occupied site (AOS): one or two adult gannets, or a chick, on a site suitable for breeding, irrespective of whether any nest material is present.
2. Apparently occupied nest (AON): one or two adult gannets occupying a site suitable for breeding, with nest material, no matter how flimsy, present, plus any large chicks without an obvious nest late in season.

N.B. Please state if you used any other counting unit and define it precisely. Please do not correct or adjust counts in any way.

**Problems/Comments:* Add notes on any parts of the colony that were uncountable (and try to estimate proportion), any reservations about the count, etc.

Plate Gn.1 Gannet chicks of varying ages (accompanied by adults): (top left) week 3; (top right) week 5; (bottom left) week 7; (bottom right) weeks 10–12. Copyright: R. Revels/RSPB, E. Wright/RSPB (x2), and D. Emerson/RSPB, respectively.

Cormorant *Phalacrocorax carbo*

Census / population-monitoring methods

In Britain and Ireland, cormorants usually nest in relatively small groups of a few dozen to a few hundred pairs; the largest colony, on Lambay near Dublin, has over 1,000 pairs. Colony sites are usually on flat or rocky islets or stack tops, less often on cliffs, and sometimes on ruins or other artificial sites. Inland colonies are also often on trees or bushes on small islands in lakes.

Colonies are usually very conspicuous, although small colonies on cliffs may easily be overlooked. The birds themselves are large, the nests are bulky, and guano-staining whitens rocks and kills vegetation (often entire trees at inland colonies). Counting pitfalls include the difficulty of seeing all nests on inaccessible sites such as stacks; for example, shore-based counts underestimated the population by a third compared with aerial photographs at the Brough of Stronsay, Orkney (Reynolds & Booth 1987). In addition, year-to-year movements of breeding birds can occur between groups of nearby colonies. This necessitates counts of all colonies within a broad area being made in the same year, to obtain good population estimates. In some years, a high proportion (perhaps 20-30%) of adult cormorants in a region may not nest (e.g. Walsh *et al.* 1992), although this appears to be less frequent than in shags. Apparent changes in the population between any two years based on breeding counts must be treated with caution.

Compared with other seabirds, the timing of breeding is highly variable, and breeding is often relatively asynchronous, both within and between colonies. A single count can therefore underestimate the number of breeding pairs (even if most adults have nested in a particular year). Local knowledge of the usual timing of breeding for particular regions or colonies is valuable, but beware of unusual seasons. Broad regional differences (e.g. earlier season in south-west England than in Scotland) may be evident, but do not apply to all colonies.

Counts are preferably made by viewing the colony from suitable vantage points (using methods similar to those developed for shags), with counts from the sea if necessary. Where complete counts from land or sea are not possible, counts based on aerial photography (*Method 2*) may need to be used. If colonies are counted from close range (e.g. after landing on islands or skerries), beware of causing large chicks to fledge prematurely if counts are made late in the season.

For detailed monitoring, comparison of peak annual counts is best. Counts at longer intervals (every 2-5 years) are also of some use, especially where they cover a long stretch of coastline. However, with this species and shag, there is a danger that less-than-annual counts may coincide with years when many adults simply have not nested. Apparent trends should thus be interpreted with caution. Annual counts will provide a clearer picture of fluctuations and provide a better context for assessment of 'real' changes.

Census units

The generally recommended unit is the *apparently occupied nest* (*AON*). This includes birds that appear to be incubating, unattended broods of young, and other attended, well-built nests including empty ones apparently capable of holding eggs. Nests at a lesser stage of construction are not included in the standard AON figures, but should be noted separately. At some colonies, the majority of nests are not visible from any vantage point and minimum counts of nests and visible adults may be all that can be achieved (if aerial or sea-based surveys are not possible).

Census method 1 (field counts)

This is a straightforward procedure, adapted from the methods developed for shags by Potts (1969) and Harris & Forbes (1987).

1. Cormorants tend to nest in discrete, well-defined groups within a given seabird 'colony', but these groups may shift slightly from year to year, and care must be taken to check all suitable habitat for isolated or newly-established groups. In some cases, islands, stacks or cliffs within a wider radius (perhaps 10 km or more) may be alternative breeding locations of a single breeding group. Assessment of local population changes should, wherever possible, be based on counts of groups of colonies or potential colonies.

2. The count should be made from suitable vantage points (including landing on islands if necessary) around the time when the maximum number of nests are occupied. This is rather variable in cormorants, and may require some judgement or local knowledge, but is often around the latter half of May. At some colonies, particular in the south of Britain and Ireland, counts are possibly best made in early to mid May. Counts during May-June are useful in most seasons if the precise timing of breeding is not known. Preferably, make a number of counts between early May and late June; the largest reliable count should be used as the final population figure.

3. If possible, make a number of counts of AONs between early May and late June. Report all counts, but use the highest reliable count at each individual colony (if >500 m apart) in arriving at a total for the whole region / length of coast.

4. Counts should, whenever possible, include an objective assessment of the general stage of the breeding cycle (e.g. ratio of trace to well-built nests, proportion of well-built nests that are empty). A subjective assessment of whether there seemed fewer nests than one would expect from the numbers of adults present may provide some indication of an unusually late or poor breeding season, or a season when many adults have not attempted to nest. Counts of 'loafing' adults, not at nests, can thus be useful (but avoid counts in the evening, when 'extra' immatures and sub-adults may come to roost).

5. Keep a note of (and map) any parts of a colony that might not be visible from land (e.g. the seaward side of a stack). Try to estimate (minimum-maximum) the number of AONs likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other

counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population). (Counts from aerial photographs may also be of use, but are obviously impractical for regular monitoring; see *Method 2.*)

6. If birds can be seen in part of a colony where nests might be hidden, keep an additional note of the number of adults visible in those parts and of the total number of adults visible at the colony. Counts of adults should *not* be included in any detailed assessment of population changes for a colony or coastline, but may be required if a whole-colony estimate would otherwise be incomplete.

Census method 2 (aerial photography)

1. This method uses aerial photography and follows the procedure outlined by Reynolds & Booth (1987). It is most useful for inaccessible sites such as stack tops where a substantial proportion of nests is not visible from ground or sea vantage points. Given the expense involved, it is not a suitable option for regular counts, but may be the only option if a complete, up-to-date count is needed for a particular population.

2. Photograph the colony from the air during the peak of the breeding cycle, when most sites are occupied. This requires some judgement, best made by direct observations of nests that are visible from land or sea; however, photographs taken during May-June are useful in most seasons if the precise timing of breeding is not known.

3. Make large prints of the photograph(s), or project slides onto a large sheet of paper attached to a solid surface (such as a wall). Count or mark all nests with adults sitting, chicks, or which appear to be substantially constructed. If using more than one photograph of contiguous breeding areas, beware of double-counting sites. If several observers count the same photograph to allow for inter-observer variability (recommended), use the mean count as the population figure.

4. Include assessments of the general stage of the breeding cycle and whether there seemed fewer nests than one would expect from the numbers of adults present, as in *Method 1* (point *4*).

Productivity-monitoring methods

The main difficulty with measuring cormorant productivity is the high degree of breeding asynchrony. In some colonies, pairs are still incubating or even nest-building when the first chicks fledge. Nevertheless, monitoring is straightforward, but an accurate result necessitates regular checks of a colony over an extended season (*Method 1*). Where this is not possible a few visits can produce a useful index for comparing success in different years (*Method 2*).

Chicks are usually conspicuous and easy to count, but large chicks may wander a short distance from the nest and form small groups with other broods (especially if disturbed by an observer). Thus it is not always clear with which nest chicks are associated. Use suitable vantage points wherever possible. If you approach nests closely, avoid disturbing adults off nests with eggs or small chicks or causing large chicks to fledge prematurely.

See *Appendix 4* for sample data sheets which can be used to record details of individual nests.

Productivity-monitoring method 1 (mapped nests)

The method outlined here is adapted from that developed for shags by Harris (1989a).

1. The method entails visiting the colony every 7-10 days from when birds start laying to check the progress of breeding at numbers of nest-sites until the young are fully feathered.

2. As with all monitoring, the problem is to reduce the chances that the samples you choose are atypical of the colony as a whole. If the colony is small (as is usually the case for cormorants), try to check all the visible nests. Even in a large colony, the higher the proportion of the population checked the better.

3. If the colony is large, sample plots must be chosen. It is better to choose many relatively small plots scattered throughout the colony than one or two large plots. A plot containing 10-30 nests is a reasonable size for this species. Two methods for dispersing these plots have been used:

a) Random selection: This is *not* haphazard. View or go through the colony and find all the groups of nests that can be checked accurately and safely, and randomly select as many subgroups as can be covered in the time available (see *General methods*).

b) Divide the colony into say four or five approximately equal parts (either by area or number of nests) and pick (say) one plot in each area. Have the same number of plots in each area. This method is not as good as a), but has been used where the number of possible plots is small.

4. Whatever you do, document exactly how you made your choice. If you are constrained to check only specific plots for some reason (e.g. safety, time, only places not to disturb birds), record this.

5. It is not strictly necessary to use the same plots each season for comparisons of breeding output.

6. Photograph each selected plot, preferably when birds are at their nests, and make a large (A4) black-&-white print. If possible, the positions from which nests are viewed (and photographed) should be sufficiently distant to ensure that large chicks will not be disturbed later in the season. This will minimise confusion caused by chicks wandering from their nests, although it may prove necessary to use a telescope when checking from longer range. Tape a transparent overlay on each photograph. Mark on the position of nests and number them. Alternatively, sketch the plot and the positions of nests, although this is more likely to cause confusion between nests during later checks.

7. Check each plot every 7-10 days from mid April onwards and for each nest record the state of the nest (e.g. few sticks, complete platform), nest contents (if visible - do not flush sitting birds), and if a bird appears to be incubating or brooding. Pay particular attention to large young as they sometimes move away from the nests. When larger chicks are present, it may be best to view the colony from a greater distance (with a telescope if necessary), to minimise disturbance of chicks (and thus the extent to which they wander from nests), provided this does not cause confusion over positions of individual nests. You will have to assume that well-feathered young that appear healthy and disappear between visits have fledged.

8. Express your results as both:

a) the total numbers of active nests (eggs or apparent incubation seen) which failed or which fledged one, two, three or four chicks. Record any further details of losses, for example predation; eggs did not hatch; chick dead in nest, possibly starved.

b) the total number of young fledged divided by the number of nests where birds were definitely or probably incubating.

9. Do not pool results from plots; there may be marked differences between plots and the mean productivity for the colony is best calculated as the mean of the plot figures ($\pm$ standard error). Also present figures for the individual plots.

Productivity-monitoring method 2 (comparison of nest- and chick-counts)

1. Decide if the whole colony can be checked in the available time; if not, select sample plots (see *Method 1*).

2. Check nests during the period when most birds are incubating. Record the total number of occupied well-built nests. This can be done at the same time as a whole-colony count.

3. Check again near the time the first chicks are likely to fledge and note the number of chicks at each nest (irrespective of age) and (if you've previously mapped nest positions) note any new nests. The index of productivity is expressed as the number of chicks divided by the number of AONs on the earlier date. If possible, keep a note of small chicks and try to check them later, to improve the accuracy of your estimate of productivity.

Shag *Phalacrocorax aristotelis*

Census / population-monitoring methods

Where shags breed in small groups or extensively along the coastline, surveys of lengths of coast are recommended. The boundaries of the census area should be clearly defined and consistent between years. In more discrete populations or for specific colonies, such as reserves, less extensive counts are also useful. For long stretches of coast, representative coverage may require counts of a random selection of short sections. Repeat counts are generally not needed, except to ensure that the (peak) count used is well timed.

Although it would be possible to map the locations of nests and record active nests throughout the breeding season (which can be protracted in this species), Potts *et al.* (1980) considered that the most consistent and accurate index of population size was the maximum number of nests occupied at one time, as breeding pairs often constructed more than one nest during a season. The timing of breeding within a colony can be highly asynchronous in some years, but, in 'normal' years, tends to be less marked than for cormorants.

A further source of inaccuracy in counts is the difficulty in finding nests. In many areas, shag nests are hidden in fissures or in caves and are easily missed. For whole colony counts, the use of a small boat or inflatable can allow many cave nests to be counted. Coverage of long stretches of sparsely occupied coast is also aided by the use of a boat. (But be careful: if counts are made too early in the season, considerable disturbance can be caused by close approaches in a boat.) Denser concentrations of birds, and stack and boulder colonies, are best counted from land, particularly if accurate information on population trends is sought.

The recommended method involves counting all apparently occupied nests at the peak of the breeding season. This is typically early June in the north and east of Britain, but may be several weeks later in some years (Harris & Forbes 1987), and several weeks earlier in the south-west (e.g. Potts 1969; Snow 1960) In some years, the peak of laying may be considerably later (or earlier) than normal, and this should be borne in mind when selecting the counting date(s). Any signs that the colony is not at the peak of laying during the count should be noted (see below). Shags may abandon breeding attempts *en masse* under adverse conditions, even at a late stage (Coulson *et al.* 1968), so, where multiple counts are available, the highest reliable count should be used.

For detailed monitoring, comparison of peak annual counts is best. Counts at longer intervals (every 2-5 years) are also of some use, especially where they cover a long stretch of coastline. However, with this species and cormorant, there is a danger that less frequent counts may coincide with years when a high proportion of adults simply have not nested. Apparent trends should thus be interpreted with caution; annual counts will provide a clearer picture of fluctuations and provide a better context for assessment of 'real' changes.

Census unit

The generally recommended unit is the *apparently occupied nest (AON)*. This includes active nests (bird sitting tight whether or not eggs or young were seen, or an unattended brood of young) and other attended, well-built nests (apparently capable of holding eggs). Nests at a lesser stage of construction should be recorded separately, as they are often abandoned, or destroyed by other pairs stealing nest material (Harris & Forbes 1987).

Census method

This is a straightforward procedure, following Potts (1969) and Harris & Forbes (1987).

1. Define clearly the boundaries of the census area, whether a length of coastline or a colony. This area should be consistent between years. For counting purposes and future reference, it is useful to subdivide this area further along natural features definable on a map, annotated with nest-counts.

2. The count should be made at the time when the maximum number of nests are occupied. For north and east Britain, this is normally early June (late incubation / early nestling period), but counts in mid June are acceptable. Further south, counts in late May are likely to be best, but local experience may be needed.

3. Counts should, whenever possible, include an objective assessment of the general stage of the breeding cycle (the ratio of trace to well-built nests and the proportion of empty well-built nests). A subjective assessment of whether there seemed fewer nests than one would expect from the numbers of adults present may provide some indication of an unusually late breeding season, or of a season where a large proportion of adults have not attempted to breed. Counts of 'loafing' adults, including those well away from any nests, can thus be useful (but avoid counts in the evening, when 'extra' immatures and sub-adults may come to roost).

4. If possible, make a number of counts of AONs between early May and late June. Report all counts, but the highest count of the whole colony/coastline on a single occasion (if considered at least as reliable as the other counts) should be entered as the final population figure. (If peak counts for each subcolony, regardless of what date they occurred on, are combined, the total is likely to be less comparable between years, as it will be dependent on effort to some extent.)

5. Keep a note of (and map) any parts of a colony that might not be visible from land. Estimate (minimum-maximum) the number of AONs likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population).

6. If birds can be seen in part of a colony where nests are difficult or impossible to see (e.g. caves, under boulders), from either land or sea, keep an additional note of numbers of adults visible. Counts of adults should *not* be included in any detailed assessment of population changes for a colony or coastline, but may be required if a whole-colony estimate would otherwise be incomplete.

Productivity-monitoring methods

Monitoring of shag productivity is straightforward, but an accurate result necessitates regular visits (*Method 1*). However, a few visits can produce a useful estimate for comparing success in different years (*Method 2*).

See *Appendix 4* for sample data sheets which can be used to record details of individual nests.

Productivity-monitoring method 1

1. The method described is taken largely from Harris (1989a) with amendments, and is used for pairs nesting on cliffs, rocks, and accessible boulder sites. It involves visits to the colony every 7-10 days from when birds start laying to check the progress of breeding at numbered nest-sites until the young are fully feathered.

2. As with all monitoring, the problem is to reduce the chances that the samples you choose are atypical of the colony as a whole. If the colony is small, try to check all the visible nests. Even in a large colony, the higher the proportion of the population checked the better.

3. If the colony is large, sample plots must be chosen. A plot containing 10-30 nests is a reasonable size for this species. If possible, check at least three study-plots (preferably five or more).

4. Two methods for dispersing these plots have been used:

   a) Random selection: This is *not* haphazard, but involves identifying all potential suitable study-plots and selecting randomly from these. See *General methods* for details of random plot selection.

   b) Divide the colony into (say) four or five approximately equal parts (either by area or number of nests) and pick (say) two plots in each area. Have the same number of plots in each area. This method is not as good as a), but has been used where the number of possible plots is small.

5. Whatever method you use, document exactly how you made your choice. If you are constrained to check only specific plots for some reason (e.g. safety, time, only places not to disturb birds or the public), record this.

6. It is not necessary to use the same plots each season, unless they are also being used for population monitoring.

7. Photograph the selected plots, preferably when birds are at their nests, and make large (A4) black-&-white prints. Tape over a transparent overlay. Mark the plot boundaries, and the positions of nests; number the nests. Alternatively, sketch the plot boundaries and nest positions, although this is more likely to result in confusion during later checks.

8. Visit the area every 7-10 days from mid-April onwards and for each nest record the state of the nest (e.g. few sticks, complete platform), nest contents (if visible - do not flush sitting birds), and if a bird appears to be incubating or brooding. Pay particular attention to large young on open ledges as large young sometimes move away from the nests. You will have to assume that well-feathered young (with little or no down remaining on mantle and upperwings) which appear healthy will fledge.

9. For each plot, express your results as:

a) the total numbers of nests where eggs or apparent incubation were recorded which failed or fledged one, two, three or four chicks. Add further notes on losses if possible, such as predation; eggs did not hatch; chick dead in nest, possibly starved.

b) the total number of young fledged divided by the number of nests where birds were definitely or probably incubating.

10. Do not pool results from plots; there may be marked differences between plots and the mean productivity for the colony is best calculated as the mean of the plot figures (±SE). Also present figures for the individual plots.

Productivity-monitoring method 2

1. This method is for use when limited time is available. Select study-plots as in *Method 1*. Again, try to cover as much of the population as is practical; in smaller colonies this may be all nests.

2. Check nests during incubation, and around the time when the first chicks are likely to fledge, when a search should also be made for additional well-built nests. Note the numbers of chicks in each nest and, if possible, their approximate size/age. A crude index of chick production is calculated as the number of chicks divided by the number of occupied, well-built nests. If plots are used, express the colony productivity as the mean of the plot means (±SE), and present data for each plot also.

3. This method will overestimate production, as it assumes all chicks survive to fledge. This can be lessened if a follow up visit or visits to check on small chicks is made. Be aware that nestling mortality can vary considerably from year to year, so results may not be directly comparable.

Arctic skua *Stercorarius parasiticus* / great skua *S. skua*

Census / population-monitoring methods

For skuas, apparently occupied territories (AOTs) can be counted relatively easily and with reasonable consistency. Although some may involve non-breeders, single counts of AOTs at the optimum stage of season may, nevertheless, underestimate actual breeding numbers by up to *c.* 7%, depending on levels of territory attendance by adults (Furness 1982; Ewins *et al*. 1988; Scanlan & Harvey 1988).

Attempts to count actual occupied nests are likely to underestimate numbers of breeding pairs to a much greater degree, unless observations are very intensive. Counts of nests are thus not recommended for general census purposes, as the completeness of such counts may vary between different observers, colonies or habitats, preventing detailed comparison of counts. (For detailed productivity monitoring, however, accuracy can be improved by individually marking and mapping nests through the season: see *Productivity method 2*).

'Clubs', where non-breeding skuas gather to rest together or display, are a common feature of large skua colonies. Counts of club areas may be useful, as the numbers present may indicate the general health of the colony, by reflecting past productivity, immature survival rates and levels of recruitment (Klomp & Furness 1992). Numbers of skuas on clubs vary markedly during the day, so it is important to record the time of day when club-counts are made. See Klomp & Furness (1990, 1992) for further details.

Further useful information can be collected during counts of arctic skuas on the relative proportions of light and dark colour-phases among territorial birds.

Complete counts have been made of skuas in Orkney and Shetland every 5-10 years since 1969. Monitoring at individual colonies is usually based on annual counts, but this may not be practicable at some larger colonies.

Census units

The recommended unit for counting both species is the *apparently occupied territory (AOT)* (Furness 1982; Ewins *et al*. 1988). An AOT is scored if any of the following are recorded:
a) nest, eggs, or chicks;
b) apparently incubating or brooding adult;
c) adults distracting or alarm-calling;
d) pair or single bird in potential breeding habitat, apparently attached to area.

The following should not be scored as AOTs:
e) bird(s) flying past, *en route* to somewhere else;
f) feeding individual(s);
g) single bird (or pair) flushed from an area, which flies completely out of sight;
h) three or more skuas of same species regularly together but not showing any signs of territoriality.

Census method

1. Areas should be surveyed between late May and mid-July, preferably in June.

2. Avoid disturbing colonies during wet weather (especially if breeding density is high, when transect walks are more likely to put birds off their eggs).

3. The best way to survey large areas of moorland is to walk rough transects at up to 500 m intervals, stopping at regular intervals (e.g. every 200-300 m) and thoroughly scanning all around. In areas of high skua density, closer transects will be needed, and it is important to sit or stand still to allow birds to re-settle.

4. Record all evidence of territorial skuas (e.g. using different code for nest, eggs, adults giving alarm calls), and plot sightings on large-scale maps. Territorial birds may utilise prominent mounds, which can be useful indicators of an AOT (though territorial birds may use more than one mound). Take care to avoid assigning members of the same pair, standing apart, to different territories.

5. If the ground is undulating, or any areas are not visible during the main transect surveys, transect walks may need to be more closely spaced. Alternatively, scan breeding areas from suitable vantage points using binoculars and telescope.

6. If there is uncertainty about the status of birds in any parts of the colony, check again on a different date in June.

7. For arctic skuas, if possible record the colour-phase of territorial adults: broadly, pale phase (light-coloured underparts) and 'dark' phase (including typical intermediates, dark apart from pale neck or ear-covert feathers). Where possible, record phases for each member of individual pairs.

Productivity-monitoring methods

The most practical method of assessing skua productivity is in terms of the number of young fledged per apparently occupied territory (AOT), by counts of AOTs in late May/June followed by counts of large or recently fledged chicks in July-August (*Method 1*).

A more intensive method is to mark and monitor the fate of individually marked nests through the season (*Method 2*), although this is usually only feasible at regularly visited colonies. Advantages of the more intensive monitoring include: (a) the timing of failure, and the proportion of eggs hatching and of chicks fledging, can be assessed (although more frequent checks would be needed for greater accuracy); (b) clutch sizes and egg volumes can be obtained for inter-colony and inter-year comparison; and (c) information on growth-rates of chicks can be collected.

Both methods are based, with modifications, on the methods outlined by Scanlan & Harvey (1988) for skuas in Shetland.

Productivity-monitoring method 1 (chicks fledged per territory)

1. Productivity can be assessed either for whole colonies (especially smaller ones, say <100 AOTs) or for sample areas of colonies.

2. If sample areas are to be used, these should if possible be selected randomly (see *General methods)*. In large colonies, try to follow 50-100 AOTs in total, preferably in two or more areas of similar population size.

3. Assess numbers of AOTs in late May/June (see *Census method*).

4. Keep a note of any chicks seen during June, and their approximate ages, as a guide to when the first chicks are likely to reach fledging age.

5. Visit the colony or sample areas about one week after you estimate the first chicks will have fledged. If the timing of breeding is not known in detail, a visit around 20-25 July will generally be suitable.

6. Using similar transect / scanning methods as for AOT counts (see *Census method*), map and count fledglings and well-grown chicks (any which have lost more than half of their down feathers on mantle / scapulars / upperwing coverts as a whole). Arctic skuas first fly when about 4 weeks old and great skuas at about 6 weeks, and fledglings of both species tend to remain in their natal area for 1-3 weeks after fledging. Fledgling arctic skuas have a distinctive dark, 'scaly' plumage because their dark brown feathers are edged light brown; fledgling great skuas appear more uniformly dark than adults. Recent fledglings also appear more round-winged than adults and fly rather poorly. Chicks that can fly stand up and are easy to see. Chicks that have not yet flown crouch and hide.

7. Be aware that some large chicks may be difficult to see, even if vegetation cover is limited. Some prior experience or practice at locating chicks is advisable.

8. If possible, try to relate each fledgling or other chick to a particular territory. In large or dense colonies, large numbers of flying young can cause confusion. In this situation it is best to retreat to a good vantage point and let the birds settle down. It should then be possible to pick out which young are associated with which territory. In any case, great care should be taken not to flush young, as they are very vulnerable to predation by neighbouring adult great skuas.

9. If individual fledglings cannot be related to particular territories, use the peak total count of fledglings/near-fledglings as your estimate of breeding output. Adults generally defend chicks that cannot fly, but once chicks are flying the adults are much less inclined to swoop at people; instead, they tend to fly with their fledglings, giving aerial protection.

10. If you notice any smaller chicks still present (i.e. ones which are still mainly downy above), keep a separate note of this. Small chicks can be *very* difficult to locate, so, if any are noticed, it may be better to delay the count of chicks by a week or so. Alternatively, on a later date, count only those 'large' chicks which would have been classed as 'small' on the first date, and add to the total of large chicks recorded on the first date.

11. For the colony as a whole, or for each sample area, divide the number of large chicks or fledglings produced by the number of AOTs. For two or more sample areas, express the colony's productivity as the mean $\pm$ standard deviation of individual figures.

12. Unless many small chicks have been missed (and not followed up), this method will usually overestimate actual productivity (chicks surviving to fly for the first time) slightly, as some breeding attempts may be missed by AOT counts and some large chicks may die before fledging. Further losses of recently fledged birds may occur. These are beyond the scope of productivity monitoring, but it is useful to record numbers of dead chicks/fledglings seen in the colony (eaten and uneaten chicks separately). Predation by other skuas is often the main proximate cause of chick losses.

Productivity-monitoring method 2 (chicks fledged per individually marked nest)

1. This more intensive method follows the fate of individually marked nests, in either the whole of a small colony or in sample areas of a colony.

2. If sample areas are to be used, these should if possible be selected randomly (see *General methods*). In large colonies, try to follow 50-60 nests in total, preferably in two or more areas of similar population size.

3. During the main incubation period (late May to mid June for arctic skua, mid May to mid June for great skua), visit the colony or each sample area two or three times at 10-15 day intervals.

4. Throughout the season, avoid colony visits during heavy rain, strong winds or prolonged wet weather, to minimise the risk of chilling of eggs or chicks,

5. On the first date, scan from suitable vantage points to locate incubating adults or other birds at nest scrapes. Mark each nest with a bamboo pole or wooden stake. To reduce disturbance, try to note the positions of several adjacent nests before marking them, rather than pin-pointing and marking each nest separately. After each nest or group of nests is marked, locate a suitable vantage point nearby from which to continue searching.

6. Nest markers should ideally be placed a set distance and direction from the nest, say 5 m SW. Care should be taken to ensure that nest markers are not too obvious, to avoid attracting the attention of people or predators to nests.

7. The positions of marked nests should be noted onto 1:10,000 Ordnance Survey maps where possible, with notes on any useful landmarks nearby, to aid locating nests later.

8. At the next check (10-15 days later), note the contents of each nest already marked. On the second and third visits, also search for and mark any other nests which have appeared since the first visit.

9. At a minimum, assess numbers of chicks fledging by visits every 5-7 days from around the date of first fledging onwards (roughly over the period 10th July to 10th August). Record numbers and approximate ages/sizes of chicks associated with each nest.

10. If possible, begin visits to check chicks every 5-7 days once hatching begins (which may be known from casual observations). At a minimum, keep a note of the approximate size/age of each chick. For great skua chicks, Furness (1983) provides some growth-curves relating wing-length and 'leg-length' (straightened leg from inner angle of intertarsal joint to tip of centre toe-nail) to age. Keep a note of any dead chicks and of any evidence as to cause of death. Preferably, chicks should be ringed by licensed ringers as soon as they are old enough (usually about 10 days, when wing-length for great skua is *c.* 40-60 mm, leg-length *c.* 80-115 mm), to allow individual identification. From that age onwards, chicks wander considerable distances and it is not safe to assume that such chicks near a marked nest necessarily belong to that nest. Ringing young chicks is essential if accurate data on production from marked nests are to be obtained.

11. If time allows, on each date weigh each chick to the nearest 1 g, and measure the wing (flattened, straightened chord of outer wing, excluding down) using a stopped wing-rule. This will provide information on growth-rates, which may give an indication of food availability. Try to ensure that handled chicks remain crouched and do not wander off (loose vegetation placed gently over the head may help). Also measure the wings of dead chicks: this will indicate approximate age at death.

12. Visits should continue until the outcome of each nest is known. Assume that any chicks surviving to 4 weeks old (arctic skua) or 6 weeks (great skua) will fledge successfully.

13. Express productivity as number of chicks fledged per nest found with eggs. Where two or more sample areas of a colony are studied, use the mean ($\pm$ standard error) of the individual figures.

14. Keep a separate note of any known post-fledging mortality, although quantitative assessment of this is difficult and it is not incorporated in the productivity assessment.

Skua recording sheet

Region: Colony: Species:

		Chick A			Chick B		
Nest	Date	Ring no.	Wing	Weight	Ring no.	Wing	Weight

Gulls (*Larus* spp.)

Census methods

The *Larus* gull species breeding in Britain and Ireland present similar problems, to some extent, for counting and population monitoring. Nevertheless, some species and situations present particular problems, for example cliff-nesting herring gulls *Larus argentatus*, large ground-nesting colonies of any species, or scattered pairs of common gulls *L. canus* or great black-backed gull *L. marinus*. The methods outlined below aim to cover most of the possible situations. Counts of gulls along coasts with cliffs and rocky islands are relatively straightforward (included in *Method 1*), and comparable to some other cliff-breeding seabirds. In general, the major difficulties arise with ground-nesting gulls, where vantage points are few or inadequate; *Methods 2-5* deal with such situations.

The main difficulties in counting gulls are the wide variation within species in the density of nesting and the size of colonies, the extended breeding season so that single counts may miss a large proportion of breeding attempts, and, for herring and lesser black-backed gulls *L. fuscus*, the impossibility of accurately differentiating nests of the two species where they breed together (unless occupied nests are viewed from a vantage point).

All of these problems can be overcome with sufficient effort, but gull counts usually have a fairly low priority compared with other survey work, and less accurate but more rapid methods are normally employed. The purposes of the count, the time and fieldworkers available (now and in future years if the count is not a one-off), and the level of disturbance counting will cause should be carefully considered before selecting a method. Rapid methods such as flush-counts of individuals may be sufficient if indications of large changes are all that are required, but flush-counts are difficult or impossible to use in any but small colonies (or discrete subcolonies). Monitoring of numbers at plots within a colony can achieve a similar objective with less disturbance (although expansion of colony boundaries will be missed), as can photographic counts, especially for larger gulls, where the colony is suitable. More intensive methods include counting quadrats and a variant of mark-recapture, where nests, not birds, are marked. Fully comprehensive methods involve pre-surveys, marking all nests, and a number of detailed counts spread over the entire egg-laying period.

Great black-backed gulls may be easier to count than other species at many colonies, as numbers may be low, with well-scattered, very territorial pairs whose positions can be mapped easily. Nevertheless, large, dense moorland colonies of this species also occur, particularly in northern Scotland.

Census units

The recommended census unit is an *apparently occupied nest (AON)*, i.e. a well-constructed nest, attended by an adult and capable of holding eggs, or an adult apparently incubating if, for example, actual nests are obscured by vegetation. Some count methods use slight variations on this (e.g. so-called active nests', containing eggs or with other signs of use, counted during transect or quadrat surveys, when attendance by adults is not possible to record). Some counts or estimates are made as 'apparently occupied territories' (AOTs), based on the spacing of birds or pairs viewed from a vantage point, if actual nests or incubation cannot be discerned. Counts of individual adults may also prove necessary on occasion.

Census method 1 (counts from vantage points, including cliff-colonies)

1. This method involves observation of the colony from one or more vantage points. It is most suitable for colonies on cliffs and rocky islets visible from the cliff-top, and for small ground-nesting colonies which can be viewed well from a distance (i.e. without many nests likely to be hidden by tall vegetation or undulations in terrain). In general, guidelines given in this method also apply to counts of roof-nesting gulls in urban or industrial situations, where access to a large number of vantage points (e.g. tall buildings) may be required for good coverage.

2. The preferred counting unit is the apparently occupied nest (AON). Where actual nests are likely to be obscured by vegetation, but sitting birds are visible, the count may need to include apparently incubating adults, but keep a separate note of these as well as presenting the overall count of AONs.

3. Where observations are made from more than one vantage point, care should be taken to avoid counting the same sites twice. This is usually easy to do using natural features. Sketches (e.g. outline map of a length of coast, with counts marked directly onto map) or photographs can also be useful, especially where boundaries are poorly defined.

4. Counts should be made during the mid incubation period, usually late May-early June, between 0900 and 1600 BST. Avoid counting in heavy rain, fog or high winds. Beware of double-counting

both members of a pair sitting in close proximity. Vegetation is usually lower earlier in the period, which may make counting easier.

5. Counts made later in June are also useful, but more difficult to achieve, as many chicks will have hatched, and careful scanning (especially of cliffs) will be needed to locate nests and chicks. Most nests will have an adult reasonably close by, but some adults may have left the colony after failing. If you are having difficulty locating nests, or lack time for detailed scans, keep a note of numbers of adults on the ground, on cliffs, or flying agitatedly over the colony. If nests without incubating adults are likely to be hidden by vegetation but standing adults are visible, count the total number of adults visible (and the number of adults separate from AONs) and attempt an estimate for 'apparently occupied territories' (AOTs) additional to AONs. This estimate can be based on the dispersion of adults over the colony, preferably quoted as a minimum-maximum range (to allow for members of some pairs standing a distance apart), although the errors involved in such figures are likely to be high.

6. If several counts of AONs are made over the period, use the highest total as the population estimate, but report all counts.

7. If parts of the colony are hidden from view, try to estimate (minimum-maximum) the likely numbers of nests involved and append to your actual count. (For cliff-colonies, a higher proportion of nests of large gulls is usually visible from the cliff-top than for species such as auks or kittiwake. However, hidden areas may be substantial for colonies on tops of stacks and at inaccessible ground-colonies.)

Census method 2 (sample quadrat counts)

1. This method is suitable for colonies that can safely be covered on foot. It is accurate but entails considerable disturbance of birds in survey plots. It may therefore not be appropriate where nest predation risk is high (almost always the case in gull colonies) and if gulls are given a high conservation value at a particular colony. A similar method is outlined in Tasker *et al.* (1991). For small numbers of great black-backed gulls nesting among larger numbers of other gull species, it may be better to attempt to map individual nest-sites or territories throughout the colony, preferably based on views from vantage points.

2. The counting unit is the active nest (effectively equivalent in this case to an AON), defined as a fully constructed nest containing eggs or chicks, or with signs of recent use such as fresh soil or nest material.

3. Early in the breeding season, map the boundaries of the colony. For small colonies, it may be possible to survey all nests. Otherwise, superimpose a grid on this map.

4. Select a number of quadrat points on the grid by the use of random number tables or some other *truly* random method (see *General methods*) even if some quadrats are open water or otherwise unsuitable for breeding. The more quadrats, the better; 30 is a reasonable sample.

5. Find the quadrat points by reference to natural or features, using triangulation and/or angles and distances where necessary. Mark these points with stakes (permanently if re-counts are planned in future). This is preferably done before egg-laying starts.

6. Quadrats can be of any shape (provided they can be easily defined and are all of equal size), but should be fairly large compared with those for other species given the relatively low density of nesting typical of gulls. Circular quadrats of 300 m^2 are generally suitable for the smaller species (provided nest density is fairly high), conveniently measured by using a rope 9.77 m long fixed to a

pole at the centre of the quadrat. Larger quadrats (up to 5,000 m^2) may be necessary for the larger species, especially where nesting density is low, as at some inland colonies on moors. Square or rectangular quadrats marked by stakes are more convenient for these larger sizes. Try to arrange the order in which quadrats are surveyed in such a manner that birds in a particular area of the colony are not continuously disturbed for longer than 30 minutes at a time. Counts of large areas will need a team of several people.

7. At a minimum, visit the quadrats when the bulk of the population is in the late incubation period (usually late May to early June). Count the number of active nests in each quadrat, and record the clutch-size (to assess the stage of breeding: many small clutches will suggest the count-date is too early). Be sure to cover the ground carefully as nests are easily overlooked; even experienced teams can miss 5-20% of nests in dense vegetation, where special care is needed (Ferns & Mudge 1981).

8. Preferably, visit the quadrats every few days throughout the laying period (which can continue well into the period when most pairs have chicks). Find and mark with a stake all active nests, including new nests as necessary on each date.

9. Where each quadrat has been counted several times, the relevant population figure for that quadrat is the maximum number of nests judged as active on any one date during the count period (otherwise the single count is used).

10. Estimate the total colony size as:

total active nests = (mean no. active nests per quadrat) x (total area of colony / area of quadrat).

Recounts of the same quadrats in future years allow comparison with this figure, but this comparison will be insensitive to changes in the area of the colony. Preferably, re-survey the colony extent each count-year, and re-establish a different random sample of quadrats.

Census method 3 (transect counts)

1. This method is based on Wanless and Harris (1984) and is generally used to provide counts of entire colonies. Like *Method 2*, it is suitable for colonies which can be safely covered on foot. If the colony is large, and the time or the number of fieldworkers available is limited, a decision may be needed as to whether sample quadrat counts (*Method 2*) will be more efficient than complete transect counts using the present method. Alternatively, see point *12* below.

2. The counting unit is again the active nest (equivalent to an AON), defined slightly differently than in *Method 2*: a fully constructed nest containing eggs and/or chicks (in or near the nest), or empty but judged capable of holding a clutch (i.e. well constructed).

3. Follow the pattern of laying by counting complete nests and clutches in sample areas (preferably randomly-selected: *General methods*) every few days and make the count of the complete colony when laying is completed. Alternatively, from casual observations you may be able to delay the count until the first chicks hatch. If this is not possible, delay the count until the last week of May, which is generally suitable for most species and regions.

4. Small colonies can be dealt with as a whole; large colonies should be divided into a number of areas along unambiguous landscape features (or if necessary rope boundary markers). Divide the colony or area into strips and station counters no more than 10 m apart.

5. Observers should zigzag across the strips so as to cover all the area.

6. Count and note contents of every complete (active) nest.

7. Mark each active nest as it is encountered. This is usually done by spraying a little paint on the side of the nest (avoid red paint or spraying the eggs), or by marking nests with bamboo canes. If the latter are used, count the canes before you start and subtract canes left over at the end to arrive at your transect totals.

8. At the end of the count, one or more observers (or better, someone who had not taken part in the count) should recount a sample of the area to determine the proportion of active nests that had been marked. This is best done by walking back and forth across the area at 90^0 to the route taken during the original count.

9. Repeat the above procedure for each transect.

10. The number of active nests in each area is recorded as:

(no. active nests marked) x (total no. of active nests on recount / no. of marked nests on recount)

11. Total population is the sum of active nests in each area.

12. In a very large colony, it may be impractical to count *all* nests in this way. A modification of this system of counting has been used effectively on Skomer (S.J. Sutcliffe, pers. comm.) by:

a) counting incubating birds and pairs within subcolony boundaries from a suitable vantage point (several such counts for each area are preferable);

b) counting some of the subcolonies by marking nests (as described above) and calculating the *ratio* of figures from *a* to figures from *b*, for the same subcolonies; and

c) applying the *average* ratios (from several subcolony counts) derived from *b* to the total from *a* to estimate the total population.

There can be very large differences between counts made by observational methods (*a*) and marking methods depending on the density of the vegetation. Subcolonies for counting using this method need to be chosen carefully to be representative of the whole colony.

Census method 4 (flush-counts of adults)

1. This method involves flushing breeding birds and is generally only used where terrain is very difficult or time is limited. It is only suitable for small colonies where all the birds can be flushed at once. The method is rapid, but the count obtained is only of use as a broad guide to colony size, and considerable disturbance is caused. Wherever possible, we recommend that other methods (*1-3*) be used, but we accept that this may not always be practicable. (A similar method can be used for counts of terns, but it is more useful for those species, as the relationship between numbers of adults and numbers of nests is better known. Also, terns tend to bunch more tightly in flight than gulls, and can thus be counted more accurately; in contrast, flushed gulls may fill the air over a colony and can be very difficult to count in large colonies.)

2. The census unit is the individual adult bird.

3. Counts can be made from early incubation until early fledging, but are best made during late incubation (usually late May/early June), during the period *c.* 0800-1600 BST.

4. Before disturbing the gulls, as a minimum estimate of numbers, count or estimate the number of adults visible on the ground and in the air.

5. Then flush adults from the colony and count them several times as they fly above the colony, separating the species as necessary. It is best if birds can be flushed from a distance using a horn or

other loud noise, but it may be necessary to approach the colony more closely in some cases. Standing in a prominent position overlooking the colony, or suddenly appearing above the skyline, will often flush most of the adults, while a sudden movement or sound may help flush those remaining.

6. Record the mean number of individuals counted. Correction factors to pairs are not advised for individual colonies, and the original counts should be reported.

Census method 5 (photography and aerial counts)

1. For large colonies of ground-nesting gulls, viewable from a distance but not accessible on foot or subdividable for direct field counts, good-quality photographs from suitable vantage points (or from a plane) are potentially useful for counts. See *Method 1* for appropriate timing of counts.

2. Using projected slides, or enlarged prints, it may be possible in some cases to distinguish and mark positions of incubating gulls, but other occupied nests are unlikely to be discernible. At best, a count of apparently incubating birds plus likely additional territories will be possible, but in many cases it may be possible only to distinguish individual adults. Separating different species will obviously be difficult or impossible, so photographic counts are most suited to single-species colonies.

3. Direct counts from the air, combined with photography, may be appropriate in some cases, such as inland areas with large gull populations scattered in many colonies (e.g. Bourne & Harris 1979). In such cases, species separation is more straightforward than from photos alone, although distinguishing AONs or apparent territories will still be difficult.

4. Aerial or photographic counts will, in general, be of little use for detailed population monitoring. However, they have potential for wider use in large-scale, basic surveys of inland gulls, in particular, and in identifying colony locations for further survey, particularly in remote areas.

Note on mixed colonies of herring and lesser black-backed gulls

It is not possible to separate nests of these species with any accuracy. For methods based on direct observation (especially *Method 1*), separating the two species is generally not difficult. For *Methods 2 & 3*, the number of active nests belonging to each species is estimated by finding the ratio of herring to lesser black-backs and partitioning the nest-count in proportion, although the error involved in this method has not been evaluated and may be considerable. Walk through all parts of the colony (as breeding pairs of the two species may be clumped) noting the numbers of birds of each species seen. Alternatively, this can be done with greater accuracy from a distance *provided* most of the colony area is visible from suitable vantage points and adults are easily visible. (If vegetation is high, differences in timing of the breeding season between species may result in a higher proportion of one species being hidden while incubating. Similarly, if the species are not well mixed throughout the colony, inaccurate species ratios may be derived from incomplete coverage.)

To some extent, this problem may also occur with black-headed gulls *L. ridibundus* and common gulls, and a similar approach can be taken. Eggs of these species are, with experience and comparison, somewhat easier to distinguish from each other, although there is some overlap in colour, weights and measurements. Assessing the species proportions from adult birds is probably more practicable than attempting to check a sample of clutches in detail (which poses sampling problems if species are unevenly mixed within the colony).

Productivity-monitoring methods

The major practical difficulty in productivity monitoring is the mobility of chicks. The standard method of controlling for this is to select naturally isolated small patches of breeding habitat (e.g. islets), to restrict the movements of chicks from a number of nests by enclosing small areas of the colony with low fences. Alternatively, ring/recapture methods can be used to estimate the total number of young produced.

We recommend (*Methods 1 & 2*) variants of a relatively simple capture/recapture approach which can be combined with ringing visits, or (*Method 3*) an approach based on fencing plots within the colony. Raw counts of ringed chicks provide some information (*Method 4*). For groups of birds nesting in inaccessible locations such as cliffs or stacks, a direct observational method may be employed (*Method 5*). All these methods involve some degree of inaccuracy. In particular, the assumptions involved in making capture/recapture estimates mean that results should be treated with particular caution.

For mixed colonies of lesser black-backed and herring gulls, see note at end on separating chicks of these species.

Table L.1 Incubation and fledging periods for gulls (overall ranges in parentheses) (Cramp 1983)

	Incubation period (days)	Fledging period (days)
Black-headed gull	24 (23-26)	*c.* 35
Common gull	mainly 24-27 (22-28)	*c.* 35
Lesser black-backed gull	24-27	30-40
Herring gull	28-30 (26-32)	35-40
Great black-backed gull	27-28	7-8 weeks

Productivity-monitoring method 1 (capture/recapture of large chicks)

1. This method estimates the number of chicks fledging from the colony. To express productivity as fledglings/breeding pair, an earlier count of apparently occupied or active nests will be required (see *Census methods*).

2. If possible, cover the whole colony as a unit. This will probably not be practical for larger colonies. These should be divided into large areas, where possible bounded by stretches of unused ground or natural barriers so that movement of chicks between areas is less likely. Chicks, particularly of the larger species or where vegetation cover is limited, can move long distances, up to 200-300 m, when disturbed. They will return to their nest-sites later but risk attack by adults. Keep visits as short as possible to avoid chilling of any eggs and small chicks still present.

3. Using capture/recapture methods, the least accurate (maximum) estimate of chicks fledged is derived if the colony is visited on a single date only (but two separate ringing runs) about a week before the first chicks fledge. If this is all that can be done, ring all chicks encountered that are large enough to be ringed safely (i.e. with no other judgement of their age); make a capture/recapture estimate as described below (*point 9*); and keep a note of the ratio of small to large chicks encountered. If, for example, the capture/recapture estimate is 150 'ringable' chicks, and a ratio of 20 small to 80 large chicks is recorded on the first run, the total estimate for chicks present is 150 + (150 x [20/80]) = 187 chicks. Because many of the small, unringed chicks are likely to die before fledging (as are many of the chicks large enough to be ringed), this estimate of chick production may be considerably higher than the actual number of chicks which fledge.

4. For the greatest accuracy, this method requires visits on two separate dates a week or more apart during the chick-rearing period, with multiple visits on each individual date. On the first date, move through the colony ringing chicks aged at least *2 weeks* (black-headed and common gulls) or at least *3 weeks* old (herring, great and lesser black-backed gulls), about a week before the first birds are due to fledge.

5. Later the same day, repeat the ringing exercise, aiming to capture all chicks of the requisite age; keep a note of how many of the recaptured birds have already been ringed, and ring any 'new' birds. At this stage, ignore any chicks below ringing age (these will be dealt with on the next date).

6. After about two weeks, repeat the above ring/recapture procedure for chicks which would have been less than 2 weeks (black-headed and common gulls) or 3 weeks old (larger species) at the time of the first count. This will allow estimation of the numbers of large chicks which have appeared since the first date. (On the second date, do not handle any chicks which look as if they might have been of ringable age during the first count, as in theory they should be included in the first date's estimate.) Also, on the second date, keep a note of any ringed chicks which have died since the first date.

7. On each ringing visit (on the first and subsequent dates), it is very important for this method that chicks are encountered at random. Therefore, ringed chicks should not be selected specially for recapture. Also, it is important that all parts of the colony are sampled at approximately even intensity on both runs. Thus it is better to move smoothly through a colony knowingly missing some chicks in all parts of it, rather than cover some areas very effectively and others not effectively at all. A useful method for achieving this is to `zigzag` through the colony in a haphazard fashion. Even coverage of the colony is easy to accomplish in small colonies but requires a conscious effort in large ones. Again, it is important to keep visits as short as possible to avoid chilling of eggs and small chicks.

8. In some breeding seasons there may be a substantial number of chicks too young to ring at the time of the second run. If so, a third run may be necessary.

9. To estimate the number of 'ringable' chicks present on the first date, divide the number of chicks ringed on the first run by the proportion of large chicks, recaptured on the second run, that had already been ringed:

> first-date estimate = (total no. ringed) x (no. of birds handled on recapture run / no. of these that were already ringed)

For example, if 90 chicks were ringed on the first run, and 100 large chicks, including 50 already ringed, were recaptured on the second run, the total number of large chicks present is estimated as 90 x (100/50) = 180 chicks (of which 140 were actually ringed over the two runs).

10. Similar calculation is done for the second date (based only on chicks that were not of ringable age on the first date):

> additional estimate = (total no. ringed) x (no. of birds handled on recapture run / no. of these that were already ringed)

11. If some of the chicks ringed on the first date were found dead on the second date, some correction for this mortality should be attempted. For example, if 10 ringed chicks were found dead (of 140 ringed), estimated number of large chicks which died = 180 x (10 / 140) = 13. The number of large chicks surviving from the first date is thus estimated as 180 minus 13 = *c.* 167 chicks.

12. Estimated number of chicks fledged is the sum of the calculated number of chicks from all runs combined.

Productivity-monitoring method 2 (assessing ratio of ringed to unringed fledglings)

1. This method estimates the number of chicks fledging from the colony. To express productivity as fledglings/breeding pair, an earlier count of apparently occupied or active nests will be required (see *Census methods*). The method is not suitable for mixed colonies of herring and lesser black-backed gulls unless observers are experienced at distinguishing the closely similar juvenile plumages. (See note at end on separating these species.)

2. As the method involves checking fledglings, which may not remain in the immediate vicinity of their nest-sites, the whole colony should be treated as a unit.

3. Ring as many large chicks as possible from the date ringable chicks first become available until about one week after the first flying young are seen. Although some small chicks may be ringable, they are less likely to survive to fledging, so ring only chicks that are at least *2 weeks* (black-headed and common gulls) or at least *3 weeks old* (larger gulls), as in *Method 1*. Keep visits as short as possible to avoid chilling of any eggs and small chicks still present. Keep a note of any ringed birds subsequently found dead in the colony.

4. Re-check the entire colony after the bulk of chicks have fledged, and check fledglings and near-fledglings for rings, using telescopes and binoculars. Note the relative numbers of ringed and unringed birds. A total count of fledglings is not needed, but you should attempt to check as much of the colony and check as many birds as possible.

5. Where movements of fledged birds to or from other colonies is not a problem (e.g. where a colony is well separated from others, and it is not too late in the season), fledglings present on tidal rocks, on the sea close inshore, or in other habitats close to actual breeding areas can be included to improve sample sizes. If there is any doubt, however, confine checks of fledged birds to those present within known breeding areas.

5. The number of fledging young is estimated as:

(no. of chicks ringed - no. of ringed chicks known dead) x (total of fledglings or near-fledglings checked / no. of these bearing rings).

For example if 500 chicks have been ringed, of which 20 are known to have died before fledgling, 480 ringed chicks are estimated to have survived; if only half of the fledglings checked bear rings, then the estimate of surviving chicks can be doubled, to 960.

Productivity-monitoring method 3 (use of enclosures or other confined plots)

1. The method involves monitoring the survival of young in accessible, small, discrete patches of breeding habitat from which chicks cannot disperse while flightless (e.g. artificial or natural islets), or in enclosures where chick dispersal is prevented. Direct counts of unfenced plots can considerably under-count the true chick population.

2. Ideally, enclosure sites should be selected at random using a grid superimposed on a map of the colony. Often, however, logistical restrictions or the convenience of using naturally isolated units result in haphazard selection of sites. If this is the case, bear in mind that nesting success often varies in different parts of the colony due to factors such as density, exposure, and the age of the subcolony.

3. Most studies have used a small number (1-5) of relatively large enclosures for logistical reasons, each enclosing up to 40 nests. A larger number of smaller enclosures may be preferable on statistical grounds, but may result in less representative data if predation occurs in the colony. Small plots may render chicks more susceptible to avian predation. Where the aim is to obtain productivity data representative of a colony, enclosed plots should not be more or less susceptible to predation than unenclosed sections of the colony. This can pose methodological problems at colonies where mammalian predators (e.g. rats *Rattus* spp.) are active. Enclosures should be constructed using stakes and chicken wire or (preferably) plastic-coated Weld-mesh, about 35 cm (1 foot) high. Care should be taken that chicks will be unable to force their way under or through seams. If possible, construct the enclosures before the breeding season, to minimise disturbance.

4. Assess average productivity of pairs in each pen by counting the number of apparently occupied nests during incubation, noting any additions during the season (if nest positions have been numbered or mapped), and counting chicks just before the first ones fledge. If chicks are ringed or individually marked, and fairly frequent visits are made, it should be possible to follow each individual to fledging through the season. For each enclosure, productivity is expressed as the number of chicks fledged divided by the total number of breeding pairs.

5. Overall productivity can be expressed as the mean $\pm$SE of the figures from individual enclosures.

Productivity-monitoring method 4 (chick ringing totals)

1. This is a simple raw count of chicks ringed, which needs to be compared with an earlier count of apparently occupied or active nests. Errors may be large, as some ringed chicks will die and probably many chicks will be missed, so productivity may be substantially overestimated in a poor season or underestimated in a successful season. Accuracy improves with increasing effort, and *Method 2*, which requires minimal additional effort, should preferably be used instead.

2. Where possible, ring over the entire colony. If this is not practical, average productivity for the colony can be estimated based on defined areas (preferably selected randomly: *General methods*).

3. Attempt to ring every chick. Several visits over the course of the season are greatly preferable, but a single visit just before the first chicks fledge is better than nothing. Also keep a note of the numbers of chicks too small to ring, and of any eggs still present.

4. Productivity is expressed as the number of chicks ringed divided by the number of pairs breeding in the ringed area. Any information to suggest that the productivity figure is an overestimate (e.g. casual reports of many dead chicks later in the season) should be noted; equally, however, in a good season the number of chicks ringed may actually underestimate numbers fledged.

Productivity-monitoring method 5 (observation of mapped nests)

1. This method may be used for groups of gulls (usually herring gulls) nesting on cliffs, or in other inaccessible locations (e.g. offshore stacks) where nests can be observed directly but not visited. It is based on the methods used for kittiwake. Accuracy is limited if visits are brief or few, but can be improved if observer has time to sit and watch the colony at weekly or two-weekly intervals.

2. Locate nests from vantage points during the incubation period. Mark their positions on sketch maps or photographs.

3. Check all again a few days before you estimate the first chicks are due to fledge. Count all the large chicks (3+ weeks for the three large gulls) visible. Note separately the number of small chicks and any nests with apparently incubating adults.

4. Estimate productivity as the number of large chicks divided by the number of nests. Also report the number of small chicks and incubating adults (preferably re-check these on later dates).

Identifying herring gull and lesser black-backed gull chicks and fledglings

This will often be necessary when productivity-monitoring is taking place in mixed colonies. Downy chicks can not be reliably separated. Well-feathered chicks are separable in the hand by several criteria. The most reliable method is to check the primary feathers (particularly the inner ones) and the primary coverts (R.G.B. Brown in Spencer 1984; Baker 1993). Fledged young can be identified in the field with more difficulty (Grant 1986).

Chicks

In the *lesser black-backed gull*, the primary-coverts and most of the primaries are a uniform black or blackish-brown (blacker than those of herring gull), and the *inner primaries are generally not different from outer in coloration* (although they sometimes have distinct pale tongue-like areas, with dark speckles, on the inner web).

In *herring gull* chicks, the primaries are generally paler brown than on chicks of lesser black-backed gulls, but (in many birds) *become darker from the innermost primary (P1) to the outermost (P10)*, which may be dark brown or blackish-brown. Specifically, P10-P8 may be dark brown with small white tips, and the paler half of inner web becomes very pale at the base. P7-P5 are similar, with the light area progressively better defined, lighter, and more tongue-shaped, sometimes centrally peppered with dark brown, particularly on P5. P4-P2 have the light area often reaching almost to the white tip,
and central peppering more prevalent; they almost always have a well-defined pale brown tongue or mirror on outer web, sometimes only weakly indicated, occasionally extending to P5 in pale birds, generally strongest on P3. P1 is similar but the mirror on the outer web is usually reduced or obscure. The *primary coverts are mid to dark brown, paler than on lesser black-backed gull,* narrowly tipped with buff-white.

Fledglings

Separation of these species is difficult in the field, but reliable identification becomes possible *with practice*. See Grant (1986) for useful photographs and additional details. The features listed in *Table L.2* features are probably the most useful for standing birds:

Table L.2 Separation of fledgling lesser black-backed and herring gulls (from Grant 1986)

	Lesser black-backed gull	Herring gull
Mantle and scapulars	'Scaly' pattern, formed by pale fringes to dark feathers, more obvious and contrasting.	Slightly paler, less 'scaly' pattern.
Tertials	Clearcut, narrow, whitish fringes to dark feathers.	Obvious pale, wide 'notches' along sides of dark feathers.
Colour of bill	Bill black without pale base.	Usually a prominent, diffuse pale area at base of blackish bill, mainly on lower mandible.

Great black-backed gull chicks

Fledglings of this species pose little identification problem, as they are obviously larger, with much heavier bills, than fledglings of the other species. Larger chicks are also fairly obvious, but mistakes may be made with smaller or medium-sized chicks. The shape of the bill is a good feature as, even in quite small chicks, the bill appears disproportionately deep in relation to its length, compared with the other large gulls. Plumage distinctions are more difficult to describe, but may become apparent with experience at handling gull chicks.

Kittiwake *Rissa tridactyla*

Census / population-monitoring methods

Population monitoring of kittiwakes is aided by their usually nesting in distinct, localised colonies, and by their construction of obvious nests. Nevertheless, for accurate and representative results, care is needed. The generally preferred method of population monitoring is to count apparently occupied nests (AONs: see *Census units*), although not all nests may be laid in, and immatures often occupy unattended or abandoned nests. Nevertheless, it remains the most accurate method of assessing the breeding population, as it is difficult to confirm laying and birds that have lost eggs usually remain in attendance at nests during the incubation and early nestling periods.

The main problem in censusing large kittiwake colonies is the combination of the high density of nests and the fact that nests may appear haphazardly positioned over large areas of cliff, not just on long, linear ledges. It is easy to double-count or overlook nests under such conditions.

Surveying longer stretches of coastline rather than individual colonies is recommended as there can be substantial variation in the rate and direction of population change among colonies (and among subgroups in a single colony). In extreme cases, entire colonies shift location over a few years. As a result, population trends within a single colony may not reflect the status of a local or regional population as a whole (Heubeck *et al.* 1986).

Some workers at Alaskan colonies recommend a series of counts of individuals as the most appropriate method of quantifying population size and detecting trends, especially in populations where a large proportion of adults may not breed (e.g. Hatch & Hatch 1988). This method has the disadvantage that relatively ephemeral changes in the population of adult-plumaged pre-breeders can strongly affect the final figure, and is not routinely used at British or Irish colonies. Nevertheless, counts of adults may be of some use in indicating changes in attendance levels from year to year, perhaps in relation to changes in food availability.

Most counts of kittiwakes aim at assessing the peak number of nesting pairs. A greater number of nesting attempts can be detected by mapping individual nests (cf. *Productivity-monitoring methods*), but this is impractical for any but the smallest colonies.

At some colonies, numbers of AONs in study-plots are counted 5-10 times in June. Study-plots are not recommended for general use, unless plots are randomly selected and cover a large proportion of the colony total. Even then, changes in population distribution between colonies may not be detected, or may be misinterpreted as population increases or declines. In any event, counts made over a period should not be averaged, as later counts can be lower in years of higher breeding failure. If several counts are available, use the peak count for all plots combined (or the entire colony if counted) as the population figure, unless there is reason to believe that the highest count is due mainly to observer error.

Census units

The generally recommended unit for counts and population monitoring is the apparently occupied nest (AON), defined as a well-built nest capable of containing eggs with at least one adult present. (Poorly built 'trace' nests with adults in attendance are more likely to involve non-breeding birds, but additional counts of these can be useful, as a high proportion of trace nests may indicate a late breeding season or, possibly, a decrease in the proportion of adults breeding.) Late in the season, large numbers of apparent trace nests may indicate that many nests have failed and subsequently deteriorated.

Census method

1. The procedure outlined here follows Heubeck *et al.* (1986), with modifications.

2. Define clearly the boundaries of the census area, whether a stretch of coast (recommended) or a colony. This area should be consistent from year to year. Within colonies, subdivide into subsections of coastline, using natural features definable on a 1: 10,000 Ordnance Survey map. Appropriate habitat along the whole census area should be checked before or during the main counting period to detect newly established colonies. In particular, look for and map any kittiwake roosts on cliffs, as they can develop into colonies.

3. On individual cliff-faces, especially where numbers are high, subdivide using obvious ledges, fissures, or other features, to avoid under- or double-counting (photographs or rough sketches are helpful).

4. Keep a note of (and map) any parts of a colony that might not be visible from land. Estimate (minimum-maximum) the number of AONs likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population). Boat counts of nests are quite useful for this species (as compared with counts of individual guillemots) as there is little danger that the nests will be hidden when viewed from below (although separating trace from well-built nests can be difficult if viewing angles are severe).

5. For colonies / coastlines with small or sparse colonies, boat counts (in calm conditions) of some sections can provide accurate figures and allow rapid checking for new colonies. However, large or dense colonies are often very difficult to count accurately from a boat, so as much of the colony as possible should be counted from land.

6. Where possible, counts should be made several times within a breeding season during the latter half of incubation (when numbers of nests are most stable), usually late May to mid-June, although a single count in early to mid-June is acceptable. In either case, counts of each section of cliff should be repeated, where possible, as a check on accuracy.

7. If the season appears to be unusually late (indicated by a high proportion of 'trace' nests or unoccupied well-built nests in June), a count in late June is a useful further check.

8. Count all apparently occupied nests (AONs). Separate counts of unattended empty nests, unattended eggs or dead chicks, occupied trace nests, and adults can be useful in addition (if time allows).

9. The final total of AONs should be reported as the highest reliable count of the whole colony (not the sum of individual subsection peaks).

10. For detailed monitoring of kittiwake populations, we recommend counts of AONs for whole colonies, or, preferably, longer stretches of coast, repeated at 1-5 year intervals.

Productivity-monitoring methods

Breeding success can vary considerably among subgroups in a colony and between colonies on the same stretch of coast, so where the population is too large for monitoring of all nests (as will frequently be the case), random selection of study-plots is recommended (see *General methods*). The safety of observers and minimisation of disturbance to birds remain paramount in study-plot selection. For highly accurate assessment of breeding output, visits to study-plots would be made every 2-3 days throughout the season, recording the degree of construction of nests, dates of laying, hatching and fledging, etc. This is too labour-intensive a method for general use. The recommended, low-input method (*Method 1*) requires 2-4 visits, to map apparently occupied nests (AONs) and record the numbers of chicks likely to fledge. If nests are not mapped, *Method 2* can still provide useful data, based on comparison of counts of AONs early in the season with counts of chicks around the time of fledging.

Productivity-monitoring method 1 (mapped nests)

This method was developed by Harris (1987, 1989a). See *Appendix 4* for sample data sheets which can be used to record details of individual nests.

1. If the colony is small, the observer should try to check as many of the nests as possible. If it is large, plots should be dispersed throughout the colony or along the stretch of coastline. Identify all potential plots of 50-100 nests that are safely viewable without causing undue disturbance. If possible, randomly select as many of these plots as practicable, or otherwise disperse them through the colony (see *General methods*). Several small plots are more likely to be representative than one or two large plots; aim for 5-10 plots of 50-100 nests. The initial check and marking of 50-70 nests on photographs may take an hour or more, but later checks will be both quicker and easier.

2. Photograph the selected plots (black-&-white prints) when the birds are present and, preferably on nests (say, during May). Photographs can be used for several years as many of the same nest-sites and ledges will be used each season. *Good photographs are essential*, with nest-positions clearly distinguishable. Have a maximum of *c.* 70 nests per print, but prints may be overlapped if necessary for slightly larger plots.

3. Make large prints (A4 size is ideal) and tape transparent overlays onto the prints. Write on these using a fine-tipped waterproof pen. (Alternatively, mount the negatives as slides, project onto clean white paper, mark the nests, sites and prominent cliff features, and make photocopies for field use.)

Sketches showing nest positions can also be used if photographs are not available early enough in the season, but even greater care is required to avoid confusion between nests.

4. Visit the colony in late May and mid June (or, if two visits are not possible, once in early June) and mark the following on the overlays or on sketch-maps:

a) nests with birds apparently incubating;

b) other complete attended nests;

c) other site-holding birds with even a trace of a nest;

d) any unattended well-built nests (empty or otherwise).

5. Do not spend a lot of time trying to estimate clutch size or to confirm nest contents for standing birds (although keep a note of any clutches or empty nests that are immediately apparent); the basic unit is the well-built nest regardless of its contents.

6. Number the nests or traces sequentially, and note the state of each on a check-sheet. (Or, to avoid using check-sheets in the field, use different symbols on the photo overlays to indicate different categories of nest.) Suitable codes include 'I' = apparently incubating adult; 'c/1' = clutch of one egg; 'c/0' = empty well-built nest with adult in attendance; 'c/x' = well-built nest with adult standing, contents unknown; etc. (see data sheet: *Appendix 4*). Using different symbols to mark nests or traces on photos can speed recording.

7. On second or later visits, ensure that all nests checked on the first visit are re-checked and their contents noted. Add any additional nests or traces that have appeared since the first visit.

8. On early visits, keep a note of any chicks which have already hatched and their approximate age (see ageing guide attached: *Tables K.1-2*).

9. Estimate when first fledging should occur (incubation period *c.* 27 days, fledging from 35 days). Make a visit as close to this time as possible, check each nest marked previously and add any new nests. Note the numbers of young at each nest on your check-sheet, with an indication of their age or size. As a minimum, mark the number of 'large' young (wing tips reaching or extending beyond tip of tail, little or no down) present alongside each nest on the overlay (different coloured pen for each visit) or check-sheet. Also note any young that are *not* near to fledging, i.e. with wing tips obviously shorter than the tail and split them into 'medium' (well-developed black-and-grey upperwing pattern) or 'small' (largely downy). More detailed notes on age are worth taking if time permits (see *Tables K.1-2* for guidance).

10. Do not waste time trying to determine the numbers of very small young in late broods. Try to return 5-7 days later and check these late nests. The more checks made, the better the result.

11. When assessing how many young you think may fledge, remember that large young sometimes move between nests, that young in broods of two or three sometimes fledge several days apart, and that fledged young may return for several days to their own or other nests. Keep a note of any obvious 'runts' noticeably smaller than their siblings and check for their presence on the next visit. Assume that any large young (wing-tips $\geq$ tail) noted on the previous check have fledged if they disappear between visits. On the final visit, assume all large and medium chicks remaining will fledge. Keep a separate record of the number of small young. Where many broods (>20%) are still small and downy, please attempt a further visit. If there are fewer small chicks, assume half of them will fledge, as a *very rough* approximation.

12. For each plot or whole colony, productivity is calculated as the number of chicks fledged divided by the number of completed nests. Where plots are used, colony productivity should be expressed as the mean $\pm$ standard error of the figures for the individual plots.

13. If you wish to follow population changes in your study-plots (or changes in use of particular nest-sites or ledges) in subsequent years, label the transparent overlays with the year and plot boundaries and retain for future reference.

14. For assessment of productivity in the same plots, keep the original photos (and negatives) safe. If major changes in distribution of nest-sites within a plot occur later, it may become difficult to mark nest-positions accurately using old photographs; in such cases, it is useful to re-photograph the plot, but in most cases this should not be necessary.

Productivity-monitoring method 2 (comparison of nest- and chick-counts)

This method can provide a useful indication of breeding output if few visits are possible in a season, or if insufficient time is available for *Method 1* to be employed.

1. Visit the colony late in the incubation period (ideally in early or mid June) and count AONs as described under *Census method* above. If you cannot count the whole colony, select plots the usual way, preferably randomly (see *Method 1* and *General methods*). Even if the whole colony is covered, it is worth keep a breakdown of your count by subcolony sections marked on a map, as this may highlight any local variation (perhaps reflecting disturbance or predation in parts of the colony).

2. If other visits are made during June, repeat your counts of AONs.

3. Note any chicks that are visible during your early visit(s), and their approximate age (see *Tables K.1-2*), as a guide to timing of the season.

4. Revisit the colony when you estimate the first chicks are capable of fledging (35 days after hatching). A visit around 15 20 July is usually suitable if chicks were not seen in early June.

5. Count chicks, and split into large, medium, and small categories. If the number of chicks in a specific nest is unclear, use the average brood size from other nests.

6. For each subcolony or plot record the number of medium/large chicks in July. If fewer than 20% of chicks are still small, assume half of these will also fledge. If a higher proportion is small, it will be necessary to redo the chick count a week or more later.

7. If the whole colony has been covered, express productivity as the sum of all chicks considered to have fledged divided by the sum of the peak AON counts from each subcolony.

8. If only a sample of the colony has been covered, divide the number of chicks considered to have fledged in each plot by the peak AON count for that plot. Then calculate the mean $\pm$ standard error of individual plot figures to give an estimate of colony productivity.

9. The figures obtained will usually overestimate actual productivity by 10-20% (partly because some breeding pairs will have been missed, partly because of subsequent loss of chicks). Overestimation may exceed 20% in some seasons and colonies (further documentation is needed), and will be greatest if the initial count of AONs was made too early in the season or if many of the chicks counted in July do not survive to fledge.

Table K.1 Guide to assessing age of kittiwake chicks (Maunder & Threlfall 1972; Harris 1987)

Description	Average age (days)
Black tips to feathers of neck just visible	9
Tail feathers erupt	10
Black tips to upper wing-coverts visible	11
Black tips to vanes of tail feathers	16
Most down lost but still some on top of head and back	25-30
Wing tips equal length of tail	30
Wing tips 1-2 cm longer than tail	36
Wing tips 3-4 cm longer than tail	40-45

Table K.2 Alternative suggestions for assessing size- or age-categories of kittiwake chicks

Description	code*	size-category
Chick completely downy	a	Small (S)
Downy chick, but black tips to upper wing-coverts just visible	b	S
Clear grey/black pattern visible on upperside of wing, but still some down on upperwing, and mainly downy elsewhere	c	Medium (M)) or M/S
No down on upperside of wings, some down elsewhere	d	Large (L) or M/L
No down visible, wing tips at least equal to length of tail	e	L
Wing tips 1-2 cm longer than tail	f	'Fledgable' (F)
Wing tips 3-4 cm longer than tail	ff	Fully fledged (FF)

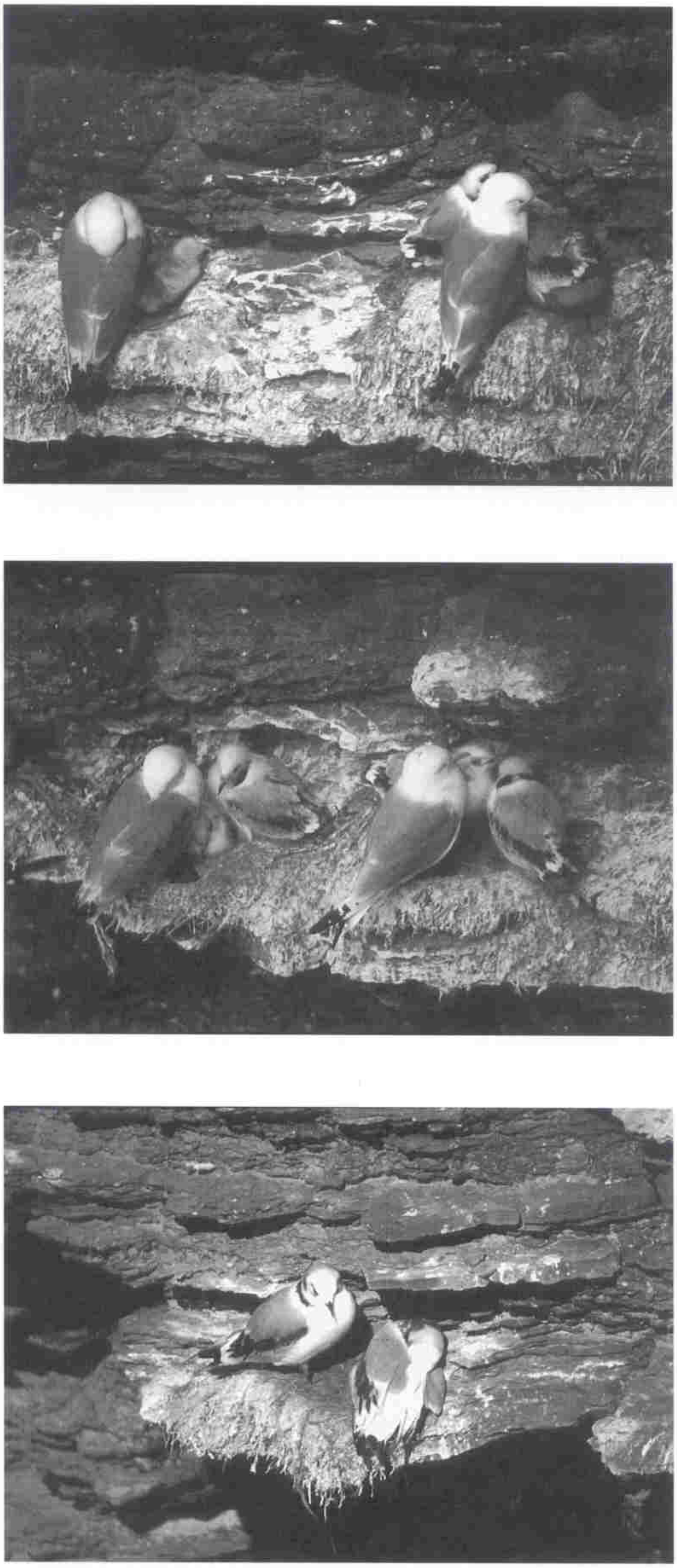


Plate K.1 Examples of (top) small and medium-sized, (middle) medium-sized, and (bottom) large kittiwake chicks. Copyright: P.M. Walsh.

Terns (*Sterna* spp.)

Census / population-monitoring methods

Population estimates for tern colonies can be difficult to make, and become increasingly difficult for larger colonies, especially where vantage points are few. Census methods need to be standardised as far as possible, although particular colonies (or regions) may present different counting problems.

In Shetland and Orkney, a simple method (flush counting of individual adults: *Method 3*) was developed by Bullock & Gomersall (1980). This method allowed rapid censusing of many arctic and common tern colonies, often large or in difficult terrain. It has subsequently been used for RSPB's 1989 census of arctic terns, and for annual monitoring, in the Northern Isles (Avery *et al.* 1993; RSPB, unpublished). The method can be used at virtually any tern colony, but should be backed up with counts of clutches (*Method 2*) or of apparently incubating adults (*Method 1*) where possible. At colonies where more than one method is used it will be possible to calibrate one against the other.

For many colonies, counts using *Methods 1* or *2* should be possible, and, if accurate and made on appropriate dates, provide a more direct assessment of numbers of breeding pairs. These methods, or variations thereof, are currently used at most monitored colonies outwith the Northern Isles. In some cases, however, the methods or count dates used may be rather vaguely defined, and we would recommend that, in all cases, the methods used should be carefully evaluated. If existing methods appear to be giving inaccurate results, consideration should be given to using one of the alternative methods. Further advice on particular colonies may be sought from RSPB's Research Department.

A general point to bear in mind about tern counts is that, in comparison with other seabirds, populations of breeding terns can be very mobile. In some cases, whole colonies may shift location from year to year or a large proportion of one colony may move to a different colony (not always nearby) in a different year. Pairs that fail at one colony early in the breeding season may even move to a different colony later in the same season. For these regions, trends or fluctuations in counts of single or few colonies may in some cases simply reflect movements to or from other colonies (or regions). Study areas for population monitoring should thus be defined as broadly as possible. In particular, attempts should be made to fill 'gaps' between currently monitored colonies.

All tern colonies are very sensitive to disturbance, and counters should attempt to keep this to a minimum. Terns should never be flushed from their nests during rain or strong winds. In Britain and Ireland, a special licence is required to disturb roseate and little terns at the nest; this also applies to Sandwich terns in the Republic of Ireland (see *Introduction*).

Census units

For general use, counts of apparently occupied nests (AONs) are recommended. Since tern nests are generally shallow scrapes and thus not apparent at any distance, these counts should be specified as referring to either apparently incubating adults or active clutches (plus empty nests with material).

Where AON counts are not practicable, record total numbers of adults visible or, preferably, flushed from the colony. (Distinguish between adults visible in or flushed from the nesting area and those loafing outside the nesting area. Loafing areas are usually adjacent to the colony and below high-water mark.)

Census method 1 (count of apparently incubating adults)

1. This method can be used at colonies where all (or most) occupied areas can be viewed from vantage points without disturbing birds from nests.

2. Assess the extent of the colony, and choose suitable vantage points from which to make counts. Be aware that growth of vegetation may obscure some areas of ground initially visible.

3. Preferably, make counts at weekly intervals between mid May and late June (especially late May to early June). Alternatively, make at least one count late in the incubation period (*c.* 3.5 weeks after the first incubating birds are seen). Counts in early to mid June will often be suitable if the timing of the season is not known in detail, but peak counts of AONs can occur as late as early July for common terns in western Scotland (J.C.A. Craik, pers. comm.). Count the number of birds that appear to be incubating a clutch of eggs. With a little practice, incubating birds may be distinguished from resting off-duty birds by their different posture. An incubating bird will be partly hidden because it is sitting on eggs in a hollow or scrape and the tail will be pointing upwards at an angle. A bird resting, but not incubating, will usually have a distinctly different appearance, as terns usually stand when resting. Resting terns will be tend to be more visible (although slightly undulating terrain may complicate this) and the tail will be held at a shallower angle than an incubating bird. Where nests are sufficiently widely spaced, it is usually possible to distinguish members of the same pair (one sitting, one standing nearby).

4. If any actual nests or clutches are visible, record minimum numbers of these. Unless terns have been disturbed during the count, unattended nests or clutches are most likely to have been abandoned.

5. If the colony is large or complex, several vantage points may be needed. Take care that parts of the colony are not double-counted (or missed), by noting any physical features that can be used to subdivide the area being counted.

6. Report counts made on each date, and use the peak count for the whole colony as the figure for year-to-year comparisons. (If peak counts are recorded separately for different parts of the colony, then summed, it is possible that any failed breeders that re-laid elsewhere in the colony might be counted twice.)

7. If a small proportion (say <20%) of the colony is believed to be hidden, attempt to estimate (minimum-maximum) the likely number of incubating birds involved, based on densities elsewhere in the colony. If possible, check this estimate using one of the other methods below.

Census method 2 (counts of apparently occupied nests, with eggs or nest-material)

1. This method is useful where a colony cannot be viewed in its entirety from suitable vantage points, but is small enough (or has enough subdivisions) that a complete 'ground' survey can be made quickly, without prolonged disturbance. Examples of such colonies might include small rocky islets that can be visited by boat and counted quickly on foot.

2. Visits should not be made to colonies in poor weather (cold, windy, wet) or very hot conditions. To minimise disturbance it may be best to make several short visits rather than one long one. As a rule, not more than 20 minutes should be spent in a colony. However, in large colonies it may be possible to work in one part of the colony without disturbing incubating birds in another part. Care should be taken that predators such as gulls and skuas do not take advantage of your presence to rob unguarded nests. Be aware of signs that birds are becoming stressed, for example flock dispersing or fights breaking out. Always err on the side of caution. If in doubt, leave the colony and return on a later date.

3. Try to assess the timing of the breeding season by briefer, periodic observations, to record the first eggs or incubating birds.

4. Counts of nests with eggs should be made late in the incubation period, *c.* 3.5 weeks after the first egg is seen in the colony. This will generally coincide with the peak number of occupied nests in the colony. Counts in early/mid June will usually be suitable if the timing of the season is not known in detail, but see *Method 1* (point *3*). Also, keep a separate note of numbers of empty nest-scrapes that contain some nest-material. If many empty nests or single-egg clutches are present on this date, this may indicate that a count a week later would be more suitable. (Empty nests may also reflect predation, although there may be other signs, such as broken eggs, about the colony. Empty scrapes, without any material, are less likely to have held eggs, and courting terns may make several scrapes before eggs are laid.)

5. If the colony is small, or different parts of the colony can be visited on consecutive days, a single observer may suffice. For larger colonies, several observers walking in line through the colony may be used. Coverage should be thorough enough, or observers close enough together (*c.* 3 m apart), that few or no nests are missed.

6. Count-accuracy can be improved and double-counting avoided if each clutch is marked with small flags or other markers (not necessarily numbered) such as clothes-pegs or lollipop sticks. Nest-markers should not be too obvious, to avoid attracting the attention of humans or predators.

7. To check the completeness of the count (especially if terrain is complex), correct for count efficiency by walking through the colony at a different angle and noting the ratio of marked to

unmarked clutches. For example, if 250 nests were initially marked, and a re-check the same date recorded a ratio of 230 marked to 15 unmarked nests, correct the initial count to ([245/230] x 250) = 266 clutches.

8. If possible, second and third counts should be made 1 week and 2 weeks later, using the same methods (but different tags to mark nests, if tags are used). Count the total number of clutches on the second and third visits, and, on each date, correct for count efficiency as on the first date.

9. If second and third visits are to be made, the highest of the three counts (each, ideally, corrected for count-efficiency on the day) can be used as an index of the breeding population.

10. If more permanent nest-markers (e.g. small stakes) are used on the first date, the *cumulative* number of clutches recorded over the three dates will provide an alternative measure of the population.

11. If clutches are not marked during on the first date, the cumulative number of clutches can also be recorded by making a second visit 3 weeks later (by which time most of the earlier clutches will have hatched).

12. If possible, record clutch sizes on each visit, but a rapid, accurate count of active nests should be the priority. Keep a note of any obviously deserted eggs (displaced, long-broken, or excessively dirty and coated with droppings).

13. Report your results as:

a) peak count of active clutches (i.e. the highest of the counts made on several days, corrected for count efficiency where possible);

b) cumulative total of active clutches recorded over all count dates;

c) counts of active clutches (both corrected and uncorrected, i.e. raw data) on *each* date;

d) additional numbers of empty nests (with material) for each date.

14. Comparisons among years or colonies are perhaps best based on peak counts. Cumulative totals of clutches may allow for the spread of breeding (e.g. some pairs may fail before others lay), but can also include repeat clutches by some failed pairs in new scrapes, so may be less suitable for comparisons.

Census method 3 (flush-counts of individual adults)

1. This method is designed for use particularly in colonies or regions where counts of apparently incubating adults or active clutches are generally difficult. It is also useful where large numbers of colonies need to be covered rapidly.

2. Flush-counts should be carried out in the last 2 weeks of incubation and first week after hatching. On each visit multiple counts should be made and an average taken; it is best, where feasible, if several people make independent counts. Counts should if possible be made on three dates (say, weekly) through this period. As second best, a single count in early June may suffice.

3. On each date, as a minimum estimate of numbers, count or estimate the number of adults visible on the ground and in the air, before you flush birds. Also count birds resting on the edge of the colony before flushing birds from the nesting area.

4. Flush adults from the colony and count them several times in the following few minutes as they wheel around above the colony in a tight flock (little terns will flock less tightly than other species). It is best if birds can be flushed from a distance using a horn or other loud noise, but it may be necessary to approach the colony more closely if it is extensive.

5. Flush-counts provide two different population estimates depending on the time of day they are carried out. Counts carried out in late morning (1000-1200 BST) can be used to give a good estimate of the number of breeding pairs (see points *7-8* regarding individual/pair conversion factors). Non-breeders tend to be absent at this time. If counts at other times are necessary, they should be confined to the period 0800-1600 BST. Keeping a separate note of birds resting outside the colony (point *3*) can also help. Record the time of the count.

6. At colonies with more than one tern species, flush-counts are more difficult (particularly so when common and arctic terns need to be distinguished). Where possible, accurate counts should be made of each species. This will be easier if more than one observer is present and one person can concentrate on a single species. In mixed colonies different species are rarely completely integrated but, when flushed, flocks may not be species-specific. At large colonies it may be impractical to count each species accurately. In this situation it will be necessary to flush-count the whole colony and obtain population figures by estimating the proportions of each species from sample counts.

7. The flush-count method is quick, quantitative and repeatable. Without calibration with nest-counts it may give inaccurate estimates of breeding numbers, but these estimates will still be useful in assessing changes in numbers from year to year. In Orkney and Shetland a relationship between flush-counts and the number of occupied nests was established for arctic terns (Bullock and Gomersall 1980). It was found that the number of flushed birds was equivalent to about 1.5 times the number of nests in a colony around midday in the main incubation period. However, the correction factor may vary according to species, time of day, state of incubation, weather, food availability, or other factors.

8. Wherever possible both nest-counts and flush-counts should be made to allow comparison of calibration factors between different colonies and species. Please send any such figures to RSPB Research Department or JNCC's Seabird Monitoring Programme.

Productivity-monitoring methods

In broad terms, productivity is assessed as by dividing the estimated number of fledged young produced at a colony by the estimated number of apparently occupied nests (i.e. fledged young/AON). At its simplest (but least accurate), this can be based on single (or peak) counts of AONs early in the season (or an estimate of breeding pairs based on flush counts of adult terns) and of large chicks and fledglings later in the season (*Methods 4-5*).

A single count of chicks (e.g. on a ringing visit) will usually underestimate the number of large chicks produced by a colony. Mark/recapture work is recommended for more accurate estimation of chick numbers (e.g. Nisbet & Drury 1972; Coulson 1987) (*Methods 1-2*). Such methods require a great deal of effort, however, so are not generally suitable for widespread use. Perhaps the most efficient method involves ringing chicks and later assessing the proportion of fledglings that bear rings (*Method 3*).

Depending on the particular circumstances at a colony, including time and fieldworkers available, some variation or combination of *Methods 1-5* may need to be used. If failure rates are high at the egg stage, or among large chicks (immediately before they fledge), all methods will tend to overestimate productivity to some degree.

Because different pairs may vary widely in their timing of breeding, and chicks may wander through a colony, it is usually not practicable to follow the survival of individual chicks (except in very detailed studies or in small colonies). As with *Larus* gulls, it will therefore usually be necessary to count or estimate numbers of chicks that reach a certain minimum age and assume that these survive to fledging. For practical reasons, this age will usually be about a week before the first chicks are capable of flight, as otherwise too many colony visits would be needed. In general, most mortality of tern chicks occurs in the first week or two after hatching (e.g. Nisbet & Drury 1972). We recommend that chicks reaching 2o weeks old (or 10 days for little tern) should be assumed to fledge, unless they are subsequently found dead before reaching the fully fledged stage. However, if predators are active in the colony, pre-fledging mortality may be seriously underestimated. If possible, watch for predation or signs of predation and report what you observe. See *Tables T.2-3* for some guidance on ageing tern chicks.

In mixed colonies of terns, separation of chicks of different species requires experience, and is particularly difficult for common and arctic terns. See the section on *Identifying common tern and arctic tern chicks*.

Productivity-monitoring method 1 (multiple visits at egg and chick stage, with mark/recapture counts of chicks)

1. This method may be used for whole colonies or for definable sub-sections of a colony. It should only be considered suitable for small colonies, or for larger colonies where several fieldworkers are available. Otherwise, the time required for marking and recapturing chicks is likely to involve too much disturbance.

1. If several sample plots are used, they should preferably be selected randomly (see *General methods*). At some colonies, there may be existing subdivisions (e.g. small islets), but at most colonies, the mobility of chicks will make it difficult to study sub-sections unless enclosures are used. Nisbet & Drury (1972) found the following set-up to be safe and effective for common terns: chicken-wire fencing of 1-inch (2.5-cm) hexagonal mesh, enclosing areas of 70-400 m^2, height 9 inches (230 cm), with a further 2-3 inches (50-80 cm) buried to prevent chicks digging their way out. Within each enclosure, medium/large chicks were easy to locate (small chicks could pass out through the mesh, but returned to their immediate nest-area for feeding). However, some studies have found that a smaller mesh (1 cm) is better (P.J. Ewins, pers. comm.). Such enclosures are *not* suitable for Sandwich and little terns, but may work for arctic and roseate terns.

2. Where the aim is to obtain productivity data representative of a colony, enclosed plots should not be any more or less susceptible to predation that unenclosed sections of the colony. Even a low fence such as that described above may reduce depredation by small mammals, if present (e.g. rats *Rattus* spp. or hedgehogs *Erinaceus europaeus*). The use of protective fencing to prevent predation by mammals is not dealt with here. If used in part of a colony only, comparative data on productivity in unprotected parts of the colony would be useful.

3. Throughout the season, avoid colony visits during heavy rain, strong winds or wet weather, to minimise the risk of eggs or chicks becoming chilled. Visits in very hot conditions should also be avoided.

4. Within the colony as a whole or each study-plot, count AONs as described fully under *Census method 2* above.

5. Marking and numbering nests may help with counts, but, except where nests are sparsely distributed, it will usually be difficult to relate large chicks to individual nests. The procedure below does not attempt to do this.

6. Marking (ringing) and recapturing of chicks should be used to estimate numbers fledging. Mark/recapture necessitates at least two ringing visits on a given date (or successive days), and visits at intervals of 7-10 days will usually be necessary to account for the spread of hatching dates of chicks.

7. About a week before you estimate the first chicks fledge (e.g. based on casual observations of timing of season: see *Table T.1*), the colony should be visited and chicks at least 2 weeks old (10 days for little tern) should be ringed by a licensed ringer (see *Tables T.2-3*). Chicks smaller than this should be ignored (even if well-developed enough to be ringed safely), as they are less likely to survive to fledging. Try to ensure that handled chicks remain crouched and do not wander off; loose vegetation placed gently over the head may help. However, large chicks may run away whatever is done.

8. Measure the wing-length of each chick (flattened, straightened chord of outer wing to nearest 1 mm, excluding down) using a stopped wing-rule, to provide a guide to chick age (*Table T.2*), or assign chicks to the broad size/age categories (cf. *Table T.3)*.

9. Later on the same date, go through the colony again, recording ring numbers of chicks already ringed, and noting any unringed large chicks (these should now be ringed). The 'search efficiency' of the first 'run' can thus be assessed, and the estimated number of large chicks for that date corrected accordingly. For example, if 110 large chicks are ringed on the first run, and a second run records 70 ringed and 30 unringed large chicks, the total number of large chicks can be estimated as (110 x [100/70]) = 157 large chicks on that date. Search efficiency will be highest in small, fenced plots.

10. On each ringing visit (on the first and subsequent dates), it is very important for this method that chicks are encountered at random. Therefore, ringed chicks should not be selected specially for recapture on second runs. Also, it is important that all parts of the colony (or of a study-plot) are sampled at approximately even intensity on at least the second run. Thus it is better to move smoothly through a colony knowingly missing some chicks in all parts of it, rather than cover some areas very effectively and others not effectively at all. A useful method for achieving this is to 'zigzag' through the colony in a systematic fashion (zigzag in different directions on the second run). Even coverage of the colony is easy to accomplish in small colonies but requires a conscious effort in large ones. Again, it is important to keep visits as short as possible to avoid chilling (or overheating) of eggs and small chicks.

11. On at least one or two further ringing visits, at about weekly intervals, repeat the mark/recapture exercise for chicks that would have been 'small' on the previous ringing date but which have now reached the 'large' stage. Again, two ringing visits are made on each date, as outlined in points *8-11* above. On the basis of measurements or size/age-class (*Tables T.2-3*), chicks encountered on these later dates can be allocated to two groups. Those that would have been 'large' on the previous visit should be *ignored* (or ringed but *not* used in calculations), and those that were below the minimum age (or not yet hatched) should now be ringed.

12. Your mark/recapture estimates for large chicks on each ringing date should thus, in theory, be mutually exclusive (though some errors/overlaps may result from inaccuracies in ageing chicks). When combined, these individual estimates will provide an estimate of the total number of large chicks produced over the season.

13. Also on these later ringing dates, keep a note of any ringed chicks found dead before they reached the fully fledged stage.

14. The estimated number of chicks fledged from the colony or sample plot is the cumulative number of large chicks recorded over the season, minus large ringed chicks found dead-before-fledging. Where sample plots are used, calculate productivity (chicks fledged per nest) separately for each plot, then calculate the mean ± standard error of the plot figures.

Productivity-monitoring method 2 (counts of apparently incubating adults, with multiple visits to mark/recapture chicks)

1. Count apparently incubating adults as described fully under *Census method 1*, preferably on several dates over the incubation period (to provide a peak figure).

2. Assess numbers of large chicks at about weekly intervals using the mark/recapture ringing techniques described under *Productivity method 1.*

3. Divide the cumulative estimate of numbers of fledged chicks (= chicks which reached 'large' stage) by the peak count of apparently incubating adults, to provide an estimate of productivity.

Productivity-monitoring method 3 (assessment of proportion of ringed birds among fledglings)

This method is from Nisbet *et al*. (1990). It yields an estimate of productivity during the peak period of nesting only, but has been successfully applied to large colonies (up to 4,000 pairs) and is less labour-intensive than *Productivity methods 1-2*.

1. Count nests during the peak incubation period only (*Census methods 1-2*).

2. Ring large chicks once, about the time of fledging by the earliest chicks. Ring as many chicks as possible.

3. Several times over the next 2-3 weeks, examine fledglings on the edge of the colony and count ringed and unringed birds.

4. Estimate the number of birds fledged as:
(number of chicks ringed) divided by (proportion of proportion of fledglings with rings).
For example, if 500 chicks have been ringed, and 40% of fledglings bear rings, estimate = (500/0.4) = 1,250 fledged.

Productivity-monitoring method 4 (nest/incubating adult count, with single count of large chicks)

1. This method is less accurate, but may be all that is possible for colonies that can be visited only infrequently. It is most suitable for colonies that are small or where laying and hatching dates are similar for most pairs.

2. Depending on the colony or other logistics, count either apparently incubating adults or 'active nests' as described fully under *Census methods 1-2.*

3. Avoid disturbing the colony during heavy rain, strong winds or prolonged wet weather, to minimise the risk of chilling of eggs or chicks.

4. Estimate when the first chicks are likely to fledge, based on observations of first eggs or early-hatched chicks; early July will often be suitable if other information is not available. Around the date of first fledging (± 1 week), count large chicks (10-14 days old, depending on species - see *Tables T.2-3*), including any fledglings nearby which are obviously associated with the colony. Chicks may be counted from a suitable vantage point at some small colonies, although some may be missed. Keep a separate note of numbers of smaller chicks and unhatched eggs.

5. Preferably, record large chicks during a ringing visit (or short visits to different parts of the colony). Care should be taken to ensure that handled chicks remain crouched and do not wander off (loose vegetation placed gently over the head may ensure this). Particularly if terrain is difficult, or colony is large, attempt a mark/recapture estimate by making a second visit later the same day (see *Productivity method 1*), to correct for large chicks missed on the first 'run'.

6. Estimate productivity as number of large plus fledged chicks divided by peak count of apparently incubating adults or active nests. This may be a substantial underestimate of productivity in some cases (as some large chicks may be missed, while smaller/unhatched chicks may also survive), although some large chicks may die before actual fledging.

Productivity-monitoring method 5 (flush-counts of adults, with single or multiple counts of large chicks)

1. This method is least accurate of all, and involves estimating breeding numbers of terns using flush-counts of adults, as described under *Census method 3*. As noted there, correction factors from individuals to pairs may vary, but a factor of 1.5 adults = 1 pair has been used for midday counts of arctic terns in Shetland and Orkney. For productivity estimation, this method should only be used where time or logistical constraints prevent more accurate censusing, or where figures for chick numbers become available for a colony that has only been censused using the flush-count method.

2. Numbers of chicks fledged can be estimated as under *Productivity methods 1-4.*

3. Express results as, for example, an estimated 50 chicks fledged from a colony where 300 adult terns were counted (estimated 200 AONs) = estimated 0.25 chicks fledged/AON. When reporting results, make it clear that the estimates are based on flush-counts, as the potential errors are high.

Table T.1 Average incubation and fledging periods for terns (overall ranges in parentheses) (Cramp 1985)

	Incubation period (days)	Fledging period (days)
Sandwich tern	25 (21-29)	28-30
Roseate tern	23 (21-26)	mainly 27-30 (22-31)
Common tern	21-22	mainly 25-26 (22-33)
Arctic tern	22 (20-24)	21-24
Little tern	21-22 (19-22)	mainly 19-20 (15+)

Table T.2 Ages at which tern chicks should be recorded as 'potentially fledging', and wing-lengths at these ages

	Chick age	Mean wing-length* (mm) of chicks *
Sandwich tern	2 weeks	-
Roseate tern	2 weeks	-
Common tern	2 weeks	-
Arctic tern	2 weeks	125-140
Little tern	10 days	varies 55-70 (50-80)

*Wing-length is maximum chord (straightened, flattened) from tip to carpal joint: presented as mean(s) of measurements for chicks 13-15 days old (9-11 days for little tern), with overall ranges, where available, in parentheses. Sources: Coulson (1987); Davies (1981); Norman 1992.

Table T.3 Plumage-classes and ageing characters defined by Nisbet & Drury (1972) for common and roseate tern chicks, with data for a few 'retarded' chicks (third chicks in common tern broods and second chicks in roseate tern broods) given in parentheses

Plumage class	Characters		Age (days) Common tern	Roseate tern
1	Newly-hatched. Legs short, fat. Chin black.		0-1 (2)	0-2 (2)
2A	Legs elongated, narrow shank between foot and joint. No pin feathers on outer wing.		2-5 (6)	few data
2B	Pin feathers present on outer wing but not erupted. Black chin almost gone.		6-9 (11-12)	few data (12)
3A	Pin feathers erupted on outer wing.		8-12 (13-19)	11-13 (14)
3B	Tail feathers erupted (shaft visible), but less than 6 mm long (white not visible). Black feathers not visible on nape.		12-15 (13-20)	13-16
4A	Tail feathers >6 mm (white visible), but down still on tips. A few speckles of black show through down on nape when brushed.		15-18 (22-23)	15-20 (21)
4B	No down on tips of tail, but down on tail coverts. Black appearing on nape. Mantle feathered with some down tips.		17-23 (21-28)	18-22 (23)
5A	Nape black with speckles. No down on back, but a little down on tail coverts. Older birds fly when frightened.		21-25 (21-31)	20-24 (28)
5B	Fully feathered, free-flying. No down except on forehead.		24 onwards	23 onwards

Notes: Plumage characters defined primarily for *common tern*. In *roseate tern*, head plumage develops relatively faster and flight-feathers relatively slower, and age-classes for roseate tern are based on the latter (Nisbet & Drury 1972). In *little tern*, pin feathers on outer wing (primaries) erupt when chick is between 7-8 and 12 days old (apparently variable between colonies: Davies 1981; Norman 1992).

Identifying common tern and arctic tern chicks

For these species, useful features are summarised by Ewins (1983), Craik & Harvey (1984),and Craik (1985). The best and most widely used method for half-grown and larger chicks is to measure the length of the tarsus, which is longer in common tern (relative to other body measurements) than in arctic tern. There is some overlap in measurements between smaller chicks of both species, but, for well-grown chicks, with bill-length to feathering >19 mm, a good general rule is that chicks with tarsus-length >20 mm are common terns, chicks with tarsus-length <19 mm arctic terns. Some practice is needed, however, to ensure that inter-observer differences are not major. See Craik & Harvey (1984) for full details.

Using a combination of down colour in smaller chicks and tarsus-length in larger chicks, virtually all chicks of these species can be separated from hatching age onwards (Craik & Harvey 1984). *Table T.4* gives a summary of the most useful plumage features. Again, however, practice is needed in applying these criteria correctly.

Table T.4 Some plumage features for distinguishing chicks of common and arctic terns (Craik 1985; J.C.A. Craik pers comm.)

	Common tern	Arctic tern
Upperwing pattern in chicks near fledging (with well-developed juvenile plumage)	Black carpal bar.	Grey carpal bar.
Colour of dorsal down (head and body) in younger chicks	Some variation between individuals, but always some shade of brown (cinnamon-brown to 'house mouse' brown); apparently *never* grey.	Much more variable than common tern, from rich walnut brown to silvery-grey with a range of intermediates. Percentage of the grey form varies between colonies.
Pattern of spotting on upperbody in small downy chicks (0-6 days)	Black spots on back are large and few.	Black spots on back are small, many, and finely elongated along body axis.
Colour of down on belly in younger chicks	Invariably pure white (unless wet or dirty).	Varies between chicks, from dark (white with a dark cast which may be intense or slight) to pure white.

Tern recording sheet 1

Region	Colony	Species	Date	Time	Flush count (adults)	Apparently incubating adults	Nest count	Comments

TERN RECORDING SHEET 2

Region: Colony: Species:

		Chick A			Chick B			Chick C		
Nest	Date	Ring no.	Wing	Weight	Ring no.	Wing	Weight	Ring no.	Wing	Weight

Guillemot *Uria aalge*

Census / population-monitoring methods

Guillemot populations are very difficult to quantify accurately. The species breeds at high densities, and builds no nest, so that identifying individual breeding attempts is not practical for whole colonies of any size. The number of birds present at the colony is highly variable, as numbers of 'off duty' adults and immatures can vary substantially from day to day. As a result, the precision of population estimates based on counts of individual birds is not high, although counting between 0800 and 1600 BST reduces the variability of counts somewhat (Harris *et al.* 1983).

Considerable effort has gone into devising more accurate methods of quantifying guillemot populations for monitoring purposes, and the most suitable technique at present is based on counts of individuals in randomised study-plots (Harris *et al.* 1983). Randomisation is important because population trends can vary considerably between different subgroups within a colony. As a result these should preferably be selected on a statistically valid basis if plot trends are to be extrapolated to the whole colony. Some existing monitoring schemes are based on plots which were chosen haphazardly or for convenience. Harris *et al.* (1983) recommended a gradual changeover between systems, although Mudge (1988) suggested that existing study plots should not be changed until the balance of advantages related to continuity and representativeness are better known.

The combination of census and monitoring methods used will depend on the time and resources available. If detailed monitoring of plots is carried out, count of the entire population should be made as a check on whether the colony appears to be expanding or contracting. Whole-colony counts may also allow limited assessment of whether plot counts are reflecting changes in the colony as a whole, although the larger errors associated with whole-colony counts may prevent a detailed comparison. Mudge (1988) suggested a re-survey of whole colonies every 5-10 years.

Detailed population monitoring should be based on 5-10 counts each year, annually if possible but otherwise once every 2-3 years.

In general, we do not recommend that observers attempt to count breeding pairs of guillemots in the field. Number of breeding pairs can be determined for study-plots if detailed, photographic checks of mapped nest-sites are made (see *Productivity-monitoring method*), but this is too time-consuming, assuming representative coverage of a colony is obtained, for most purposes. Detailed studies at some colonies have found that a count of one bird at a guillemot colony is roughly equivalent to *c.* 0.67 pair (Birkhead 1978a; Harris 1989b) , but such a conversion factor should *not* be used routinely. Counts should *always* be expressed in the census unit actually used in the field, to avoid problems of interpretation. There is also some evidence that the relationship between numbers of adults and numbers of breeding pairs is different at some colonies (e.g. del Nevo 1990).

Further details of census methods for guillemots, including an intensive method for relating numbers of individual guillemots to numbers of breeding pairs, are given by Birkhead & Nettleship (1980).

Census units

The recommended census unit is the *individual adult* on land. Counts of breeding pairs are virtually impossible without highly intensive observations of mapped study-plots.

Whole-colony census method

The following method is modified from the method in Evans (1980).

1. Define the limits of the colony and keep a breakdown of counts by subdivisions clearly definable on an Ordnance Survey map. Counts of individual cliff-faces will be aided by further subdividing counts according to obvious ledges, fissures, or other features.

2. Counts are best made in the first three weeks of June (incubation/early nestling period), between 0800 and 1600 BST. Counts in late May or late June are acceptable if counts are not available for the optimal period. Counts in July are not recommended as numbers decline rapidly after chicks begin to fledge. Avoid counting on days with heavy rain, fog, or winds stronger than Beaufort Force 4. Note weather conditions at the time of each count.

3. Count individuals on potential breeding ledges, but do not count birds only loosely associated with the colony, i.e. at the base of the cliffs or on the sea. (Attempts are sometimes made to exclude 'obvious non-breeding areas' on the cliff-face itself, e.g. temporary 'clubs' of non-breeders which may be present high on cliffs. We do not recommend such attempts, as judgements of breeding status can be very subjective and may prevent comparisons with counts from other colonies or by other observers.)

4. When time is limited, or the colony is very large or dense, numbers may be assessed in groups of 5-10 birds if necessary (helped by practice and trial runs). Less accurate counts or estimates may be necessary if time is very limited, but such figures will be of little use for detecting other than very large changes in numbers.

5. Flat-top subcolonies, for example on stacks, can be extremely difficult to count where there is no good vantage point from above, and in such cases aerial photography might be the most accurate method. In most cases, estimates will have to suffice.

6. Cave subcolonies are usually difficult to count. They may require climbing down the cliff for a better view (but avoid disturbing birds or compromising on safety), or approaching from the sea. It is normally only possible to obtain minimum counts for these areas.

7. Where guillemots are breeding underneath boulders, large numbers may be hidden, and it may only be possible to obtain minimum counts of visible birds. If some boulder areas are accessible, however, it may be possible to derive correction factors for hidden birds (see *Razorbill, census method 1* for full details).

8. Keep a note of (and map) any parts of a colony that might not be visible from land. Estimate (minimum-maximum) the number of birds likely to be hidden, based on numbers on visible sections

(although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population).

9. If possible, the count of sections visible from land should be repeated on about five days in early and mid June, dispersed over a couple of weeks to prevent serial correlation of counts, and the mean value and standard deviation recorded as the final figure. (Report the counts for individual dates also.) For many more remote colonies, or where limited time is available, a single count may be all that can be made.

10. If possible, the entire length of the colony should be photographed, preferably from the same level or slightly above, to produce a permanent record of its precise limits. There may be future extensions or contractions of the colony, and by photographing the whole colony such changes are more readily detected.

Population-monitoring method

1. The following method derives from the procedures outlined by Harris *et al.* (1983), Mudge (1988), and Rothery *et al.* (1988).

2. Define the boundaries of the colony on maps or photographs.

3. Divide those parts of the colony which are safely viewable from land into plots of about 100-300 birds. Make sure the boundaries of the plots can be defined unambiguously.

4. Potential plots should exclude ledges, or parts of ledges, where many birds are hidden under overhangs, or are otherwise difficult to observe.

5. Plots should preferably be selected randomly, or otherwise dispersed through the colony (see *General methods*). Select as many plots as can be counted in the available time (at least five). It may be possible to count most or all of the birds in smaller colonies. Selected plots can be contiguous. Photograph all selected plots. Mark and annotate the photographs before counts begin, showing unambiguous boundaries and allowing for possible future expansion.

6. Count the number of guillemots between 0800 and 1600 BST on 5-10 days in the first three weeks of June (or before the first chicks fledge). The counts should be well spaced out in the available sampling period, and *all* plots counted on each count-date. Where possible, avoid counts on consecutive days (at least not on more than two or three consecutive days), to avoid problems of serial correlation between counts (Rothery *et al*. 1988). Do not count birds on tidal rocks at the base of the cliff or others just above the high-tide mark.

7. Guillemots in study-plots should be counted as accurately as possible, as the use of sample plot counts is intended to increase the precision with which population changes can be detected. Plot counts thus should never be hurried - do *not* simply estimate numbers or attempt to count rapidly in groups of five or ten birds or nests (although this may be acceptable for a whole-colony count if time is limited). If you find it difficult to count a particular plot, attempt several counts, and report the individual counts and their average. See *General methods* for further guidance.

8. While counting guillemots along a ledge, ignore any birds which land behind or which take off ahead of the immediate position you have reached in your count, i.e. only count birds present at the 'correct' position as you visually scan from bird to bird.

9. Evans (1980) recommended that counts should not be made during winds stronger than Beaufort Force 4, or during heavy rain or fog. This recommendation is followed in most existing guillemot monitoring schemes.

10. Alternatively, make counts regardless of weather conditions, provided count accuracy is not affected, on randomly-selected dates. This is the method used on the Isle of May (Harris *et al.* 1983), where the attendance of guillemots was not found to be greatly influenced by bad weather. Whichever approach you take, state this when you report data, and include weather details with your raw data.

11. Once established, use the same study-plots each year.

12. Colonies should be completely re-surveyed at 5-10 year intervals, looking in particular for any expansion/contraction in the extent of the colony and for major internal redistribution. Photographic comparisons of the extent of the colony are best.

Productivity-monitoring method

The main difficulties in monitoring productivity in guillemots are judging which birds bred and which chicks fledged, and obtaining a sample representative of the population as a whole. Fledging age varies considerably between 15 and 30 days (mean 22 days), and declines later in the season. Survival of older chicks is generally high, so the method below assumes that all chicks aged 15 days and over which disappear have fledged (Harris 1989a; Harris & Wanless 1988).

Ideally, plots should be placed with strict regard to random positioning (see *General methods*). Some schemes may be forced to adopt a more pragmatic approach but even so attempts must be made to reduce the chances of the plot being atypical. Well-established and recently occupied areas have been found to differ in productivity (Harris & Wanless 1988), and in some colonies productivity is positively related to breeding density (Birkhead 1977). Therefore, resist the temptation to have study-plots solely in areas where study is easy, for example where pairs are at low density in isolated groups or at the fringes of colonies. The productivity of high-density breeding groups can be determined if the group can be viewed from above; such groups should be included in the 'pool' of potential plots.

These considerations inevitably mean that productivity monitoring in this species requires some effort. Considerable experimental work has gone into developing a valid technique (below) which, with moderate effort, will provide a fairly accurate measure of guillemot productivity. The method is adapted from the approach developed by Drury *et al.* (1981), Murphy *et al.* (1986), and Harris (1989a). For more accurate results, daily or near-daily checks throughout the season (from first egg-laying) are preferable. Where possible, we would encourage observers to make such frequent visits. The method below, based on fewer visits, has been found to overestimate breeding output by, on average, 11% (range 3-28%) compared with more detailed assessment of chicks fledged per pair laying (Harris 1989a).

See *Appendix 4* for sample data sheets which can be used to record details of individual nests.

1. Select several study-plots where the birds can be viewed from the same level or from above. Plots should, if possible, be selected randomly or otherwise dispersed through the colony (see *General methods*). Aim for five or more plots (if possible) of about 50 breeding pairs each.

2. Take photographs when the birds appear to be incubating. Good, large-scale photographs are essential. Photographs taken in a previous season are quite adequate. Make large prints. Delimit the

area to be checked on the photographs. Tape on transparent overlays so that photographs can be annotated. When annotating a photo taken in an earlier year, take care that you clearly indicate the positions of pairs or sitting birds in the *current* year (which may not all coincide with birds present on older photographs).

3. View each plot from the position from which the photograph was taken, late in the incubation period or early in the chick-rearing period. In Britain this is early June. Plot the positions of all active sites, defined as:

a) birds with an egg; b) birds with a chick; c) birds that appear to be incubating.

Also plot:

d) any other pairs attending sites which appear capable of supporting an egg (i.e. any horizontal surface of a ledge).

The last category will include pairs which failed at an earlier stage of the season, which usually continue to occupy the nest-site (Harris 1989a). It is important to include any such 'inactive' sites in your sample, to minimise the degree to which numbers of breeding pairs are underestimated (and thus breeding output overestimated). Unpaired guillemots will often preen each other, so care is needed, but actual pairs will usually be more obvious.

4. Make several visits (at least three), including some when large numbers of guillemots are present, until you are satisfied that you have found most occupied sites. Keep a note of whether each sitting bird, and each member of a pair, is of the bridled or unbridled form. This will help reduce mistakes in identifying particular pairs (e.g. if sitting birds shift position slightly, or extra birds crowd in). Record any chicks without an adult in attendance.

5. The sample for productivity purposes is the total of 'active' sites (egg or chick, or adult apparently incubating on two consecutive checks), and other 'inactive' but 'regular' sites (say, pair in attendance on two out of any three consecutive checks).

6. Number the active sites and note their contents every 1-2 days (or, as second best, begin such checks before the young are near fledging). Add any new active sites as necessary. Any young disappearing when aged 15 days or more old (known from regular checks or estimated on the basis of size and plumage development: see *Table Gm.1*) can be considered as having been reared successfully. The more visits made during the chick period, and the longer their duration on each date, the more accurate will be your assessments of chick's ages. In particular, if you detect most chicks when they have clearly just hatched within the last day, it will be much easier to confirm if they reach 15 days old.

7. For each plot, present the results as x young fledged from y active (i.e. a, b, c above) and z active + regular (a+b+c+d) sites. Express productivity for the colony as a whole as the mean $\pm$SE of plot results.

8. Make notes if you have any reason to suppose that the season, or the results, may have been atypical.

9. It is usually convenient, and statistically valid, to use the same study-plots each year, but it is not necessary to do so.

Table Gm.1 Guide to ageing guillemot chicks (based largely on Maunder & Threlfall 1981; Nettleship & Birkhead 1985; Birkhead & Nettleship 1985)

Age (days)	Description of typical chick
<2	Obviously small and weak-looking, unable to move around ledge and barely able to sit upright. Egg-tooth very prominent. Completely covered in down feathers (which look 'spiky' on guillemot chicks).
4-5	Feather quills emerge.
6-7	Contour feathers begin to erupt from quills, with little down remaining on wings. No white on head, which is still dark and down-covered. Egg-tooth faded but still present.
*c*12	Contour feathers well developed everywhere, except on head and neck. Beginnings of dark 'mask' through eye (*c.* 10-12 days), with some white on chin / below mask but little or no white above rear-extension of mask..
c15	Plumage well developed, with white of belly almost continuous with the more recently developed white of throat and cheek regions (though usually a sparse band of dark down-feathers remaining in throat region). Obvious black 'mask' from base of bill through eye, with thinner black line extending behind eye, contrasting with white cheek and with greyer plumage above (usually some white above rear extension of mask also). Egg-tooth sometimes still present, but flakes off easily.
>15 d	Major plumage development completed by now, except for further growth of feathers (especially on wings) and loss of most of the remaining spiky down (producing cleaner-looking black and white plumage). Body-size and weight continue to increase, and oldest birds can look strikingly large and big-billed (though smaller chicks may be quite capable of leaving ledge and swimming out to sea).

Plate Gm.1 Well-grown guillemot chick (>15 days old). Copyright: M.P. Harris.

Plate R.1 Well-grown razorbill chick (>15 days old). Copyright: T.R. Barton.

Razorbill *Alca torda*

Census / population-monitoring methods

Whole-colony counts of razorbills usually rely on counts of individuals at cliff sites, and estimates or corrected counts of individuals in boulder colonies. The ease with which razorbill colonies can be counted varies according to the type of nest-sites in use. Where birds nest wholly on open cliffs, counting is relatively straightforward, the main problem being that some birds may be difficult to pick up among guillemots, while others may be scattered in small recesses or on small ledges. Birds nesting in deep crevices or among boulders or scree are more challenging, and may be present even at apparently straightforward cliff colonies.

Counts of individuals should be quoted as such, and not 'corrected' to pairs. As with guillemot, a *rough* conversion factor of one bird : 0.67 pairs (Harris 1989b) can been used, for example if counts in different units need to be combined. The margin of error involved means that such 'converted' figures are of little use for detailed comparisons of counts. Counts should always be reported in the census unit actually used in the field, to avoid misleading other observers or analysts wishing to compare counts.

Census methods derive in part from those originally devised for guillemots, and counts of the two species are often made at the same time. For detailed population monitoring, plots used for guillemot monitoring can conveniently be used for razorbills (Harris & Wanless 1989) where the species are well mixed, although plots for razorbills should ideally be selected separately from guillemots and on a random basis. Where a substantial proportion (> *c.* 10%) of the population nests in areas not used by guillemots (e.g. among other species or among boulders), care should be taken to include (or select from) these areas in any monitoring scheme.

Monitoring counts follow the established practice for guillemots and rely on repeat counts of individuals in study-plots which have, preferably, been selected randomly. This amounts to counting a subset of the colony in the same way as for whole colony counts, which are therefore preferable when time and resources permit (e.g. small colonies which can be counted in their entirety on 5-10 separate dates).

An alternative census method, still at the experimental stage, is based on counts of razorbills in the immediate pre-breeding period. Preliminary work on Fair Isle suggests that, on calm evenings at that time of year, razorbills show themselves well near the entrances to nest-sites and provide a good indication of the number of breeding pairs (N.J. Riddiford and P.V. Harvey, pers. comm.) Later in the season, the locations of nest-sites under boulders or in deep crevices are much less apparent. Further work is needed to clarify the general applicability of this method.

Census units

The recommended unit is the individual bird on land at a colony. Counts of apparently occupied sites are sometimes possible, but are difficult to define unambiguously and, in general, are not recommended.

Whole-colony census method

This method is based, with modifications, on the recommendations of Evans (1980).

1. Define the limits of the colony or length of coast being counted, and keep a breakdown of counts by subdivisions clearly definable on an Ordnance Survey map. Counts of individual cliff-faces will be aided by further subdividing counts according to obvious ledges, fissures, or other features.

2. Avoid counting on days with heavy rain, fog, or winds higher than Beaufort Force 4. Note weather conditions at the time of each count. Counts are best made in the first three weeks of June (incubation/early nestling period), between 0800 and 1600 BST. Counts in late May or late June are acceptable, but counts in July are not recommended as numbers may decline rapidly after fledging of chicks has begun.

3. On cliffs, count all visible birds, except for those only loosely associated with the colony (i.e. on intertidal rocks, or on the sea). On parts of the cliff higher than the intertidal areas, do not attempt to judge breeding status of individual birds which appear to be 'unattached' - even if they are not obviously associated with a potential crevice, they should be counted.

4. Where birds are nesting among boulders, divide the occupied area into discrete subcolonies, and count visible birds from suitable vantage points. Select *c.* 5 of the accessible subcolonies *randomly* (see *General methods*). Then, move carefully into and through each subcolony, counting the actual number of individuals by direct observation and by flushing from crevices. Try to minimise the time spent in each subcolony, especially when many eggs or small chicks are present. Calculate the ratio of birds visible from the vantage point to the total birds for each group. Use the average factor derived in order to estimate 'hidden' numbers of individuals at other boulder subcolonies.

5. Keep a note of (and map) any parts of a colony that might not be visible from land. Estimate (minimum-maximum) the number of birds likely to be hidden, based on numbers on visible sections (although these may not necessarily show similar densities to hidden sections) or on previous sea-based v. land-based counts. However, in reporting these estimates be very clear that they are of unknown reliability, and may not be directly comparable with other counts. If at all possible, check and count hidden sections from a boat on a calm day (especially if you estimate that hidden sections are likely to total more than *c.* 10% of the population).

6. If possible, land-based counts of cliff colonies should be repeated about five times on different days, dispersed over several weeks in early and mid June, and the mean value and standard deviation reported, along with the detailed counts. Boulder colonies should be counted in detail once only (if using the method above), to minimise disturbance; however, repeat counts of visible birds at inaccessible boulder colonies are useful. For many remoter cliff colonies, or where limited time is available, a single count may be all that can be made.

7. If possible, the entire length of the colony should be photographed, preferably from the same level or slightly below, to produce a permanent record of its precise limits. There may be future extensions or contractions of the colony, and by photographing the whole colony such changes are more readily detected.

Population-monitoring method

The following method is based on the procedures outlined in Evans (1980), and those developed for guillemots by Harris *et al.* (1983) and Mudge (1988).

1. Define the boundaries of the colony, or of subcolonies where razorbills occur in discrete groups within larger seabird assemblages, and mark them precisely and unambiguously on maps or photographs.

2. Divide those parts of the colony which are safely viewable into plots of about 20-100 birds where possible. For convenience, these potential plots may be the same as those used for guillemots if both species are being monitored, but also keep a note of any potential plots of 20+ razorbills lying outside the monitored parts of a guillemot colony. Make sure the boundaries of the plots can be defined unambiguously.

3. Select as many plots as can be counted in the available time (at least five). Plots should preferably be selected randomly or otherwise dispersed through the colony (see *General methods*). It may be possible to count all the birds in smaller colonies. Selected plots can be contiguous. If counting razorbills in plots also used for guillemot population monitoring (usually a good idea), ideally you should randomly select additional plots specifically for razorbill in rough proportion to the numbers of razorbills breeding outside the main guillemot concentrations. Photograph all selected plots. Mark and annotate the photographs before counts begin, showing unambiguous boundaries.

4. Count the number of razorbills between 0800 and 1600 BST on 5-10 days in the first three weeks of June. The counts should be well spaced out in the available sampling period, and *all* plots should be counted on each date. Do not count birds on the sea or on tidal rocks.

5. Evans (1980) recommended that counts should not be made during winds stronger than Beaufort Force 4, or during heavy rain or fog. This recommendation is followed in most existing razorbill monitoring schemes. Note weather conditions at the time of each count.

6. Alternatively, make counts regardless of weather conditions, provided count accuracy is not affected, on randomly selected dates. This is the method used on the Isle of May (Harris *et al.* 1983), where the attendance of razorbills was not found to be greatly influenced by adverse weather.

7. Once established, use the same study-plots each year. Monitoring counts are best made annually, but counts every two or three years are also useful.

8. Colonies should be completely re-surveyed at 5-10 year intervals, looking in particular for any expansion/contraction in the extent of the colony and for major internal redistribution. Photographic comparisons of the extent of the colony are best.

Productivity-monitoring methods

Razorbills may breed in large numbers either on open cliffs or among boulders or scree, so no uniform method of productivity monitoring is appropriate for the species. Methods have generally been adapted from those devised for other species, particularly for guillemots and puffins (Harris 1989a). It is important to attempt to monitor all major types of breeding site within a colony, as productivity may vary in different situations (Hudson 1982). *Method 1,* for use at plots on open cliffs (which hold the bulk of razorbills at many colonies), is similar to that developed for guillemots. *Method 2,* for use in areas where the site cannot be observed directly (e.g. boulder colonies), involves examination of sites at least twice in the breeding season. A more labour-intensive, but less intrusive, technique is outlined in *Method 3*, for areas where nest-sites cannot be observed directly and direct examination is ruled out for safety or disturbance reasons.

Where the types of site used are mixed within a colony, it may be necessary to combine methods to obtain representative results. Suggestions as to how this should be accomplished are given after the listing of methods.

In all methods outlined below, the safety of observers and minimisation of disturbance to the birds are of utmost importance. This may mean that plots cannot be established in certain areas of the colony. If this is so, note these areas and if there is any obvious reason why their productivity may vary from the population as a whole.

It is usually convenient, and statistically valid, to use the same study plots each year, but it is not necessary to do so. Make notes if you have reason to believe that the season, or the results, may be atypical.

Productivity-monitoring method 1 ('open' nest-sites viewable from a distance)

1. This method is intended to measure the productivity of cliff-breeding groups of razorbills, or other groups where the nest-site can be observed directly.

2. Divide the colony into clearly-definable plots of 10-50 nest-sites that can be viewed readily, and map the sites of on sketch maps or photographs. Be sure that all safely observable areas of cliff are included.

3. Select at least five plots (or as many as can be covered in the time available), randomly if possible or otherwise dispersed through the colony (see *General methods*). For small colonies, it may be possible to cover all potential plots. Plots in use for guillemot monitoring may be employed for convenience if they hold enough razorbills.

4. Take photographs of the selected plots when the birds appear to be incubating or brooding small young. Good, large-scale photographs are essential. Photographs taken in a previous season are quite adequate. Make large prints. Delimit the area to be checked on the photographs. Tape on transparent overlays so that photographs can be annotated.

5. If the colony also contains birds breeding among boulders, see the *Note on combining methods* (below) before selecting plots.

6. If the colony holds few or sparsely-distributed breeding razorbills, smaller plot sizes may be necessary (or a large area of cliff, covered by several photographs, may need to be treated as a plot).

7. View each plot from the position from which the photograph was taken, late in the incubation period or early in the chick-rearing period, In Britain this is mid May to early June. en, late in the incubation period or early in the chick-rearing period. In Britain this is early June. Plot the positions of all active sites, defined as:
   a) birds with an egg; b) birds with a chick; c) birds that appear to be incubating.
Also plot:
   d) any other pairs attending sites which appear capable of supporting an egg (i.e. any horizontal surface of a ledge).
It is important to include any such 'inactive' sites in your sample, to minimise the degree to which number of breeding pairs is underestimated (and thus breeding output overestimated).

8. Make several visits (at least three), until you are satisfied that you have identified most occupied sites. Record any chicks without an adult in attendance.

9. The sample for productivity purposes is the total of 'active' sites (egg or chick, or adult apparently incubating on two consecutive checks), and other 'inactive' but 'regular' sites (say, a pair in attendance on two out of any three consecutive checks).

10. Number the sites and note their contents every 1-2 days (or, as second best, begin such checks before the young are near fledging). Add any new sites as necessary. Any young disappearing when aged 15 days or more old (known from regular checks or estimated on the basis of size and plumage development) can be considered to have fledged successfully (Harris and Wanless 1989). The more visits made during the chick period, and the longer their duration on each date, the more accurate will be your assessments of how old chicks are. In particular, if you detect most chicks when they have clearly just hatched within the last day, it will be much easier to confirm that they have reached 15 days old.

11. For each plot, present the results as *x* young fledged from *y* active sites (a+b+c, point *7*), and as *x* young fledged from *z* active + regular sites (a+b+c+d).

12. Average productivity for cliff-breeding razorbills in a colony is calculated as the mean ±SE of the productivity figure for individual plots. Plots containing <10 sites should be combined with the nearest other small plot(s) before calculating the overall mean. If all plots (or all except one or two) have <10 sites, combine all data and calculate the overall productivity figure as (*x* fledged from a total of *y* sites). Report productivity estimates for each individual plots also.

Productivity-monitoring method 2 (enclosed but accessible nest-sites)

1. This method is intended to measure the productivity of razorbills breeding amongst boulders or in other deep crevices, where the nest-sites are not directly observable from long range. It may not be important to check these sites if they form only a small proportion (<10%) of the colony as a whole.

2. Divide the area into plots containing 10-50 pairs and sketch their positions on rough maps or photographs.

3. Select as many safely accessible plots as can be covered in the time available: at least five if possible. Preferably, select these plots randomly, or otherwise disperse them through the study area (see *General methods*). For small colonies it may be possible to cover all potential plots. Mark the boundaries of these plots unambiguously on large-scale photographs or maps.

4. If the colony contains birds breeding on cliff sites, see the note on *combining methods* (below) before selecting plots.

5. Check through the plot after the peak of laying (which is usually in mid-May). Try to find as many active nests (egg, chick or tightly sitting adult) as possible. Many will be in relatively shallow recesses which can be observed fairly easily, while others will be further in under boulders. A small torch may be useful for examining darker recesses. A bird sitting tight should be taken as evidence of an active nest. Avoid flushing incubating birds if possible, and try to spend no more than 30 minutes among any breeding group. A quick search by several observers will cause less disturbance than a prolonged search by a single observer. Nests in some crevices may be checkable only by touch. Feel with your arm into holes where you believe a nest may be. For more difficult recesses, a stick or bamboo can be used. Incubating birds may move away from the egg, which can be felt on the nest floor. Be careful not to break the egg.

6. Mark the entrance to each site found with a stake or other marker, e.g. a dab of paint on the rock. Preferably, number these markers also. Some sites will probably be missed and others will be inaccessible, but this is relatively unimportant so long as a reasonable sample size (>10) is found.

7. Re-check the marked sites in the immediate pre-fledging period, usually mid June (*c.* 15th-20th) in northern Britain. The chick can usually be seen or felt, though beware of the occasional chick hiding in crevices off the main nest chamber. Hidden chicks will usually call, however. Pull out any chicks which are not directly visible (using a piece of bent wire, hooked around the chick's legs, if necessary). Note any eggs present (which may include replacement eggs) and, if possible, check these in early July.

8. Assume that large chicks >10 days old (wing-length greater than 60 mm) are likely to fledge. Keep a note of smaller chicks, and check them again a week or so later.

9. Success is expressed as the number of large chicks present divided by the total number of sites refound where presence or absence of a large chick was determined. Sites where a replacement egg was laid and a chick subsequently found count as successful sites. If only one visit can be made to check fledging, estimate productivity on the assumption that all chicks fledge and all replacement or late eggs fail.

10. More frequent checks during incubation and chick periods will improve accuracy (i.e. reduce overestimation by detecting a higher proportion of early failures), but beware causing excessive disturbance. For routine monitoring, we do not recommend checks more frequent than weekly at any stage, or plot visits longer than 30 minutes.

11. Average productivity for boulder-nesting razorbills in a colony is calculated as the mean $\pm$SE of the productivity figure for individual plots. If all plots have <10 sites, combine all data and calculate the overall productivity figure as (*x* fledged from a total of *y* sites). Report productivity estimates for each individual plot also.

Productivity-monitoring method 3 (enclosed but inaccessible nest-sites)

1. This method is intended to measure the productivity of razorbills breeding amongst boulders or crevices, where only the entrances to nest-sites (but not the nest-sites themselves) are directly observable . The method is labour-intensive, and will be unnecessary in many colonies (e.g. where <10% of the population breed in such areas). Where similar but accessible groups of breeding sites occur, it is usually preferable to monitor those sites instead, using *Method 2*.

2. Divide the area into plots likely to contain 10-30 pairs and sketch their positions on rough maps or photographs.

3. Select as many safely accessible plots as can be covered in the time available: at least five if possible. Preferably, select these plots randomly, or otherwise disperse them through the study area (see *General methods*). For small colonies it may be possible to cover all potential plots. Mark the boundaries of these plots unambiguously on large-scale photographs or maps.

4. If the colony contains birds breeding on cliff sites, see the *Note on combining methods* (below) before selecting plots.

5. Mark sites (or the positions of sites) clearly on the photograph/map early in the season and during the incubation period by observing birds attending sites and visiting hidden sites to change over incubation shifts. We suggest that if you see a bird enter or leave a possible site on at least two occasions (separate days) it should be considered an occupied site.

6. When birds are feeding large chicks, during the immediate pre-fledging period (*c.* 15-20 June in northern Britain), make a few watches to determine which sites have fish taken to them. This is best done in the early morning when feeding frequency is highest.

7. Express success as the number of apparently successful sites divided by the number occupied early in the season. This method is likely to overestimate success compared with *Methods 1* and *2*, but can still provide useful information if other methods cannot be used.

8. Average productivity for inaccessible, boulder-nesting razorbills in a colony is calculated as the mean ±SE of the productivity figure for individual plots. If all plots have <10 sites, combine all data and calculate the overall productivity figure as (*x* fledged from a total of *y* sites). Report productivity estimates for each individual plots also.

Notes on combining methods

At many colonies, razorbills will nest at a range of sites, some observable from a distance, others hidden but accessible, still others both hidden and inaccessible. Since there is reason to believe that there may be systematic differences in productivity between types of site (Hudson 1982), it will often be necessary to combine methods to obtain a representative overall figure. However, it is probably not worth attempting to include areas/habitat types (e.g. boulder colonies) which hold <10% of a population. If combining methods is necessary, at least two options are available (both involving stratified random sampling - see *General methods*): :

1. From whole-colony counts (see *Census methods*), determine the proportion of birds present in the types of site covered by the three monitoring methods. Determine the number of plots of each type to be used in proportion to this - e.g. if twice as many birds breed in boulder subcolonies as on cliffs, twice as many plots should be in boulder subcolonies. For each habitat, select plots (preferably randomly) until you have as many as are required. Assess productivity as normal. The overall productivity figure is expressed as the mean ± standard error of figures from all plots.

2. If a whole population count is not available, use the number of study-plots available (assuming the whole colony has been apportioned into potential study-plots) in each habitat as a rough guide to the relative number of birds breeding in each. Use this proportion to determine the proportion of study-plots of each type to be selected for monitoring; again, random selection is best. Express the overall productivity as in point *1*.

3. Results for each type of site should also be reported separately. In any case, keep the results for each study-plot monitored to allow for further calculations if better estimates of breeding distribution within the colony become available.

Black guillemot *Cepphus grylle*

Census / population-monitoring methods

Black guillemots usually nest as single pairs or in small groups scattered along the coastline. Counts and population monitoring should therefore aim to cover sections of coastline rather than discrete 'colonies'. The nest-sites are difficult to count with great accuracy, given their scattered distribution and general inaccessibility, and carefully timed counts of individuals provide the most accurate general guide. Various correction factors to pairs have been suggested in the past, but are either fairly crude (e.g. one bird = one pair for counts during incubation), or vary considerably among breeding groups and so necessitate intensive studies for each group in each year (Cairns 1979; Ewins 1985a). Counting individuals is best done when most adult birds are present on the sea immediately offshore from breeding areas: early in the morning during the pre-laying period.

Counts of black guillemots outside the pre-breeding period are not recommended. If counts using the recommended census technique are not available for a particular colony or stretch of coast, it may be worth keeping a note of any adults or nest-sites seen while other species are being counted (e.g. in June). However, such counts should be considered only a very rough indication of the size of a population. Counts of adults late in the season can substantially underestimate the local population (e.g. many adults may be hidden at nest-sites while others are feeding away from the colony). Attempts to count apparently occupied nest-sites will usually underestimate populations, to an even greater degree, except, for example, where nest-holes in artificial structures such as piers can be viewed easily.

Census unit

The generally recommended counting unit is the individual adult, ideally counted in the early morning (before 0900 BST [0800 GMT]) in the pre-breeding season. Apparently occupied sites (AOS) can sometimes be counted reasonably accurately at small colonies, later in the season, but numbers are easily underestimated. Accurate correction factors to breeding pairs require specialised study of individual breeding groups, impractical for most general surveys and for other than very localised monitoring.

Census method

1. This method is based on techniques described in Tasker & Reynolds (1983) and Ewins (1985a,b), and is the preferred method for complete counts of a coastline, and for regular monitoring. The basic count unit is 'adults associated with a colony'. A standard *recording form* is attached.

2. Studies have shown that the accuracy of the count is quite strongly influenced by the familiarity of the observer with the study area and with experience in counting black guillemots. Pre-surveys of the study area and practice in counting should be considered, and novices should perhaps accompany experienced fieldworkers initially to learn techniques and compare accuracy.

3. Counts should be made in the pre-laying period - ideally the first three weeks of April in most of the range, although possibly earlier in the Irish Sea. Counts in late April or early May are acceptable, although these tend to underestimate the population slightly. (By early May, birds are less easily disturbed into flying onto the sea, and more birds are missed, especially during counts from the cliff-top. In Shetland, counts in late March, 25th onwards, have proved more useful.) Counts should be made in the early morning, from first light to *c.* 2 hours later (*c.* 0600-0800 BST in the north, but as late as 0900 farther south). Winds should not be stronger than Beaufort scale Force 4, and preferably not blowing onshore. Sea-swell should be slight to moderate. Note weather conditions at the time of the count.

4. Counts may be made from the sea or from the land. Land-based counts are usually slightly more accurate (unless cliffs are high, say >70 m), but a much longer stretch of coast (up to 35 km) can be covered each morning in a suitable small boat. The use of boats is preferable for high cliffs, offshore islands, coasts with many islets where birds might be hidden on the blind sides, or long stretches of coast with little or scattered suitable breeding habitat.

5. On main islands and the mainland, birds normally only nest on cliffs >10 m in height (sites inaccessible to mammalian predators). Counting can therefore concentrate on such areas. This does not hold true for uninhabited offshore islands, where birds may be much less restricted in nesting site.

6. Move along the coast counting all birds seen on the sea within *c.* 300 m of the shore and any on land. Birds ashore are often difficult to see but a cliff-top observer can flush them onto the water by clapping, shouting or making other noises. Scan the sea frequently, particularly in bad light conditions. Divide the count into the following categories:

a) birds in adult summer plumage;

b) birds in other plumages (largely or partly grey, or with dark bars visible in white wing-patch);

c) any birds seen >300 m offshore (thus less obviously associated with potential breeding habitat).

Also, record separately:

d) any birds seen feeding, as these should not be considered 'associated' with the colony.

7. For each group of birds, also record:

a) the location (grid reference if possible, easiest if counts are recorded directly onto 1: 10,000 Ordnance Survey maps);

b) situation of probable breeding area (most birds will be clearly associated with potential breeding habitat such as cliff-crevices, talus slopes, burrows, boulder beaches);

c) weather conditions;

d) other notes, e.g. presence of breeding gulls in vicinity; signs of mammalian predators; behaviour, e.g. display, whether many birds were ashore, whether they flushed easily or stayed close inshore.

8. For monitoring, counts should cover all available suitable coastline in a given study area, or lengths of coast should be selected randomly from the entire length of potential breeding habitat. More, shorter stretches are preferable over fewer, longer stretches, but should be bounded by coasts with no black guillemots, to avoid problems in deciding with which part of coast birds are associated. Lengths of coast with 50+ adults, *and* sufficient suitable-looking breeding habitat to allow for potential increase, are best. Very localised colonies, for example at isolated piers or geos where all potential nest-sites may already be occupied, are much less useful for monitoring purposes. Sample areas selected on grounds other than randomisation (e.g. accessibility) may not be representative of local populations (e.g. if black guillemots breed in smaller numbers or less successfully along more accessible coasts).

9. If possible, make two counts of the whole coastline or of the sample stretches (a week or more apart - *not* on successive mornings), and use the higher of the two counts as your basic estimate of the local population. For continuous stretches of coast, or adjacent islets, counts on any single date should be summed *before* calculating the mean of several days counts. This allows for possible short-range movements of birds within a larger areas. If smaller sample areas are used, peaks for each area can be used provided areas are well separated (as a rough guide, by 500 m or more).

10. For comparisons between years, however, it is better to compare means (or compare the mean of two counts in one year with a single count in another year), provided there is no good reason (apart from higher numbers) to believe that one count is better than another. If this is not done, higher numbers are likely to be detected in a year when two counts were made, thus potentially biasing comparisons. Counts should, in any case, be excluded from calculations of means if they are made during poor conditions, for example if weather deteriorates or sea-swell increases after counts have begun.

Productivity-monitoring methods

Black guillemots use a variety of nest-sites, often inaccessible, under boulders, in burrows and crevices, and occasionally artificial sites in harbour-walls, piers or buildings. The measure of productivity obtained by *Method 1* will not be highly accurate, although it should be sufficient to detect any major changes in breeding output. *Method 2* provides a measure of the number of successful nests in groups of black guillemots nesting amongst boulders, but not of overall productivity since it cannot distinguish between nests fledging one and two chicks.

Productivity-monitoring method 1 (accessible nest-sites)

1. This method is adapted from the methods developed by Harris (1989a) for puffins and shags, and can be used wherever most nest-sites are accessible for checks of their contents.

2. Check a series of sites after the peak of laying (usually early May). Identify potential nest-sites by watching for adults arriving or leaving.

3. In some cases (e.g. under boulders), the nest may be visible directly without too much difficulty. A small torch and mirror may be useful to illuminate dark recesses. A tightly sitting adult or a view of egg(s) should be taken as evidence of an 'active' nest-site. Otherwise, attempt to feel with an arm or stick into the burrow/crevice. Any incubating bird will move off, allowing the egg(s) to be felt on the floor of the nest chamber. Be careful not to break the egg(s).

4. Aim for a sample of 10-50 accessible sites (the more the better) at which eggs or sitting adults have been confirmed, dispersed throughout the breeding area if possible. Mark all sites where breeding is detected with stakes or other markers.

5. Re-check the nest-sites when the birds have large chicks, before the first chicks fledge (usually in mid to late July in northern Scotland). Feel inside for the chicks, bearing in mind that there may be more than one - if necessary, remove one temporarily (bring a bag for the purpose) when searching for a second chick. As an approximation, assume that any chicks more than 3 weeks old (wing length ≥90 mm: Ewins 1992) are likely to fledge.

6. If possible, re-check nest-sites later one or more times to follow up smaller chicks. If any chicks previously noted as 'large' are found dead, subtract them from the number of chicks deemed to have fledged.

7. Accuracy is greatest if regular (say, weekly) checks are made from the late nestling period onwards, and if more stringent criteria are used to assess numbers of fledged chicks. The first chicks may fledge when 31-32 days old, so chicks reaching 30 days (wing-length usually >115 mm: Ewins 1992), or which could have reached that age between weekly nest-checks, are, in this case, counted.

8. Success is expressed as the number of large chicks divided by the total number of marked breeding sites that were refound, where presence or absence of a chick or chicks was determined. Keep a note of the number of failed attempts and of broods of one and two chicks, and of how many visits were made. Results based on a single count of chicks are more likely to overestimate productivity.

Productivity-monitoring method 2 (inaccessible nest-sites)

1. This method is adapted from Harris (1989a), and is suitable for black guillemots nesting in inaccessible boulder or other sites when nest contents cannot be checked directly.

2. Find a vantage point from which the colony or breeding group can be watched from a distance.

3. Observe the area during the early incubation period (usually late May: Ewins 1989) for birds changing over at the nest. The morning peak of activity is best, up to *c.* 0900 BST (changeovers occur most frequently in the first two hours of daylight). Mark these sites with numbered stakes or other markers (e.g. small cairns of stones), or plot them on large-size photographs taken from the observation point if you are sure that the terrain is sufficiently varied to identify sites unambiguously from photographs.

4. When birds are feeding large chicks but before fledging begins (usually mid to late July in northern Britain), make a few watches to determine which nest-sites have fish delivered to them. This is best done in the early morning when feeding frequency is highest. (At regularly observed sites, fledging should begin *c.* 31 days after the first adults are seen bringing fish back to the colony.)

5. Express success as the number of successful nest-sites divided by the number occupied early in the season. Brood size will usually be unknown.

JNCC / Seabird Group black guillemot survey

Summary of instructions (see *Seabird monitoring handbook* for further details):
Surveys must be done between 0600 and 0900 BST, late March to early May. Avoid days with winds > Beaufort Force 4. Give priority to coastline with possible black guillemot breeding habitat, and cover on foot or by boat. Count all adult-plumaged black guillemots within 300 m of shore (including birds ashore, or disturbed from shore). Mark each group of adults encountered on a map of the coastline covered, and provide details for each group on a separate form.

Site name (refer to Ordnance Survey map) ....

Grid reference: **Start** .... **Finish** ....

Date: .... **Time (BST):** ....

Counted from (circle one): land, sea

Shore slope: gentle $<30^0$, med. $<70^0$, steep $\leq 90^0$

Cliff height (metres): <1, 1-10, 11-25, 26-50, 51-100, 101-150, 151-200, >200

Wind speed (Beaufort scale): 0, 1, 2, 3, 4

State of sea: calm, medium, rough

Sea-swell: none, slight, moderate, heavy

Precipitation type: snow, rain, none

Precipitation amount: heavy, light, showers Cloud cover (in eighths): ....

Light conditions: good, moderate, poor (any specific problems, e.g. sun-glare? ....)

Shore substrate (circle one or more): solid rock, loose rock, boulders, scree, sand/shingle, marsh, artificial, other

Birds seen onshore or within 300 m of the shore:

No. of birds in full adult summer plumage: .... Other plumage: ....

Total birds within 300 m of shore: ....

Number of additional birds seen >300 m from shore: ....

Notes on birds' activity (on land, calling, courtship, etc.):

Situation of probable nesting area: 'open' cliff, geo, cave, grassy, boulders, artificial, other

Prospecting/breeding gulls present: Herring, GBB, none Proximity (m): ....

Other notes (PTO if required): ....

Puffin *Fratercula arctica*

Census / population-monitoring methods

Puffins commonly nest in large, and sometimes immense, colonies, are prone to mass aerial wheeling above the colony, and nest in burrows. Exaggerated early estimates of population size were often based on subjective impressions of (admittedly awe-inspiring) congregations of birds, without much attempt at rigorous counting. Numbers of puffins on the surface of a colony fluctuate enormously from day to day (and hour to hour), and include a variable number of immature birds. Except perhaps at small colonies, such counts are seldom of much value for assessing population size and detecting other than very large population changes *(Method 3*). Little information is available on the relationship between peak numbers visible on land and the number of pairs breeding in an area. Counts made early in the breeding season, before immatures arrive at the colony, are potentially the most useful, but further research is needed.

The detailed survey method most often used in the past (*Method 2*) is based on the use of transects running through the colony and extending beyond the boundaries to allow for expansion or contraction of the breeding area (Harris & Murray 1981) Within these transects, apparently occupied burrows are counted. The disadvantage of this method is that the accuracy of counts is difficult to determine, as the sample size for statistical purposes is the number of transects. A statistically more reliable method (*Methods 1a & 1b*) is to determine the burrow density at a number of randomly selected points (*General methods*, Harris & Rothery 1988). Such a sample allows estimation of the total breeding population, and provides a better statistical basis for assessment of population change. (Alternatively, systematic positioning of quadrats can be used, for example quadrats at fixed intervals within the colony: see Anker-Nilssen & Rostad 1993 and *General methods*.)

Where colonies are divided obviously into areas of markedly different density, often associated with differences in vegetation, greater accuracy is obtained by treating each area as if it were a separate colony ('stratified sampling': see *General methods* and Harris & Rothery 1988). Counting methods are as for unstratified counts, but final calculations differ somewhat, so for clarity we have presented stratified (*Method 1b*) and unstratified (*Method 1a*) counting procedures separately.

The final calculations involved in *Method 1* are relatively complex, especially for stratified samples, but can be performed with a scientific calculator by following the step-by-step procedure. Alternatively, the raw data (quadrat counts, areas of colony as a whole and of any subdivided strata) can be sent to JNCC's Seabird Monitoring Programme or RSPB's Research Department for calculation.

Randomly placed quadrats are unlikely to detect variation in the population caused by changes at the boundaries of the colony (i.e. a small increase or reduction in colony area rather than an overall increase or loss of density), and ideally monitoring requires a combination of both randomly placed quadrats (*Method 1a or 1b*) and fixed transects (*Method 2*), or assessment of colony boundaries before every count.

In puffin colonies, it is important to take particular care not to trample burrows; some colonies, or parts of colonies, are more at risk than others. When surveying a colony, wear soft shoes if possible, tread with care, and, if necessary, reject potential quadrat or transect positions as too fragile if it is evident that burrows will readily collapse.

For detailed monitoring purposes, counts are best repeated annually or at up to 5-year intervals.

Census units

The best count unit is the *apparently occupied site* (AOS), usually an *apparently occupied burrow* (AOB). At cliff colonies, individual birds may be all that can be counted.

Apparently occupied burrows are characterised by signs of regular use, such as fresh digging, hatched eggshells, or fish in the entrance. Rabbit burrows are usually larger, usually have much soil outside, and often have droppings at the entrance and conspicuous runs through the vegetation leading away. There is no simple way to separate Manx shearwater and puffin burrows, although mixed colonies are relatively uncommon.

Census method 1a (quadrat method: unrestricted random sampling)

This method is for use where colony density is not known to vary markedly, or there is no objective basis for subdividing the colony (see earlier notes). The method described was developed by Harris & Rothery (1988).

1. Sampling is best carried out before or during the laying period, when birds are digging or cleaning burrows and when ground vegetation is short; late April is optimal in south-east Scotland, early to mid May in north-west Scotland. However, acceptable counts can be made at any time from late April to early August, although assessments of population change should preferably be based on counts made at the same time of year.

2. Define the limits of the colony and make a map. Identify clearly any inaccessible areas.

3. Many colonies will be too large to count completely. In this case, superimpose a grid on the map and, using a table of random numbers, or another *truly* random method (see *General methods*),

determine a number of random points on the map of accessible areas of the colony. Aim for about 30 random points.

4. Place quadrats at these points *regardless of whether or not there are burrows present,* even if the whole area is bare rock, but avoid areas which would be dangerous to fieldworkers, or which are so heavily eroded that many burrows could be collapsed by walking over them From a statistical viewpoint, many small quadrats are preferable to fewer large quadrats. The location of the point should be fixed by measuring angles and distances from fixed points, such as rock outcrops or other structures. These points may be staked permanently and used for counts in later years, or new points can be selected randomly whenever counts are repeated. Other forms of marker (e.g. small cairns of stones) may be needed on some substrates. Permanent quadrats increase the precision with which change can be estimated (Harris & Rothery 1988). Ensure that stakes penetrate well into the ground, to reduce the likelihood that they will be displaced by burrowing puffins; be careful to avoid penetrating any burrows, however. If using permanent quadrats, keep the original map of grid points so that the positions of missing stakes can be relocated.

5. The size and shape of quadrats is not important so long as the average quadrat includes some burrows. Experience suggests that circular quadrats of 20 m^2 (where burrow density is high) and 30 m^2 (low burrow density) are the most easily and quickly managed. Only one quadrat size should be used within a given colony. A rope 2.52 m (area 20 $m^{2)}$ or 2.96 m long (area 30 m^2) can be rotated around a fixed stake and the number of burrows within the radius counted.

6. Count all apparently occupied burrows where $\geq$50% of the burrow entrance lies within the quadrat, regardless of the direction of the tunnel. AOBs are characterised by signs of regular use, e.g. fresh digging, hatched eggshells, or fish in the entrance. Rabbit burrows are usually larger, usually have much soil outside, and often have droppings at the entrance and conspicuous runs through the vegetation leading away. There is no simple way to separate Manx shearwater and puffin burrows, although mixed colonies are relatively uncommon.

7. If possible, keep a separate note of burrows which seem to be unoccupied, for example with overgrown entrances or no evidence of use.

8. Calculate the mean number of AOBs per quadrat and the sample variance of this figure (using a scientific calculator), for example mean 4.8 AOBs per quadrat, sample variance 6.25.

9. To obtain an estimate of the total population, first divide the quadrat mean from step *8* by the area of each quadrat (typically 20 m^2 or 30 m^2), giving the average density per m^2. Multiply this figure by the total area (in m^2) of the colony (derived from a map plotted on graph paper or using a planimeter). For example, 4.8 AOBs per 30 m^2 = 0.16/m^2. If colony area is 12,000 m^2, estimated total is 0.16 x 12,000 = 1,920 AOBs.

10. To obtain the standard error of the population estimate (for the above example):

a) Multiply the square of the area of a quadrat by the number of quadrats, e.g. $(30)^2$ x 20 quadrats = 18,000.

b) Divide the square of the total area of the colony by the figure obtained in step *a*, e.g. $(12,000)^2$ / 18,000 = 8,000.

c) Multiply the figure obtained in step *b* by the sample variance of the quadrat mean (from step *8*), e.g. (8,000 x 6.25) = 50,000. This figure is the variance of the population estimate.

d) The square root of the variance is the standard error of the population estimate, e.g. square root of 50,000 = 224 occupied burrows in the above example.

11. Report :

a) raw data;

b) the mean number and sample variance of AOBs per quadrat;

c) the total estimate of AOBs (±SE) for the whole colony;

Or, simply provide raw data for calculations (area of colony, number of apparently occupied burrows in each quadrat).

12. Assessing the statistical significance of year-to-year changes is also complex (see Harris and Rothery 1988). Preferably, pass data to JNCC or RSPB for calculations.

Census method 1b (quadrat method: stratified random sampling)

This method can be used where areas of the colony are known to differ markedly in density and which can be defined on an objective basis. The method is described in greater detail by Harris & Rothery (1988).

1. As *Method 1a*.

2. Define the limits of the colony and make a map. Map and determine the relative proportions of the areas of markedly different density ('strata') within the colony. Distinguish between accessible and inaccessible areas. Measure or estimate the area of each stratum.

3. Many colonies will be too large to count completely. In this case, superimpose a grid on the map and select quadrat points randomly (see *Method 1* and *General methods*), this time within each stratum. Points falling in inaccessible areas should be discarded and another chosen randomly. A reasonable number of quadrats for the colony as a whole is about 30.

4-7. As *Method 1a*.

8. *Separately for each stratum*, calculate the mean number of AOBs per quadrat and the sample variance of this figure (using a scientific calculator), as in *Method 1a*.

9. Obtain an estimate of the total population *within each stratum*, as described in *Method 1a* (point *9*).

10. Calculate the variance of the population estimate *for each stratum*, as described in *Method 1a* (points *10a-10c*).

11. For an estimate of the total population of the colony, sum the population estimates from all strata (obtained in point *9*).

12. Calculate the standard error of the estimate of total population as follows:

a) Add the figures for variance obtained for the various strata (point *10*), to give the variance of the population estimate for the whole colony.

b) Calculate the square root of the whole-colony variance obtained in step *a*, to give the standard error of the total population estimate.

13. Report :

a) raw data;

b) the mean number and sample variance of AOBs per quadrat, separately *for each stratum*;

c) the total estimate of AOBs and variance of that estimate *for each stratum*;

d) the total estimate of AOBs (±SE) for the *whole colony*.

Or, provide raw data for calculations (area of colony, area of each stratum, which quadrats were in each stratum, number of AOBs in each quadrat).

14. Assessing the statistical significance of year-to-year changes is also complex (see Harris and Rothery 1988). Preferably, pass data to JNCC or RSPB for calculations.

Census method 2 (transect method)

1. Sampling is best carried out before or during the laying period, when birds are digging or cleaning burrows and when ground vegetation is short; late April is optimal in south-east Scotland, early to mid May in north-west Scotland. However, acceptable counts can be made at any time from late April to early August, although assessments of population change should preferably be based on counts made at the same time of year.

2. Establish transect bands running through the colony (avoiding areas which would be dangerous to fieldworkers, or which are so heavily eroded that many burrows could be collapsed by walking over them), including apparently unoccupied areas beyond the boundary of the colony. The number of transects will depend on time available and the shape of the colony (more transects in long, thin colonies). Larger numbers of transects improve the prospects of demonstrating that changes in populations are statistically significant; we suggest five or more. Mark the boundaries of the line of the transect at short intervals with stakes. Transect lines should be permanently marked so that the same lines can be checked at each count.

3. In colonies where there are no marked differences in density between different areas, transects should preferably be placed randomly within the colony as a whole (see *General methods*). (Previous knowledge of the colony, or a preliminary survey of relative burrow densities, will be needed.) To determine positions for transects, divide a map of the colony into bands of 3 m width perpendicular to the long axis of the colony (thus, a colony 300 m long would have 100 potential transects), number them, and select several using random methods (*General methods*). Otherwise, position transects so that all distinct subgroups (especially strata of different density) are sampled (again, randomly if possible). At some colonies, there may be few accessible locations to position transects.

4. Count all apparently occupied burrows along each 3-m-wide transect. Running ropes along the boundaries of the transect will improve accuracy. Include all burrow entrances lying 50% or more within the transect strip, regardless of the direction of the tunnel.

5. Record numbers for each transect separately, and the overall total.

6. The whole colony total may be estimated if the area of the colony is known. If transects were placed randomly in the colony as a whole, calculate the mean density/m^2 for each transect, then multiply the mean of the transect means by the area of the whole colony, i.e. treat transects as if they were large random quadrats of variable size.

7. If transects were placed within particular subgroups (strata) of the colony, calculate mean density/$m^2$for each transect and the mean of all transect means through each stratum. Multiply this up to the area of the stratum transected. Sum the population estimates from each subgroup for the whole colony figure.

8. Report the raw data (colony extent, number and sizes of transects, numbers of AOBs in each transect), and any calculations you have done. Advice on statistical assessment of changes from year to year is available from the handbook compilers.

Census method 3 (counts of individuals)

1. This method is useful only for estimating the general size of small colonies. Even at best, it may provide only a broad indication of colony size.

2. Count:

a) the number of individuals present above ground, on as many dates as possible in a season.

In addition, provide separate counts for:

b) birds flying over the colony or nearby sea;

c) birds on the sea within 200 m of shore.

Numbers visible on land or close inshore are usually highest in the evenings or during foggy conditions, so try to make some counts at these times.

3. Record the peak number of birds seen on land early in the season, in the pre-laying period (before mid April on North Sea coasts, late April off north-west Scotland), and any subsidiary counts made at the same time of flying birds and birds on the sea. If counts cannot be made at this stage, try to make them before June, when substantial numbers of immatures begin to attend the colony. Also record the peak numbers seen at any stage of the season.

4. Note any positive evidence of breeding, for example adult entering burrow with fish. Puffins occasionally attend mixed seabird colonies without breeding there, but only deliver fish to chicks in burrows or crevices.

5. Relating counts of visible birds to breeding numbers is difficult, but the likely order of magnitude of the population (e.g. 10-100 or 100-1,000 adults) may be indicated by the counts available..

Productivity-monitoring methods

Accurate productivity monitoring is labour-intensive because of the burrow-nesting habits of the species. However, a reasonably good estimate can be obtained from two visits taking about a day each, if confusion with Manx shearwater burrows is not a problem. Puffins do not tolerate much disturbance when nesting so none of the methods which have been developed involve handling the adult. Studies indicate that where this is avoided, productivity is not affected (Harris 1980). The recommended method involves direct examination of a sample of nests (*Method 1*). Where confusion with shearwater burrows is a problem, or where burrows are among rocks preventing physical examination, time-consuming observational methods (*Methods 2* & *3*) are the only practical alternatives (although they may provide less reliable results).

Productivity-monitoring method 1 (staked burrows)

1. This method was developed by Harris (1989a). It is suitable for colonies where burrows are in soil and where there are no Manx shearwaters present, and involves feeling down a burrow with a short bamboo or stick.

2. Check a series of burrows after the peak of laying; early May is usually best.

3. Disperse the burrows checked through the colony. Try for a sample of 100^+ burrows.

4. Select a series of sticks or thin bamboos 15-50 cm long. Take the longest, lie on the ground and push the stick and your arm down the burrow. Any incubating puffin will move off the egg, which can usually be felt with the stick on the floor of the nest-chamber. If the stick is too long to go around a bend in the burrow, try again with a shorter one. Be careful not to break the egg. Any burrow where an egg is felt is then staked (but not necessarily numbered), being careful not to drive the stake through actual burrows. Bear in mind that the vegetation may well grow quite tall and you will want to find the burrow again, so stakes may have to be 1 m or more long. These checks are best made when the ground and burrow floor are dry.

5. Re-check the burrows when most pairs have very large chicks (usually early July in north-east Britain, mid-July elsewhere), but before the first chicks fledge. It is usually easy to determine if the nest has been successful, either by feeling the chick, finding the chick's latrine at the first bend of the burrow, or searching for moulted down among the nest-lining. Keep a note of any evidence of predation of chicks or flooding of burrows, and any chicks found dead.

6. Success is expressed as the number of chicks present divided by the total number of burrows refound where presence or absence of a chick was determined (i.e. burrows not refound are not included in calculations).

Productivity-monitoring method 2 (staked burrows plus observations from hide)

1. This method is adapted from Harris (1989a), and is suitable where birds nest accessibly but the colony is shared with Manx shearwaters.

2. Find a vantage point where burrows can be watched from a distance with binoculars (preferably from a hide).

3. Mark all visible burrows with large numbered stakes and early in the season record which burrows are being regularly used by puffins. As a rough guide, burrows entered by a puffin on two separate dates may be included in your sample. Aim for a sample of *c.* 100 puffin burrows if possible.

4. Check these burrows for presence of an egg in early to mid May, as in *Method 1*, point 3. (Assume the burrow occupants, if any, to be puffins, based on earlier observations, unless there are indications - e.g. calls - that Manx shearwaters are present).

5. Check for chicks as in *Method 1*, point *5*. Check the shape of the bill by touch, or remove the chick, to confirm it is a puffin.

6. Success is expressed as the number of chicks divided by the number of puffin burrows in which eggs were found.

Productivity-monitoring method 3 (mapped burrows plus observations from hide)

1. This method is adapted from procedures developed by Harris (1989a). It is suitable for assessing productivity in colonies where nest-site entrances cannot be approached and/or the nest chamber is inaccessible (e.g. steep slopes, scree, deep crevices among rocks). It can be used in colonies shared with Manx shearwaters.

2. Find a vantage point where burrows or the entrances to potential nesting crevices can be watched from a distance.

3. Mark the position of burrows or crevices regularly used by puffins early in the season on a good photograph or, where the entrance can be safely approached, place a numbered stake. As a rough guide, burrows or crevices entered by a puffin on two separate dates may be included in your sample. Aim for a sample of *c.*100 nest-sites if possible, though many colonies may be too small, or only small parts may be visible.

4. When birds are feeding large chicks, make a few watches to determine which burrows/crevices have fish taken down them. This is best done in the early morning when feeding frequency is highest.

5. Express productivity as the number of successful nest sites divided by the number occupied early in the season.

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Appendix 1

Terminology

The following terms are used at various points in this handbook, and, although their broad meanings may be clear from the contexts in which they are used, further background is provided here, to avoid misunderstanding over meanings. This list should not be treated as in any way definitive, or generally applicable, but may be of some use within the context of seabird work.

Breeding population

Strictly, this is the total number of adult birds (or number of pairs), in a defined study area, which make a breeding attempt (i.e. produce an egg) in a particular year. To measure the true breeding population with complete accuracy would generally require prolonged, daily (or more frequent) observations of a study population composed of individually recognisable birds. In practice, what is measured as the breeding population involves several approximations.

The recommended census unit for a species will usually be the best practical (but not 100% reliable) indication of a breeding pair, because proof of breeding may too difficult to obtain for other than very small populations (e.g. if eggs are not readily visible, or if eggs are lost from some nests before a count). For example, apparently occupied nests (AONs) are usually defined as well-constructed nests, attended by at least one adult and capable of holding an egg (even if nest contents are unknown, or the nest is known to be empty). Some empty AONs may have already lost their eggs (even though adults may remain in attendance), whereas others may not be laid in at all.

Another approximation involves the relationship between peak or average counts of the relevant census unit and the total population breeding in a season. Without very detailed mapping studies, in combination with daily observations throughout the incubation period, breeding pairs that lose eggs and abandon the colony, or whose nests deteriorate, will be missed on any single date, and some pairs may not have laid (or constructed complete nests) by the time of a count (e.g. Green & Hirons 1988). Depending on the species, either the peak count of AONs (or other measure of breeding population) or the average count within a defined period, is generally used, providing at least an *index* of the total breeding population. In general, the peak count of AONs for relevant species is likely to correspond to at least 90% of the true breeding population (e.g. various studies of shag and kittiwake). This figure may on occasion be lower, for example in an unusually extended breeding season where many pairs have already failed by the time others begin to breed.

Census

Equivalent to 'survey' here (see below): a count at a particular location at a particular time. This may be a one-off count, or may be part of a long-term programme of counts (and thus form part of a monitoring scheme).

Colony (cf. subcolony)

A 'local' concentration of breeding birds, with no deeper sociobiological meaning necessarily implied. For recording and archiving of seabird counts, we recommend that a 'colony' should refer to a multi-species assemblage, rather than to discrete groups of one species (which may or may not overlap with discrete groups of other species). The more species-specific meaning of colony (involving interacting birds of the same species) is not used here, except in a vernacular sense when describing techniques to be used for one species at a time. In practical terms, defining a 'colony' is difficult to do objectively. One suggestion (made for terns) is that, if it is possible to walk between two groups of breeding birds, without causing any disturbance to either group, each should be considered a separate colony (Bullock & Gomersall 1981). Instructions for Seabird Colony Register surveys during 1985-87 suggested a minimum distance of 100 m between such groups but that definition of colony boundaries was best left to on-site assessment (Lloyd *et al.* 1991). In practice, quite large islands have been treated as single 'colonies' by the observers involved, particularly where little clear division is evident between stretches of occupied cliff, and between cliffs and upper slopes (or island plateaux).

Index

In the context of breeding seabirds, this refers to a measure of breeding population or breeding output that is considered to be proportional to, but not necessarily identical to, the 'true' figure for population or breeding output. For example, if we are unable to measure total breeding population of a species in a colony, the peak count of apparently occupied nests or of individual adults could be considered an *index* of the population. The average number of guillemots present at a colony under defined conditions can be considered an index of the breeding population, although the number of guillemots does not equate to the actual number of breeding pairs (and the precise relationship between the two units can be somewhat variable). For assessment of breeding success, a method that provides a result that overestimates breeding success by, on average, 10-20%, can be considered an index of breeding success. In practice, results derived from practical methods may be described as referring to the 'breeding population' or 'breeding productivity' of a species at a colony, but those using the data should always be aware of the approximations involved. See also the note on *Breeding population* above.

Study-plot / sample plot

A subgroup, within a colony, whose position has been defined in some way, for example on a map or photograph, on the basis of physical features.

Subcolony (cf. colony)

Any subgroup, within a colony, whether it has been accurately delimited or not. As with 'colony', no deeper meaning should be inferred.

Monitoring / surveillance / survey

Baillie (1990), in the context of land-bird monitoring, noted that "*monitoring* may be defined as comparing observed changes with a standard measurement" and that "it implies some pre-defined threshold which will be used to trigger action". Such action might include further research; initiation of a protection scheme; or an attempt to modify a human influence. Baillie noted that "monitoring should be distinguished from surveys (i.e. studies of numbers and distributions of birds at particular points in time) and from surveillance (... measuring changes in population variables with time)".

A more basic definition, provided for seabirds by Hatch *et al.* (1994), is that "Seabird monitoring is the accumulation of time series data on any aspect of seabird distribution, abundance, demography or behaviour. ... The key requirement is that observations are replicated over time, and made with sufficient precision and accuracy to permit the meaningful analysis of variability and trends."

Clearly, there is some overlap/ambiguity between terms, as monitoring implies surveillance (which often involves 'survey', particularly where whole-colony or area populations are counted/estimated). For the purposes of this manual, we use the term 'monitoring' in the broader sense of surveillance of populations and their breeding productivity. Nevertheless, the potential to act on the results of such monitoring is implicit, and, on occasion, action *is* taken by the relevant conservation bodies in response to highlighted trends.

Appendix 2

The Seabird Colony Register

The numbers of seabirds breeding on the coasts of Britain and Ireland are of international importance. Effective conservation policies for seabirds depend on the availability of accurate and up to date information on the size and location of colonies. The first comprehensive survey of these colonies was the Seabird Group's *Operation Seafarer* in 1969-70 (Cramp *et al*. 1974). In 1984, the Seabird Group and the Nature Conservancy Council jointly planned a repeat survey, carried out mainly in 1985-87. At the same time, the Seabird Colony Register (SCR) was established as a computerised database for storage and analysis of these and other counts on a continuing basis. As with most ornithological surveys, fieldwork for both projects was conducted largely by volunteers.

For the intensive 1985-87 survey, appeals were made for help among the Seabird Group membership and British and Irish birdwatchers in general. Fieldworkers from many conservation bodies also took part. Observers were also encouraged to submit unpublished counts from previous years. Many additional counts were abstracted from local bird reports, other published sources, and the files of various conservation bodies. The SCR now holds information on the size and location of virtually all seabird colonies on the coasts of Britain and Ireland for the period 1969 onwards. Available information for inland colonies is also stored.

Over 500 observers and organisations took part in 1985-87 fieldwork, and virtually complete coverage was obtained of UK coasts. Most of the Republic of Ireland was also surveyed, with gaps being filled during 1988-90. Standardised count methods were used. For future reference, the boundaries of defined 'colonies' or coastal stretches were recorded, with access and descriptive details where possible.

A detailed summary of 1985-87 counts, was published in *The status of seabirds in Britain and Ireland* (Lloyd *et al*. 1991).

JNCC and the statutory nature conservation agencies use SCR counts to identify seabird colonies qualifying for protection under national and international conservation measures. The counts are also used in assessments of the implications of human activities that might conflict with seabird conservation. In addition, counts provide much useful information on short-term or year-to-year changes in seabird populations at some colonies. SCR counts are also supplied to other *bona fide* individuals and organisations, for example for use in Environmental Impact Assessments.

The SCR is now maintained as an integral part of JNCC's Seabird Monitoring Programme, on behalf of JNCC and the Seabird Group, with new counts continually being added. Previously unsubmitted counts, or counts of coastal or inland colonies in future seasons, are always welcome.

Copies of the *instructions* and *recording forms* for the SCR are attached overleaf. These are versions as at December 1994, incorporating some modifications for consistency with the *Seabird monitoring handbook*. Further updates are likely to be available in the near future.

Address for correspondence regarding the SCR:

Seabird Monitoring Programme, JNCC, 17 Rubislaw Terrace. Aberdeen AB1 1XE.

JNCC / Seabird Group Seabird Colony Register

Instructions

Important

Please read these instructions carefully and keep them available for reference. Please be sure to obtain permission before venturing onto private land; this survey does not give you right to enter private property. Your own personal safety is paramount; *do not* go near the edge of unsafe cliffs.

The recording forms

Three forms are provided for the Seabird Colony Register:

i. ***10-km square summary***

This card is intended to provide information on the exact position of colonies, and also areas with no breeding seabirds. Each colony and area with nesting seabirds should be named and details given on ii.

ii. Colony register form

The relatively permanent features about each site and the current status of its seabird population are given on this sheet. It provides a convenient summary of knowledge about the site, including details of any species work carried out there.

iii. Data sheet

Each count made at the colony is recorded on this sheet. Only one is needed per year, but there is no need to change either the colony register form or the 10-km square summary each year unless the birds' distribution alters.

Instructions on how to use the forms

i. 10-km square summary

Using an Ordnance Survey map (preferably scale 1:50,000) locate the 10-km square on the coast you wish to cover. Complete one card for all the coast in that square, or amend an existing card (if available from JNCC) to indicate any new colonies. Sketch the shoreline on the grid using black pen, and mark seabird colonies or breeding areas clearly, using names given on the O.S. map if possible. Where seabird colonies occur away from the coast, mark the approximate colony limits on the relevant 10-km square. In areas where fulmars breed extensively inland (e.g. Shetland, Orkney), please try to record numbers in each 1-km square. Use two 10-km square summary cards but one colony register form for any site that overlaps two 10-km squares.

ii. Colony register form

We suggest the definition of a colony for this survey should be that if it is possible to walk between two groups of breeding birds without disturbing them, then they are counted as two colonies. This distance should be a minimum of 100 m. However, we feel that the exact definition of a colony's boundaries is best left to an on-site assessment. If in doubt, it is usually best to subdivide an area so long as this can be done unambiguously, and submit full details.

Colony Name:	Please use same names as on 10-km square summary.
Location:	Fill in O.S. grid references for the start and finish of a cliff section, or for the approximate centre of a flatter colony.
Description:	e.g. north side of Firth of Forth, near Crail.
Status:	e.g. National Nature Reserve, SSSI, RSPB reserve.
Description:	Details of cliff height and aspect, habitat on island, etc. If possible, sketch a map on back of form or enclose photograph(s) of the colony to show where each species nests and to mark features of interest.
Access:	e.g. ease of access, boatman and/or landowner's name and address, other useful information for anyone wishing to visit the site.
History:	Be brief; refer to bibliography if possible.
Seabirds:	List breeding seabird species and summary of status (i.e. increasing, decreasing, or stable) if known, e.g. 'colony expanding rapidly according to local boatman.'
Counting Problems:	Indicate approximately what percentage of the colony can be counted from land, how much can be seen only from sea, and any particular problems encountered, e.g. birds nesting in caves.
Other Notes:	Any relevant information on the colony, e.g. site of extensive seabird ringing since 1956, or site of annual monitoring counts.
Bibliography:	Give details of books, scientific papers, or reports which mention this colony.

iii. Data sheet

Complete one sheet for each year's observations including all counts carried out, even partial ones. If you have data for the colony that do not exactly fit on the form, e.g. additional counts of individual fulmars on land, include them on the back of the sheet.

Colony name: Use same name as on 10-km square summary and colony register form with qualifications if necessary, e.g. Auskerry, south side.

Year: Year of counts.

Date: Record month and exact dates during which counts were made. If the figures given are the means of counts from several days (or are otherwise derived from a series of counts, e.g. highest of several counts for kittiwakes), give details on the back of the sheet.

Please read the following section carefully: it is the most important part of the instructions

Count & estimates: In some seabird colonies, every breeding bird or nest can be seen and counted accurately; in others a careful estimate of numbers (ideally made by subdividing the colony into sections) is the only possible way of censusing the breeding birds. Usually the birds in part of the colony can be counted accurately (i.e. with an estimated error of ±10% or less), and the remainder must be estimated. For example, sections of a stretch of cliff that are visible from land might give accurate counts, whilst the sections viewed only briefly from the sea would give estimates. If counts are made from land only, but some sections are not visible, try to estimate the likely number of birds or nests hidden (as a minimum-maximum range).

Fill in what you count and what you estimate separately so that the two parts of the census *together* give an approximate total for the colony. For example, you count 233 nests (233 in the 'Accurate Count' column) and you estimate there were a further 10-25 nests out of sight (10 in the 'Minimum Estimate' column and 25 under 'Maximum Estimate'). For some colonies only the count column will be needed, for others only one or both of the estimate columns, but for many colonies there will be entries in all three columns.

Put 'N' against any species that is present on land in the colony but apparently not breeding. For breeding species present but not counted, put 'P'. However, where no recent counts exist for a colony, please attempt at least an estimate of numbers for all nesting species.

Unit: Follow the recommended counting techniques attached, with special attention to the counting unit required. Code the unit you use for your counts as follows.

1 = Individual birds at colony (on land for guillemot and razorbill, excluding birds loafing at the cliff-base; on sea >300 m from shore for black guillemot; on land, sea and air for puffin).

2 = Apparently occupied nest-sites.

3 = Apparently occupied breeding territories.

4 = Other, give details in Notes.

Counting method: Record how each species was counted.

1 = From land.

2 = From a boat.

3 = From the air.

4 = From photo.

5 = From land and sea.

6 = Others, give details in Notes.

Breeding status: Use the highest code possible to record how certain you were that each species was breeding in the colony. *N.B.:* This is unrelated to the unit used for counting. You might count individual guillemots but give a breeding status of 15, 'nest with eggs'.

01 = Bird seen in suitable nesting habitat during the breeding season.

02 = Bird singing in suitable nesting habitat during the breeding season, e.g. petrels.

03 = Pair of birds seen in suitable nesting habitat during the breeding season.

04 = Bird seen defending territory, two records at least one week apart.

05 = Courtship displays, etc. recorded.

06 = Nest-site found.

07 = Agitated/anxious parents seen.

08 = Bird seen incubating.

09 = Bird seen building a nest.

10 = Distraction display recorded.

11 = Used nest found, e.g. broken eggshell, droppings, food remains, etc.

12 = Recently-fledged young present. Do not use for birds that may have travelled some distance, e.g. petrels.

13 = Occupied nest, contents unknown.

14 = Food seen being brought to young.

15 = Nest with eggs found.

16 = Nest with chicks found.

Comments: As with any survey, it would be surprising if all observations could be fitted into categories. Please do your best. If you are unsure or cannot fit a count into one of the sections of the data sheet, give details of your method and results on the back of the sheets. This is more easily processed than an accompanying letter.

Completed Forms: Mark clearly any records or information you wish to remain confidential. Please return all used forms *as soon as possible* after your count. Send forms to:

Seabird Monitoring Programme, JNCC, 17 Rubislaw Terrace, Aberdeen AB1 1XE

Thank you for your help

Recommended techniques for counting breeding seabirds

N.B.: See the *Seabird monitoring handbook* for fuller details of techniques, units, count dates, etc.

At all times, please be mindful of your own safety, and avoid disturbance of breeding birds.

Do not count seabirds on days with heavy rain, fog or high winds (wind-strength is especially critical for fulmar, guillemot, and razorbill). Most species should be counted in the middle of the day (0800-1600 BST). Note any departures from these instructions on the back of the data sheet, for example counts made after 1600.

Fulmar

Count *apparently occupied sites*, ideally in June but late May to early July will suffice. A site is counted as occupied only when a bird is sitting tightly on a reasonably horizontal area large enough to hold an egg. Two birds on such a site, apparently paired, count as one site.

Manx shearwater, storm petrel, Leach's petrel

A total census usually involves sample quadrats and possibly a ringing study. Otherwise, record the presence/absence of birds on land at night in suitable habitat, and each species' breeding status. If possible, roughly estimate the size of the colony and/or the number of birds singing in burrows.

Gannet

Count *apparently occupied sites*, either directly or from a good quality photograph: all sites occupied by one or two gannets, irrespective of whether or not any nesting material is present, so long as the site is suitable for breeding. Alternatively, count all *occupied nests* including those with only a trace of nest material. Count in the early to mid nestling period, usually June.

Shag, cormorant

Count *apparently occupied nests* in the early to mid nestling periods, usually late May or early June. Include all substantial or well-constructed nests occupied by at least one bird.

Arctic skua, great skua

Count *apparently occupied territories* ideally when most nests have complete clutches or when eggs have just started to hatch, approximately early June. Choose a suitable vantage point and scan from a distance using binoculars. Beware of counting paired birds standing apart as two territory holders, and of overlooking birds that are hidden against the background. Ideally repeat the procedure on several days during the count period and mark territories on a sketch map.

Black-headed gull, common gull, lesser black-backed gull, herring gull, great black-backed gull, all terns

Count *apparently occupied nests* in the mid incubation to early nestling period (usually late May and June); where actual nests are not visible, counts or estimates of apparently incubating adults or of apparently occupied territories may be required. Counts of individual adults may be necessary in some situations, and are particularly useful for terns. With all these species, particularly the terns, keep disturbance to a minimum. Large colonies may require the use of a team of counters or sample quadrats.

Kittiwake

Count *apparently occupied nests*. These are substantial or well-constructed nests capable of holding two or three eggs, occupied by at least one bird standing on or within touching distance of the nest. Count during the late incubation to early nestling period, usually early to mid June; easiest if the cliff is divided into sections and each counted separately.

Guillemot, razorbill

Count *individual birds on land* during the incubation to early nestling period, normally the first three weeks of June. All counts should be made between 0700 and 1600 BST; record the time for counts made outside this period in Notes. It is easiest to divide the cliff face into a series of sections and count the birds in each separately. If possible, estimate numbers of birds nesting in caves, and use photographs from higher adjacent land to count/estimate birds on flat-topped stacks.

Black guillemot

Differs from all other species: counting is recommended in the pre-breeding period, April to early May, in the very early morning (0500-0800 BST). Count all *adult plumaged birds* on land, or on sea within 200 m of shore, and note other birds separately. All coastline should be checked but the species is rarely present off low-lying coasts and or on islands accessible to rats.

Puffin

Optimum count is of *apparently occupied nest sites* (usually burrows) made during laying period (May). Ideally this should cover the whole colony or be based on quadrats or transects used to sample larger areas. Burrow-occupancy is determined by signs of fresh digging, droppings and, during the nestling period, by broken eggshell or fish in the burrow entrance. Rabbit burrows are usually larger with more soil outside, and bare earth and droppings in the entrance. Separation of puffin and Manx shearwater burrows is difficult and will usually require observation of the burrows to identify those visited by puffins (incubation changeover or feeding of chicks).

Probably all that can be achieved at cliff colonies is a count of *individual birds* on land and adjacent sea. Although not absolutely essential, these give best results if carried out just before dusk. Record land and sea counts separately and note the time of day (BST) of the count in Notes. *N.B.:* Be sure to record exactly which unit you used when censusing this species.

Seabird Colony Register

10-km square summary

Square no.

Observer ______________________

Address ______________________

____

Date ________________________

County / district __________________________

Sketch coastline using 1-km squares marked in box. Show exact position/extent of seabird colonies and indicate any parts of the coast that have *not* been surveyed. Use space below to list colonies or for additional details.

EXAMPLE

Square no. X X 9 9

County / district COUNTY X

A = Colony A (sand/clay cliff)

B = Colony B (sheer rocky cliff)

C = Colony C (island with grassy summit & sheer cliffs)

D = Colony D (sheer rocky cliff)

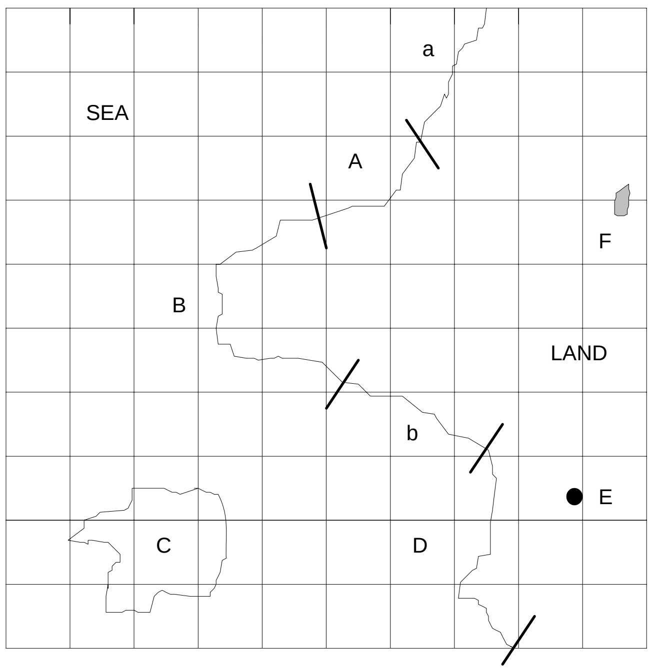
E = Colony E (rooftop gulls in village)

F = Colony F (lake & marsh)

Other sections:

a = not surveyed (sheer rocky cliffs)

b = no seabirds (beach and low clay cliffs)



Seabird Colony Register

Colony Register Form

OFFICE USE

COLONY NAME

LOCATION (OS grid ref.)

Cliff start			
Cliff end			
Col. centre			

DESCRIPTION OF LOCATION

COMPILER'S NAME & ADDRESS if different from 10-km summary

CONSERVATION STATUS

DATE OF COMPILATION

COLONY DESCRIPTION

LANDING / ACCESS /OWNERSHIP

ORNITHOLOGICAL HISTORY

BREEDING SEABIRDS & STATUS

COUNTING PROBLEMS

OTHER NOTES

BIBLIOGRAPHY

FOR OFFICE USE

Seabird Colony Register

Data Sheet

Name: ________________________ Year: ______________

Give address on back of sheet if different from Colony Register Form

Colony name: ______________________________

Notes: Use back of sheet

County or District: __________________________

SPECIES			DATES OF COUNTS	ACCURATE COUNT	+ RANGE OF ESTIMATE min.	max.	Unit	Method	Br. status
Fulmar	022								
Manx shearwater	046								
Storm petrel	052								
Leach's petrel	055								
Gannet	071								
Cormorant	072								
Shag	080								
Arctic skua	567								
Great skua	569								
Black-headed gull	582								
Common gull	590								
Lesser black-back	591								
Herring gull	592								
Great black-back	600								
Kittiwake	602								
Sandwich tern	611								
Roseate tern	614								
Common tern	615								
Arctic tern	616								
Little tern	624								
Guillemot	634								
Razorbill	636								
Black guillemot	638								
Puffin	654								

UNIT

1 = Individual bird at colony
2 = Apparently occupied nest
3 = Apparently occupied territory

COUNTING METHOD

1 = From land
2 = From sea
3 = From air
4 = From photo
5 = From land and sea
6 = Others, give details in Notes

BREEDING STATUS

01 = Bird in habitat
02 = Singing in habitat
03 = Pair in habitat
04 = Territory
05 = Display
06 = Nest-site
07 = Anxious parent
08 = Incubation
09 = Nest building
10 = Distraction
11 = Used nest
12 = Fledged young
13 = Occupied nest
14 = Food for young
15 = Nest + eggs
16 = Nest + chicks

Appendix 3

Recording form for counts of study-plots on cliffs

This is based on recording forms used by RSPB and JNCC, and can be used for up to ten counts at a single plot in a given year.

Time of day

Counts are generally made in the period 0800-1600 BST (0700-1500 GMT). At a given colony, individual plots should be counted at approximately the same time of day (say, within the same one- or two-hour period) on different dates and in different years.

Weather details

Where several plots are counted on a give date, it is not essential that weather details are recorded separately for each plot, provided any changes are noted on the forms for individual plots.

Species / census units

The species and units to be counted should be pre-defined for each colony and plot. At some colonies, for example, only guillemots and razorbills may need to be counted in particular plots, and fulmars in separate plots. At others, fulmars, kittiwakes, guillemots and razorbills may need to be counted in all plots. Usually, the required census units will be individuals for auks, apparently occupied sites (AOS) for fulmars, and apparently occupied nests (AONs) for kittiwakes and shags. Counts of other units or species may be required at some colonies. For existing sample-plot schemes, always consult any documentation available (e.g. from RSPB, JNCC or other organisation responsible for the scheme).

Counts at study plots

Please use this form to record the results of your counts. For guillemot and razorbill, a minimum of five counts should be made during 1-22 June (0800-1600 hours BST); for fulmar, a minimum of five counts during 1-30 June (0900-1730 BST). Use a separate form for each study plot. If more than ten counts are made, use an additional form.

Colony name: Year: [ ] Observer name:

County/district: Address:

Study plot name/No.:

Height of cliffs: Grid reference: [ ][ ][ ][ ][ ][ ][ ][ ]

Type of colony:
- cliff [ ]
- boulder scree [ ]
- flat top [ ]
- cave [ ]
- vegetated slope [ ]

Method of observation:
- binoculars [ ]
- telescope [ ]
- unaided eye [ ]

Photograph taken: [ ]

Map drawn: [ ]

Weather conditions: Count number	1	2	3	4	5	6	7	8	9	10
Cloud cover (in eighths)										
Rain 1 = none, 2 = discontinuous light, 3 = discontinuous heavy, 4 = continuous light, 5 = continuous heavy										
Sea conditions 1 = flat calm, 2 = small waves, 3 = large waves, 4 = white wave crests, 5 = waves breaking high onto rocks										
Swell conditions 1 = no swell, 2 = light swell, 3 = moderate swell, 4 = heavy swell										
Light conditions Plot in sun (1), shade (2) or half/half (3)										
Visibility 1 = good, 2 = fair, 3 = poor										
Wind speed (Beaufort scale 0-10)										
Wind direction										
Count standard Good (1), intermediate (2), poor (3)										

Counts

Counting unit: AON = apparently occupied nest
AOS = apparently occupied site
IND = individual adult

Year: ______

		Count number	1	2	3	4	5	6	7	8	9	10
Date												
Time of day (BST)		start										
		finish										
Fulmar		Total AOS										
		1										
	Study plot sections	2										
	(if applicable)	3										
		4										
Shag		Total AON										
Kittiwake		Total AON										
		1										
	Study plot sections	2										
	(if applicable)	3										
		4										
Guillemot		Total IND										
		1										
	Study plot sections	2										
	(if applicable)	3										
		4										
Razorbill		Total IND										
		1										
	Study plot sections	2										
	(if applicable)	3										
		4										
Other species												
/ units												

Appendix 4

Data sheets for recording breeding success at numbered nest-sites

Check-sheets A or *B* can be used to record details for individual nest-sites over a series of visits.

The basic formats of sheets A and B are similar. *Check-sheet A* is most useful for fulmar, guillemot, and razorbill, while *Check-sheet B* is useful for species which construct a nest (including gannet, cormorant, shag, kittiwake, and other gulls).

Data sheets for skuas and terns are included with the main text for those species.

Breeding success check-sheet (A) *Species*: *Observer:*

Colony name: *Plot name / no.:* *Year:*

Date											
Time											
No. 1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											

c/1 = clutch-size I = adult sitting tight, apparently incubating, contents not seen

b/1 = brood-size with remark of large, medium or small (L, M, S etc., or other age-codes)

/1, /2 = one or two adults present but not sitting tight P = apparent pair

Breeding success check-sheet (A) *Species*: *Observer:*

Colony name: *Plot name / no.:* *Year:*

Date											
Time											

c/1 = clutch-size I = adult sitting tight, apparently incubating, contents not seen

b/1 = brood-size with remark of large, medium or small (L, M, S etc., or other age-codes)

/1, /2 = one or two adults present but not sitting tight P = apparent pair

Breeding success check-sheet (B) *Species*: *Observer:*

Colony name: *Plot name / no.:* *Year:*

Date											
Time											
No. 1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											

c/1, c/2, c/3 = clutch-size c/0 = occupied, but empty, well-built nest

c/x = adult standing at well-built nest, contents unknown I = adult sitting tight, apparently incubating

b/1, b/2, b/3 = brood-size with remark of large, medium or small (L, M, S etc., or other age-codes)

/1, /2 = trace of nest, with one or two adults present

Breeding success check-sheet (B) *Species*: *Observer:*

Colony name: *Plot name / no.:* *Year:*

Date											
Time											

c/1, c/2, c/3 = clutch-size c/0 = occupied, but empty, well-built nest

c/x = adult standing at well-built nest, contents unknown I = adult sitting tight, apparently incubating

b/1, b/2, b/3 = brood-size with remark of large, medium or small (L, M, S etc., or other age-codes)

/1, /2 = trace of nest, with one or two adults present