Census methods for murres, *Uria* species: a unified approach
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1 Department of Zoology, University of Sheffield, Sheffield, England S10 2TN
2 Canadian Wildlife Service, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada B2Y 4A2
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Abstract

Methods are presented for estimating (a) population size and (b) population status of Common Murres (Uria aalge) and Thick-billed Murres (U. lomvia). Four colony types in which murre breeds are described and methods for estimating population size for major colony types are presented. Population status can be determined only through the use of study plots within selected study colonies. Two methods of counting (e.g., oil fouling, drowning in fish nets, disturbance and predation) and indirectly (e.g., toxic chemical poisoning, fisheries developments and other activities which may affect the food supply) (Nettleship 1977).

Many seabird species are currently at risk as a result of increases in pollution and the exploitation of non-renewable resources in the marine environment. Auklets (Alcidae) have decreased throughout much of the North Atlantic during the last 30 or 40 years. The reasons for the decline are not known, but seem likely to involve a number of factors. The main threats to auklets include factors which affect the birds both directly (e.g., oil fouling, drowning in fish nets, disturbance and predation) and indirectly (e.g., toxic chemical poisoning, fisheries developments and other activities which may affect the food supply) (Nettleship 1977).

Murres and Thick-billed Murres are threatened because offshore oil drilling and commercial fisheries developments are occurring in their habitats. We therefore urgently need to establish a unified monitoring system to detect real population changes in murre numbers throughout their ranges, so as to establish a baseline for comparing population changes over both short and long periods. This can be accomplished only through a carefully integrated management program undertaken jointly by nations responsible for the welfare of migratory bird populations inhabiting the waters of the Arctic, Atlantic and Pacific oceans.

Introduction

This paper describes methods for estimating population size (Cramp et al. 1975, Brun 1969, Hedgren 1975) while others present little or no information on techniques employed (e.g., Tuck 1961, Cramp et al. 1974). Where descriptions of methods are lacking or insufficiently precise, it is often impossible to assess previous estimates of population size and thus determine whether any change has occurred between censuses, since observed changes may be due to a number of factors alone. Clearly it is essential to have both a unified approach to censusing and consistency in methods.

Figure 1

Diagram showing colony type and census procedures for determining (a) population size and (b) population status of murres at breeding sites.

a: Population size estimate

<table>
<thead>
<tr>
<th>TYPE OF COLONY</th>
<th>COUNT</th>
<th>MEAN</th>
<th>CLIFF TOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLIFF</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SHORE</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>OPEN</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AERIAL PHOTO</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GROUND COUNT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b: Population status

<table>
<thead>
<tr>
<th>SELECTION OF STUDY COLONIES</th>
<th>SELECTION OF STUDY PLOTS</th>
<th>TIME AVAILABLE FOR POPULATION CENSUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) WITHIN A SHORE COLONY</td>
<td>(b) IN THE OPEN</td>
<td>(c) ON SHORE COLONY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TYPE</th>
<th>COUNTS OF INDIVIDUALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FULL SCALE METHOD</td>
<td></td>
</tr>
<tr>
<td>DETAIL RECORDING</td>
<td></td>
</tr>
<tr>
<td>DAY COUNTS OF INDIVIDUALS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RESULT</th>
<th>INDEX OF POPULATION STATUS BASED ON MEAN NUMBERS OF INDIVIDUALS ON STUDY PLOTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>b.</td>
</tr>
</tbody>
</table>
Murre colonies can be classified into four main types based on characteristics of the habitat used for breeding: (1) cliff, (2) flat top (either on low-lying islands or stacks), (3) boulder scree and (4) cave. Different colony types require different techniques for censusing. A short description of each colony type follows.

1. **Cliff colonies**

   Common Murres and Thick-billed Murres breed either on narrow ledges in long rows, on broad ledges in dense groups, or on many small ledges each large enough for only one or two pairs. They do, however, display certain differences in their selection of habitat for breeding: Thick-billed Murres prefer individual sites and narrow ledges, and never form dense groups as Common Murres do on broad ledges and on stacks or low-lying islands (see below and Williams 1974). Examples of cliff colonies are shown in Figures 2 and 3.

2. **Flat-top colonies**

   Only Common Murres form colonies of this type. Birds breed in densely packed groups consisting of tens, hundreds or thousands of individuals, depending upon the topography. At Funk Island, off east Newfoundland (49°46'N, 53°51'W) (Figs. 4 and 5), a flat, low-lying granite slab, Common Murres breed in three vast groups each composed of about 100,000 pairs. In contrast, at the Gannet Islands (54°00'N, 56°31'W), Labrador, where the topography is very uneven, Common Murre colonies are composed of many small groups of tens or just a few hundred birds (Fig. 6). For colonies on stacks e.g., Farne Islands, England (55°30'N, 0°39'W) and at Bear Island, Svalbards Archipelago (74°25'N, 18°46'E), group size is determined by the area of the stack top (Fig. 7).

3. **Boulder-scree and cave colonies**

   Both species of murre form colonies of these types, but they are more frequent among Common Murres. In boulder-scree colonies, birds may either breed in the open between boulders or in the spaces beneath (Fig. 8). In most cliff and flat-top colonies, a small proportion of Common Murres breed in cracks between rocks or under boulders.
Figure 3
Thick-billed Murre cliff colony, Prince Leopold Island, NWT. (a) General view of 300 m high cliffs around study plot S, late July 1971. Study plot S is outlined in black. (b) Specific view of study plot S, 23 June 1975, which contained 178 breeding pairs.

Figure 4
Common Murre flat-top colony at Funk Island, N.W.T. (a) Aerial photograph of Funk Island, 19 June 1972. (b) Sketch-map drawn from enlarged aerial photograph of (a), showing the three subcolonies of murre: Southwest, Central and Indian Gulch (see also Fig. 5 and Table 2).
Figure 5
Common Murre flat-top colony at Faux Island, Nfld. from ground. 3 July 1971.
This view of Central subcolony shows the almost continuous carpet of breeding birds.

Figure 6
Part of Common Murre flat-top colony at Grenfell Island, Labrador, early July 1971. This view is typical of the colony and shows irregular masses of breeding habitat, with many small breeding groups of birds (compare with Figs. 4 and 5; see also Fig. 10).

Figure 7
Part of Common Murre flat-top colony on the Stacks at the Farnes Islands, northeastern England.
1. Time of counting

The census period, during which all counts must be made, runs from the end of egg-laying to the start of fledging (i.e., early chick-rearing period). Murre numbers at this time are less variable than at any other stage of the breeding cycle (Lloyd 1975, Gaston and Nettleship in press). Unfortunately, it is sometimes difficult to predict the dates for the census as the timing of murre breeding seasons is often unknown, and because timing of breeding varies between colonies and between years. At British murre colonies (50°-60°N) the census period usually falls during June and counts are made then regardless of whether the season is early or late (Table 1). At high latitudes, breeding takes place later: for example, at Prince Leopold Island (74°22'N, 90°00'W) in 1975-1977, the census period fell between mid July and mid August (Table 1).

Counts or photographs should be made during the middle part of the day (Lloyd 1975, Gaston and Nettleship in press). It is essential that all details of counts be recorded (App. 1). We describe methods appropriate for each major colony type below.

2. Cliff colonies

The entire length of the colony should be photographed, either from the cliff tops, the sea or the air, to produce a permanent record of the precise limits of the colony. With populations of less than 10,000 birds on cliffs 25 m high or less, it may be possible to count all individuals directly (from the cliff-tops and/or the sea) (e.g., see Fig. 3). Alternatively, counts can be made from photographs as long as their accuracy has been previously checked by counting samples of about 200 birds and then photographing the area immediately. This procedure should be repeated with at least five sample counts. It is not sufficient to quote other studies which may provide "correction factors", since such factors will vary according to local conditions (e.g., lens and camera quality, weather, lighting, distance from colony).

With larger populations on higher cliffs, difficulties of counting are increased and accuracy reduced (e.g., see Fig. 3). If direct counting is impossible, estimate the density of murres per unit area of cliff either from photographs or from the cliff top. Estimate the total area of cliffs occupied by birds from photographs and delineate the areas occupied. These figures can then be used to estimate the population size, as shown in the example below. It is important to note that such a method is only feasible if the colony is not greatly indented and does not vary in height, so that all areas can be seen on photographs.

Example 1: Cape Huy, Bylot Island (73°46'N, 103°25'W).

An estimate of population size was made on 13-14 August 1976. The entire length of the colony was photographed from the air at a near-horizontal viewpoint, and as much of the colony as was visible from the cliff-top. The aerial photographs were used to produce a photo-mosaic (Fig. 9), from which the extent and area of the colony were measured. Four representative areas, examined and photographed from the cliff-top, and counted from photographs, contained 23,175 individuals.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Timing of breeding in Common and Thick-billed Murres at different localities.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>Locality</td>
</tr>
<tr>
<td>Common Murre</td>
<td>Smokey Island, Britain (53°45'N, 70°13'W)</td>
</tr>
<tr>
<td>Common Murre</td>
<td>Puffin Island, Eire (51°50'N, 10°25'W)</td>
</tr>
<tr>
<td>Common Murre</td>
<td>Stora Karls, Baltic Sea (57°15'N, 17°10'W)</td>
</tr>
<tr>
<td>Common Murre</td>
<td>Nefurt, Faroe Islands (55°50'N, 18°10'W)</td>
</tr>
<tr>
<td>Thick-billed Murre</td>
<td>Kipun Island, Greenland (72°31'N, 36°45'W)</td>
</tr>
<tr>
<td>Thick-billed Murre</td>
<td>Prince Leopold Island, Canada (74°02'N, 90°00'W)</td>
</tr>
</tbody>
</table>

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* Period between end of egg-laying and start of fledging.
** Based on one study plot only.

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The area counted was estimated at 15% of the colony, leaving out an area of unoccupied screes at the east end and the low cliffs on the west end of the colony. The number of individual birds present was estimated to be 180/15 x 23175 = 154,500. To this estimate was added a further 8300 individuals (counted directly from the land and not visible in the air photos) located in an inlet at the west end of the colony, and an estimated 3800 individuals on the low cliffs west of the inlet, visible only from a survey aircraft. The total number of individuals present was thus 154,500 + 8300 + 5000 = 167,800 (Gaston and Nettleship 1978).

Example 2: Skomer Island, Wales (51°40'N, 0°51'W) (see Fig. 2). This is a small colony of Common Murres comprising 3851 individuals in 1975 (Birkhead 1978). Cliffs are all less than 60 m and 90% of birds breed on narrow ledges, with about 5% in dense groups on broad ledges and 5% under boulders and in caves. A direct count of all individuals in the Skomer population has been made annually since 1963. In mid-June during the middle part of the day, and the locations of all breeding areas on the island have been mapped (see Birkhead and Ashcroft 1975).

3. Flat-top colonies

Vertical aerial photographs are essential for measuring the area occupied by breeding birds. Workers should produce detailed photo-maps (or rough sketches) of the colony. Ground counts are also essential for checking the composition of breeding groups. In accessible colonies, this can be done in the following way: count (and if possible photograph) birds in specific groups without disturbing them. Then, extremely carefully, drive the birds from their eggs and count the eggs. If breeding groups consist mainly of incubating birds, the egg:bird ratio should be near 1:1. After counting the eggs, measure the area occupied by the breeding groups using either 1 x 1 or 2 x 2 m quadrats, whichever are appropriate. If possible, take a photograph (from a high vantage point) of the eggs with a quad in place as a permanent record. This will provide a measure of density (i.e., eggs or incubating birds per m²). Count all eggs, but distinguish between those which were being incubated and those abandoned (i.e., eggs which were cold, broken or addled, or wedged in cracks). Using these figures together with a figure for total area occupied (derived from aerial photographs), you can then estimate population size.

For isolated stacks which cannot be climbed or where it is particularly undesirable to disturb incubating birds (e.g., because the colony is small or the risks from predators are high), the following method can be used. Densities where there are few spaces between birds and relatively few clefts, non-incubating individuals (i.e., off-duty birds), are probably fairly constant at an "average" maximum density figure of 20 pairs/m². This method can be used together with the total area occupied to estimate population size.

Example 1: Funk Island, Nfld. An extremely large colony of Common Murres, composed of three discrete sections (Figs. 4 and 5). The area occupied by each section was measured from an aerial photograph and found to total 17 049 m² (see Fig. 4 and Table 2). On the basis of censuses of eggs and chicks, the density of breeding pairs was measured using 10 rope quadrats, 2 x 3 m, which provided the estimates of population size given in Table 2.

Example 2: Gannet Islands, Labrador. Here Common Murres are distributed in a large number of relatively small breeding groups. Because of this, very large black-and-white aerial photographs (Fig. 10) must be used to estimate the area covered by incubating birds. Ground counts showed that

<table>
<thead>
<tr>
<th>Sub-colony</th>
<th>Area occup. (m²)</th>
<th>Mean density (pairs/m²)</th>
<th>No. breeding pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southwest</td>
<td>645</td>
<td>22.3</td>
<td>952</td>
</tr>
<tr>
<td>Central</td>
<td>645</td>
<td>21.3</td>
<td>952</td>
</tr>
<tr>
<td>Indian</td>
<td>479</td>
<td>20.1</td>
<td>952</td>
</tr>
<tr>
<td>Totals</td>
<td>17049</td>
<td></td>
<td>2856</td>
</tr>
</tbody>
</table>

* Estimate only; counts not made.

4. Boulder-scree and cave colonies

Birds in these habitats are very difficult to count. Fortunately, as far as we are aware, such colonies are relatively infrequent and rarely hold large numbers of birds. Perhaps the only feasible way to determine the order of magnitude of scree-and-boulder colony size is to make a number of counts of individuals and compare annual maxima. There is no obvious method of counting birds in cave colonies.
Population status

To detect changes in population status, one must first select study colonies and then study plots within them. We use two methods employing study plots for estimating population status (see Fig. 1b). The full-scale method (referred to here as type 1) provides the most accurate measure of the number of breeding pairs in a particular area, but is very time-consuming because an observer has to be present at the colony for at least 6 weeks, from just before the start of egg-laying until 8 days after it ends. However, the observer can obtain additional data on the timing of hatching, fledging and overall breeding success by staying until the end of the breeding season.

The second method (type II) requires an observer at the colony for about 10 days during the census period. Since counts are not particularly time-consuming, an observer can count several study plots each day.

1. Study colonies

Each organization (government or independent body) responsible for executing and co-ordinating counts of seabirds must decide, within its own geographic area of concern, the locations of representative study colonies. Ideally, study colonies should be located throughout the species' ranges, but for economic and logistic reasons this is not always feasible. Since financial resources and manpower are limiting, it is important to consider the location of study colonies rather carefully. As far as possible, colonies selected for monitoring the population status of a species through a large geographic area should together satisfy the following criteria:

(1) Choose easily accessible sites, such as mainland colonies, islands that are easy to reach, or islands with either resident wardens or other individuals who could conduct the counts.

(2) Include sites within areas which are vulnerable, for example, populations breeding or wintering in areas with offshore drilling or commercial fishery developments.

(3) Include a number of control colonies which are not currently at risk for purposes of comparison.

(4) Colonies should be spaced so as to cover as much of the range as possible. Be sure to select some study colonies at the edge of the range, since colonies in those areas may be the first to respond to changes in environmental conditions. The decline in Common Murres in the northeast Atlantic over the last 30-40 years was most pronounced towards the southern limit of their distribution (Cramp et al. 1974).

2. Study plots

Careful selection of study plots is essential to the success of these two methods. Ideally, study plots should be selected only by experienced observers, and the plots must meet the following criteria:

(1) Location and characteristics of study plots. Counts of types I and II can be made only at cliff colonies, where birds breed in single ranks on narrow ledges or on many small ledges. Study plots must be clearly visible from a suitable and safe viewing location, where an observer can look down on to the breeding birds (Fig. 11). Mark the position of the observer in some way to ensure that precisely the same position is used from year to year. This should be sufficiently close to provide a clear view of each bird, but far enough away that the birds are not disturbed.

(2) Numbers of birds per study plot. Each plot must be limited to a manageable number of birds; we suggest in the order of 100 individuals (equivalent to 70-80 breeding pairs). Study plots should be chosen so that all birds and their breeding sites are clearly visible — do not use particularly dense clumps of birds.

(3) Distribution and number of study plots per colony. The number of plots at each colony will depend partly upon the size of the colony and partly upon the time or manpower available. Ideally, larger colonies should have a greater number of study plots than smaller ones. We suggest one study plot per 1000 birds up to a maximum of 10 plots. Study plots should be selected from areas both at the centre and the edge of the colony, with others placed through the remainder to form a series which would allow differences within the colony (centre, middle or edge) to be detected.

An important assumption implicit in the use of study plots is that they reflect changes in numbers in the whole colony. In some seabirds (e.g., Northern Fulmar (Fulmarus glacialis), Durand et al. 1979) numbers in different parts of a colony may change independently of each other. We have checked for this effect in the few Common Murre colonies for which we have data on a sufficient number of years, and in each case there were significant positive correlations between different study plots, suggesting that numbers at such plots change in parallel. However, investigators responsible for the analysis of numbers at study plots must be aware of the possibility that this might not always be the case. In expanding colonies, certain areas may become saturated and new areas subsequently utilized. The same effect may occur in reverse in declining colonies.
3. Type 1: full-scale method

3.1. General details

This method involves plotting for each study plot the precise position of each egg soon after it has been laid. Ideally, the observer should have a photograph of each study plot taken the year previously, at a time when most birds had laid, to show the position of incubating birds. To accomplish this, the observer in the first year of the study should number each site as eggs are laid and, if possible, check the presence and fate of each egg on subsequent days (Fig. 12). Since inter-colony differences in the behaviour of the bird and the topography cannot be standardized, these represent irreducible contrasts. However, the intensity of observation and sizes of study plots can be standardized to a certain extent. On the basis of detailed study by Gaston and Nettleship (in press), we recommend the selection of study plots containing about 80 breeding pairs and observation for about 3 days. This should enable you to observe about 60% of eggs each day and detect about 50% of new eggs within 48 h. It means that a single observer could monitor three plots comprising a total of 200–250 breeding pairs by working 9 h every day. The only source of inaccuracy, and it is probably slight, is the chance of missing eggs that were laid and lost before the observer had detected them. There is no practical way to measure the number lost in this manner, but in two field studies where this method has been employed, workers considered that they overlooked only a very small proportion of eggs. Moreover, since many birds replace lost eggs, the observer has a second chance to record the location of a breeding pair (Birkhead and Hudson 1977, Gaston and Nettleship in press).

In addition, the observer must count all birds present on the study plot at the same time each day during the census period, so that the relationship between the number of breeding pairs and the mean number of individuals present (k) can be calculated for a particular time of day. This value is used to determine the number of breeding pairs at study plots using type II counts.

3.2. Specific details

(1) The procedure for type I counts is as follows.

(a) Observers occupy a number of large, good quality, black-and-white prints of each study plot, showing the positions of incubating birds and the limits of the plot.

(b) The study plot observation point for counting birds should be marked and identified by a permanent marker (e.g., iron stake, rock cairn) and photographed with an observer in situ.

(c) Observers should visit the colony at least once each day (at a standard time) prior to laying to ensure that first eggs are recorded. At most colonies of Common Murres in boreal regions, non-incubating birds leave their colony at dusk (i.e., spend the night at sea and return early next morning), and therefore evening checks may make new eggs easier to detect.

(d) Once observers have recorded the first eggs, they should revisit the plots at least once each day at a standard time. Observers should not assume that birds in an incubating position have an egg. Each site should be checked in turn for the presence or absence of an egg, and each site assigned a number as an egg is recorded. This method depends upon the movements of incubating birds, which expose the area beneath their broodpatch. Normal bird activity can provoke the observer with a chance to see and record the presence or absence of an egg (e.g., rising slightly from their egg in order to wing-flap or turn the egg). Birds without eggs make similar movements, so do not use any activity or posture alone to decide whether or not an egg is present — the egg must be seen. Since the intensity of observation strongly affects the results obtained, you should keep a precise record of time spent daily examining the birds within each study plot.

(2) Counts of individuals

(a) Record data in a tabular form using standard symbols as shown in Appendix 2.

(b) Egg-laying usually follows a similar pattern, with a larger number of birds producing eggs early in the laying period (i.e., a slightly skewed distribution). Continue to check sites each day for at least 40 days, to record both the fate of eggs and the appearance of first eggs at sites late in the season. If possible, continue to check each site until all eggs have hatched, since this will yield valuable information on both timing of breeding and breeding success. Note that the start of the census period should coincide with the end of egg-laying.

(c) Determine k values by making one count each day for 5–10 days through the census period (as described in the methods for type II counts given below) and calculating the mean number of individuals for each study plot. Divide the known number of breeding pairs (value derived from a completed study plot data sheet) by the mean number of individuals for each study plot to obtain k.

4. Type II: counts of individuals

4.1. General details

This much less time-consuming method is widely used in Britain (NERC 1977), but there are problems with the interpretation of counts (see below). Counts should be made between the end of egg-laying and the start of fledging.

For Common Murres breeding in boreal regions where there is a marked light-dark regime, studies at a number of colonies (e.g., Birkhead 1978, Jones 1978, Hedgren 1975, C. Bibby pers. comm., P.G.H. Evans pers. comm.) have shown that consistent diurnal patterns in colony attendance occur throughout the census period. In general terms, the pattern seems to be as follows: lowest numbers occur at night, increase after dawn, with a fairly constant level during the middle part of the day, and then decline again towards dusk. Since numbers remain fairly stable during the middle part of the day, most counts are conducted at this time over a number of consecutive days to obtain a mean of known accuracy for each study plot (NERC 1977). Such counts use the following assumptions:

(a) that diurnal patterns of colony attendance are similar from year to year; in fact it seems that diurnal patterns of attendance...
are similar from year to year for a particular colony, though patterns vary between colonies (Birkhead 1978, Hedges 1975, Jones 1976, Gaston and Nettleship in press); (2) that k values (ratio of breeding pairs: mean number of individuals) remain constant from year to year. The latter assumption is more difficult to assess because k values have been calculated in few studies. The only data for boreal Common Murres are from Stora Karlsö in the Baltic (Hedges 1975) and Skomer Island (Birkhead 1978), and these show similar k values within each colony from year to year. However, among Thick-billed Murres at Prince Leopold Island, NWT, marked differences in k values occurred between 1976 (k = 0.72) and 1977 (k = 0.62) (Gaston and Nettleship in press). Clearly, we need much more information before we can assess the "normal" variation in k values between years. Furthermore, since k values vary from colony to colony, extrapolation from one to another could be extremely misleading. For example, between 1973-1975 the Skomer value was 0.67, but at the Gannet Islands in Labrador, at the same phase of the breeding cycle, k values in 1978 were much closer to 1.0. Application of the Gannet Islands k values on Skomer Island would result in overestimation by about 50% (the reverse would underestimate by about 30%).

Another problem is that differences in mean counts between years could be statistically significant, but would not necessarily mean that a change in the breeding population had occurred. This could happen in a number of ways due to: (1) differences between years in weather conditions (see Discussion). (2) changes between years in the size of the non-breeding population owing to differences in breeding success and juvenile mortality, and (3) differences between years in the amount of time off-duty breeding birds and non-breeders spend at the colony, perhaps as a result of differences in the relative abundance of food. For example, for Thick-billed Murres at Prince Leopold Island, NWT (Gaston and Nettleship in press), the number of breeding pairs on study plots in 1976 and 1977 was almost identical, but there was a 10% difference in the mean number of birds counted during the census periods of the 2 years. As a result, k values also varied between years.

Variation of the size observed at Prince Leopold Island may occur frequently, and emphasizes the need for extreme caution in interpreting counts. In particular, we believe that it is dangerous to draw conclusions about population changes from just 2 years' counts. Annual monitoring over a number of years will provide the most sensitive measure of population status. For each year a mean ± SD of 5 to 10 counts made during the census period, at the same time each day, for each study plot will provide an index of the status of the population. For high arctic colonies, where there is only slight diurnal variation in light intensity, there is no "best" time to make counts, though peaks in attendance should be avoided (e.g., bird numbers were consistently higher in the evening at Prince Leopold Island). Thus it is essential for observers to determine the fluctuations in numbers over a 24-h period on at least two occasions during or immediately before the census period (Gaston and Nettleship in press).

4.2. Specific details

The procedure for type II counts is as follows.

(1) Observers require a large-scale photograph of each study plot, with the limits of each plot clearly marked on it. Accuracy will be increased if the observer is familiar with the study plot (Gaston and Nettleship in press), and if possible the observer should have visited the plot earlier in the season to make a number of practice counts.

(2) The observation point for counting birds should be fixed and identified by a permanent marker (e.g., iron stake, rock cairn) and photographed with an observer in situ.

(3) Counts of individual birds should be conducted at the same time each day for 5-10 days during the census period.

(4) On at least two occasions the observer should count individual birds present on the study plot at 2-3 hour intervals over the entire daylight period.

(5) The observer should complete a census form for each daily count at each study plot (App. I).

Discussion

We have described a census system which, at the first level, will enable observers to estimate population size in different colony types. At a second level, the methods described will provide figures from which we will be able to assess population status. We have emphasized the need for a unified approach with standardized procedure, so that in 50 years' time, if need be, we can produce counts which are directly comparable with those being made now (App. 3).

The next point concerns the availability and use of observers. At certain study colonies, resident wardens and enthusiastic amateurs living near the colony would be able to conduct type II counts. In addition, both kinds of observer would be in a position to make trial counts prior to the census period as suggested earlier. It may also be possible for coordinating organizations to employ biologists specifically to make type II counts at certain remote study colonies.

1. Frequency of counts

From our experiences of trying to interpret census figures collected many years apart, we believe that type II counts should be conducted annually at accessible colonies and every 2-3 years at those colonies which are less easily accessible and/or more expensive to reach.

Annual monitoring has several advantages: (1) it facilitates interpretation of type II counts in that one can use statistics to detect trends within the data, and (2) it provides a more sensitive method of detecting dramatic population changes. Rapid detection of such changes may mean that we are better able to mit the cause of the decline and, possibly, prevent any further decrease. Clearly, monitoring on a less frequent basis makes interpretation of counts more difficult, and reduces the chances both of rapidly detecting a decline and of being able to do something about it.

2. Sources of error

Several sources of error arise in type II counts. First, heavy seas, high winds (greater than force 5, Beaufort scale) and heavy rain all depress counts and can make counting difficult. Environmental factors must be recorded at the time of each count (App. 1). Fog can obscure study plots and prevent any count being made. However, an observer might be able to compensate for making another count later in the census period, after the count would normally have been finished. Second, disturbance by the close approach of other observers, low-flying aircraft and predators can lower the counts. Most of these factors can be checked and appraised if the observer is present for some time prior to or after making the count.

Finally, observers differ in their counting ability. This is undoubtedly a real problem, but error can be reduced by: (1) recording each observer's name and address, so that those responsible for analyzing and interpreting the counts can record changes of observer between years; (2) choosing good study plots in the first instance, so that all birds are clearly visible, which will undoubtedly reduce inter-observer error; (3) arranging for a 1-year overlap between observers — this would enable them to compare counts and provide the analyst with some indication of possible differences between the counting ability of the two observers; and (4) conducting counts conscientiously. We know of instances in which observers 'farmed out' their counting responsibilities to inexperienced persons, so that prescribed procedures were not followed and spurious results were obtained.

To summarize, efforts in applying census techniques on murres for management purposes must focus upon determining both population size and population status. It is essential to know precisely when bird numbers are changing, because rapid detection of such changes permits an early assessment of their significance, and affords the opportunity to do something about them after identification of possible causes. Improved methods for estimating population size at individual colonies should provide the means for a more precise measure of overall numbers, but population status can only be determined by using representative study plots within the colony area. We recognize that the application of population status methods (types I and II) are demanding both in time and effort. Nevertheless, we view these methods as the only available approach to accurate monitoring of population levels of murres in a way that enables biologists and wildlife managers to identify species' problems and the factors responsible.
Appendices

Appendix 1
Study plots recording from is completed for all marks counts, i.e., counts to be used to estimate population size and status (form modified from Nettleship 1976 and Jones 1978).

<table>
<thead>
<tr>
<th>Item</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Observer</td>
<td>name and address</td>
</tr>
<tr>
<td>2. Colony</td>
<td>name and locations</td>
</tr>
<tr>
<td>3. Study plot</td>
<td>number, letter, or name designation</td>
</tr>
<tr>
<td>4. Study plot location</td>
<td>date and reference and position (latitude and longitude)</td>
</tr>
<tr>
<td>5. Date of count</td>
<td>day, month and year</td>
</tr>
<tr>
<td>6. Time of count</td>
<td>start and finish times using GMT-24-h cycle; maintain precise record of actual time spent daily observing the study plot (minutes/hours)</td>
</tr>
<tr>
<td>7. Species</td>
<td>Uria aal in or U. lomvaa</td>
</tr>
<tr>
<td>8. Total count number of individuals counted</td>
<td></td>
</tr>
<tr>
<td>9. Observation method</td>
<td>good, fair, or poor, and study plot in sun or shade</td>
</tr>
<tr>
<td>10. Photography</td>
<td>details of photographs taken and focusing location and time of day (overcast, overcast, etc.)</td>
</tr>
<tr>
<td>11. Weather during details of cloud cover (clear to overcast)</td>
<td></td>
</tr>
<tr>
<td>12. Wind during count</td>
<td>direction (N, NE, E, S, SW, W, NW) and speed</td>
</tr>
<tr>
<td>13. State of sea during count</td>
<td>good, fair, or poor, and study plot in sun or shade</td>
</tr>
<tr>
<td>14. Phase of breeding cycle</td>
<td>comments and details of counts of eggs and chicks</td>
</tr>
<tr>
<td>15. DISTANCE FACTORS</td>
<td>none, or comments and details of course (shooting, aircraft, etc.)</td>
</tr>
</tbody>
</table>

Appendix 2

<table>
<thead>
<tr>
<th>Date</th>
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<tr>
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<td>3 July</td>
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<td>5 July</td>
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</tr>
<tr>
<td>6 July</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
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<tr>
<td>17 July</td>
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<td>20 July</td>
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<td>24 July</td>
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</tr>
<tr>
<td>13 September</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>14 September</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

* Each site represents locations of one breeding pair (see Fig. (2 for each location of sites within study plot U). |

Appendix 3
Records and materials for each study plot in each colony to be held by co-ordinating organization (government or independent body).

<table>
<thead>
<tr>
<th>Item</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Colony</td>
<td>name, precise location of colony and map reference</td>
</tr>
<tr>
<td>2. Study plots</td>
<td>(a) details of precise location of each study plot including large-scale map with exact positions identified (each plot must be numbered, lettered or named) (b) details of identification marker at each study plot (e.g., nest box, rock cairn) (c) original negative (taken when study plot first established) and photo-prints of each study plot showing limits of plot and subsections (where used) for counting (Note: plot boundaries should follow geographical features rather than being straight lines study plot photos are essential to successful counts by observers) (d) negatives and photo prints of study plots taken in subsequent years</td>
</tr>
<tr>
<td>3. Count data</td>
<td>copies of all raw data and completed count forms (App. 1) summary sheet for each study plot giving mean ± SD and the number of counts for each year</td>
</tr>
</tbody>
</table>

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