Requirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Scheme

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1. INTRODUCTION

1.1 Scope

This document is intended to form part of the Revised Management Scheme (RMS)[1] of the International Whaling Commission. Its main purpose is to aid the process of obtaining estimates of abundance for use in the Revised Management Procedure (RMP)[2]. by:

(i) stating the requirements of the RMS in this respect (Section 2); and
(ii) providing guidance on methods of conducting surveys and analysing data (Sections 3-6).

Sections 3-6 provide guidance on survey and analysis methodology that has been accepted by the Scientific Committee. That is, the methods have been reviewed by the Committee prior to the acceptance of estimates of abundance calculated from the data for use in the RMP either as input to the *Catch Limit Algorithm* (*CLA*)[3] or as input to *Implementation Simulation Trials* (*ISTs*)[4]. Novel methods, i.e. those that have not been reviewed by the Committee in this context, are referred to in Section 7. Estimates of abundance calculated from data collected and analysed using methods not yet accepted by the Committee would not be suitable for use in the RMP without further consideration by the Committee.

It is intended that the guidelines in Sections 3-6 will also be useful for those conducting surveys to obtain estimates of abundance for species/stocks not covered by the RMP. These include whale stocks subject to harvesting under the rules of the AWMP, whale stocks recovering from over-exploitation, and small cetaceans.

The most appropriate way to conduct a survey and analyse the data will depend on the aims, the species and the region. This document is intended to be an information guide to help those planning surveys to choose the most appropriate methods. It is not prescriptive except where there are requirements under the RMP (Section 2). Persons planning surveys not directly involved in providing input to the RMP are also encouraged to take advantage of the experience of the Scientific Committee by submitting plans to the Scientific Committee prior to conducting surveys.

The RMP does not preclude the use of direct methods of estimating absolute abundance other than shipboard or aerial sightings surveys, such as land-based surveys or capture-recapture analyses using photo-identification of natural markings. However, the Committee has not yet accepted estimates obtained from these methods for use in the RMP. Until the properties of such estimates and the implications for their use in the RMP have been further examined, sightings surveys remain the primary tools for obtaining suitable estimates of absolute abundance for input to the RMP. The guidelines in this document, therefore, are targeted towards the estimation of abundance from data collected on sightings surveys.

To estimate trends in abundance, it is desirable to have consistency in a time-series of estimates. However, the priority from the perspective of the *CLA* is to reduce bias. Thus, changes in survey methodology that reduce bias should not be sacrificed in order to ensure consistency in a time-series. However, collection of data using both the old and new methodologies in order to calibrate estimates is desirable and should be attempted where this is practical.

1.2 Reference material

These guidelines do not contain an extensive bibliography. Key references are given where appropriate and priority is given to review papers and papers describing the application of methods. A more extensive key-worded bibliography, updated annually, is available from the IWC Secretariat.

Important reviews that cover both practical and theoretical aspects of surveys are Buckland *et al.* (1993), Buckland *et al.* (2001) and Buckland *et al.* (2004)..

2. REQUIREMENTS UNDER THE RMS

2.1 Oversight by the Scientific Committee

The design and conduct of surveys and the verification and analysis of data from such surveys that are intended to provide estimates of abundance to be used in the *CLA* shall be under the oversight of the Scientific Committee to ensure that they adequately follow the requirements described in Section 2 and take into account the guidelines described in Sections 3-6. The following sub-sections describe the manner in which this shall be achieved. The Committee recognises the value of international collaboration and the desirability of participation of scientists representing the Committee in the design, conduct and data analysis of surveys intended to provide estimates of abundance for use in the RMP. It encourages interested scientists to collaborate with those planning and conducting surveys and to participate, as appropriate.

2.2 Notification and planning

Plans for survey design and proposed methods of data collection, verification and analysis that are intended to provide estimates of abundance to be used in the *CLA* shall be reviewed by the Committee in advance of their being carried out. The Committee may make suggestions or recommendations for modification to the plans but prior approval by the Committee is not a requirement.

The Secretariat shall be notified of surveys (by giving general information on area, timing and objectives) that are intended to provide such estimates at least 4 months prior to their start. Information on survey design, conduct and data analysis should normally be available for discussion at the Annual Meeting of the Scientific Committee. Final details, including field instructions and data sheets may be agreed at a cruise planning meeting attended by a member of the Scientific Committee or by a Standing Review Committee, where appropriate.

[1]*Revised Management Scheme* (*RMS*): This includes all scientific and non-scientific aspects of management, as covered in the Commission's resolution (IWC, 1993). However, it should be noted that at present the Commission has ceased working on the RMS.
[2]*Revised Management Procedure* (*RMP*): This is the scientific part of the RMS (pp. 483-494, this volume).
[3]*Catch Limit Algorithm (CLA)*: This is the process used to calculate the limit for a Management Area under the RMP.
[4]*Implementation Simulation Trials* (*ISTs*): These are case-specific simulations, the results of which lead to the recommendation of a particular variant of the RMP for a species in a Region.

Oversight by the Committee shall be at a level sufficient to ensure that the accepted methods are adequately followed. Depending on the methods to be employed and the experience of those proposing the survey, this may involve: participation in cruise planning meetings, the survey itself and the post-cruise meeting; or determination of a plan to facilitate the work necessary to obtain an abundance estimate in a timely fashion.

2.3 Survey conduct and personnel

The Committee will generally require that scientists familiar with the requirements of the methodology, and especially the implications of violations of survey protocol, participate in the survey. Based on review of the proposed survey plans, including the experience of scientists participating in the surveys, the Committee will determine the level of oversight required.

(a) For surveys in which the proposers have previous experience in applying the methodology for the species and region being surveyed, the Committee will generally specify one of the proposing scientists as its representative to oversee survey conduct;
(b) If the proposers request Committee oversight, or if the Committee judges that the proposers have insufficient experience of conducting the planned surveys, independent oversight by a scientist appointed by the Committee will be required to assess the adequacy of survey conduct. In the latter case, the Committee recommends that the Commission should normally pay expenses associated with this oversight role, including travel, per diem and salary, as required.

Committee representatives should submit independent reports to be considered at a post-cruise meeting or at the following annual meeting of the Committee, and/or as specified in any work plan established by the Committee under Section 2.2.

The Committee welcomes the participation of independent scientists knowledgeable in sighting survey conduct and analysis, but will not generally identify specific experience requirements for such participants.

2.4 Survey documentation and data provision and verification

The following documentation shall be provided to the Secretariat no later than six months prior to the meeting of the Scientific Committee in which data from the survey are to be used as input to the *CLA*:

(1) cruise planning report;
(2) field instructions and example data sheets;
(3) cruise summary report;
(4) documentation of any experiments conducted, e.g. to estimate measurement error in distances and angles;
(5) documentation of methods used to estimate distances and angles to sighted groups;
(6) specification of data accuracy verification procedures;
(7) documentation of observations excluded for any reason;
(8) description of analysis methodology planned to be used, including factors or covariates to be used in the derivation of the estimate; and
(9) documentation of additional information related to the conduct of the survey necessary for interpretation of the data.

The data outlined in Appendix 1 shall be provided to the Secretariat no later than six months prior to the meeting of the Scientific Committee in which they are to be used.

Data shall be provided to the Secretariat in fully documented computer readable data files. The Secretariat shall be consulted as to the most appropriate format.

Verification of the data should be carried out by those carrying out the survey. This verification will be audited by the Secretariat.

2.5 Data analysis

Estimates of abundance presented to the Committee shall be accompanied by a full description of methods used in analysis, including documentation of any variations from the description given prior to the survey (Section 2.4 point (8)) and any options chosen in analysis.

Abundance estimates intended to be used in the *CLA* (in contrast to their use in *Implementation Simulation Trials*) must meet the standards required by the RMP. The data and analyses from which the estimates are calculated must be adequately documented to allow the Committee to judge their acceptability for this purpose. The documentation should be sufficient to allow: (i) independent replication of the estimates; (ii) evaluation of the appropriateness of the estimates presented relative to possible alternatives (e.g. model selection procedures, pooling/stratification of the data); and (iii) evaluation of whether the estimates, associated variances and potential biases fall within the ranges used in evaluating the *CLA*. Appendix 2 provides an outline of the minimum level of data summaries and analysis documentation required. The appropriate level of documentation will depend in part on the nature of the survey and the novelty of the analyses.

If any part of the analysis has been undertaken with computer software that is not readily available, a full description and computer programs, including documentation to allow such programs to be validated, shall be provided to the Secretariat for eventual validation. The timing of this provision and subsequent validation shall be in accordance with the work plan established by the Committee under Section 2.2. Readily available software includes the line transect abundance estimation programs contained in the IWC Database and Estimation Software System, program DISTANCE[5], standard statistical software, and programs previously used and held by the Secretariat.

Documented data analysis and results shall be provided to the Secretariat and circulated to the Scientific Committee no later than three months prior to the meeting of the Committee in which they are to be used. Alternative analyses carried out in response to this shall be circulated no later than two months prior to the Scientific Committee meeting. These timings may be varied to meet the requirements of any work plan established by the Committee under Section 2.2.

If alternative analyses are carried out and substantial differences in results are apparent, authors shall try to reconcile or explain such differences and circulate the results via the Secretariat at least one month in advance of the meeting. Such alternative analyses shall also be carried out in accordance with any work plan established by the Committee under Section 2.2.

A previously accepted estimate should be reconsidered by the Committee if a major problem subsequently comes to light. The Committee should, in due course, also revise previous estimates when methods of analysis are updated or superseded.

[5]Program DISTANCE is available from *http://www.ruwpa.st-and.ac.uk/distance.*

3. SURVEY DESIGN

3.1 Area and timing

The RMP requires estimates of abundance for use in the *CLA* from wide areas of ocean. In some cases wide scale surveys have been conducted but in most cases, for practical reasons, the whole area of interest will not be surveyed at one time. Consideration therefore needs to be given to which particular areas should be surveyed in the context of providing the information on abundance needed by the RMP. For example, estimates of common minke whale abundance for the eastern North Atlantic have been obtained from surveys conducted in a single year (Schweder *et al.*, 1997) and also by combining estimates from surveys in different years (Skaug *et al.*, 2004).

In cases where whaling may be considered during migration (e.g. North Pacific common minke whales) rather than on feeding grounds, the timing of surveys can also be important.

3.2 Choice of platform

The choice of platform for a survey may be determined by factors beyond the control of those designing the survey. For example, the area to be covered may be so large or so remote that it is impossible to survey from any platform other than a ship. If the platform is not predetermined, some points to consider are as follows.

If the prevailing weather is variable but unpredictable over the survey area and it is close to land, aircraft can exploit these conditions more efficiently than ships. The characteristics of the target species of the survey are also important in choice of platform. For example, in an aerial survey, use of the cue counting approach (see Section 5.1) is not appropriate for animals that are usually found in groups of more than three to four animals. Table 1 summarises the platform and methods used to obtain abundance estimates accepted by the Scientific Committee for various species of great whales by geographical area.

Care should be taken to ensure that the platform chosen allows unrestricted viewing of the search area. It is also important to ensure that it is suitable for use in the prevailing conditions in the survey area.

3.3 Cruise tracks

The first stage is to define the area that is to be surveyed and to which the resultant estimates will apply. In many cases, the most efficient way to survey an area is to stratify it. The shape and size of strata will be determined by physical factors such as the surrounding land masses and limitations on the endurance of the survey platforms. If prior knowledge of the distribution and relative abundance of whales is available, this should be used when delimiting strata. If qualitative or quantitative information on the relative abundance of animals is available, more effort should be devoted to strata of known high abundance e.g. see Fig. 1.

Surveys should be designed so that the coverage probability in each stratum is uniform, or close to uniform, or can otherwise be determined. Estimates of abundance obtained from a survey design that does not meet this criterion will not be accepted for use in the *CLA* unless they have received prior approval from the Scientific Committee.

The aim of a survey should be to maximise searching effort in the area within the resources available. However, this should not be done at the expense of the experimental and calibration work necessary to ensure proper analysis of the data (e.g. estimation of $g(0)$, distance estimation; see

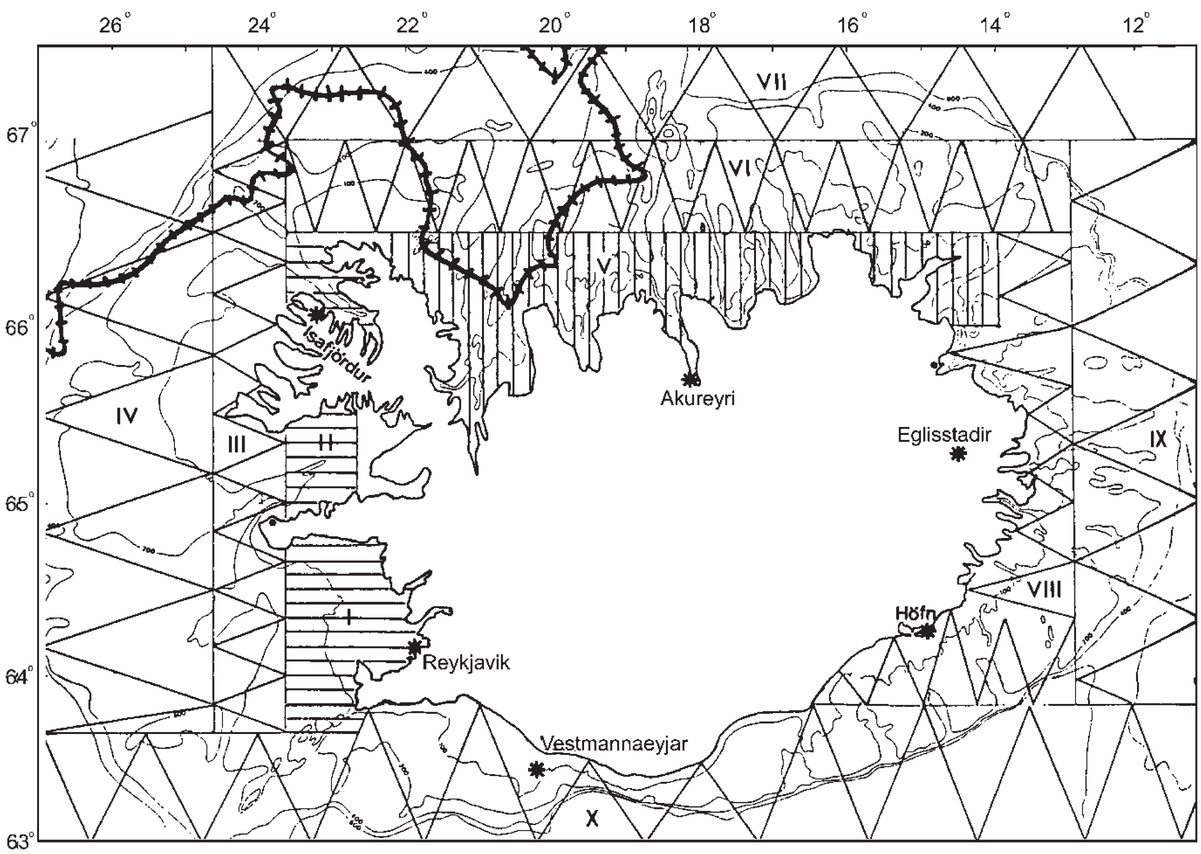

Fig. 1. Some examples of cruise track design, showing (i) parallel lines, away from the coast, (ii) regular zig-zag lines (iii) higher coverage in areas of higher relative abundance (iv) strata based on oceanography, endurance of the survey platform (in this case an aircraft), oceanography/physical features and previous knowledge of relative abundance and distribution. *RIWC* 44:170 (1994)

Section 4). When determining the length of cruise tracks, due consideration should be given to time that may be expected to be lost as a result of bad weather.

When considering the placement of cruise tracks, care should be taken that they do not follow physical features that may be correlated with whale abundance. For example, cruise tracks should not run parallel to the coastline or to depth contours in the vicinity of shelf breaks but should rather run across such features. Although the 'classical' approach is to place a random grid of evenly spaced parallel lines within each stratum, this can be inefficient if line separation is large, particularly for shipboard surveys. A commonly accepted alternative is to use regular zig-zag lines with a randomly chosen start point. Fig. 1 provides examples of different types of cruise track design. Program DISTANCE will design equal or known coverage probability cruise tracks for defined areas.

If more than one stratum is to be surveyed by different platforms operating at the same time, consideration should be given to the timing of the surveys in order to minimise the difference in time between surveying the area on one side of a stratum boundary and the adjacent area on the other side of the boundary.

If there is a known or suspected migration of whales through the survey area, care should be taken when designing cruise tracks and survey direction to ensure that the data collected are representative. For example, it is clearly inappropriate to survey following the direction of the migration, particularly with a slow moving platform.

3.4 Personnel

It is essential that survey teams contain at least some personnel who are experienced in conducting sightings surveys for whales. Requirements under the RMS are specified under Section 2.3. All personnel should be properly trained in shipboard or aerial procedures and data collection methods including: use of equipment; identification of species; measurement/estimation of angles and distances; estimation of group size; completion of data forms; and a basic understanding of how the data will be used. Cruise leaders should have sufficient knowledge of the analytical methods to enable them to make informed decisions in the face of unforeseen circumstances, e.g. with respect to modification of cruise tracks and coverage due to weather, ice extent etc.

4. SHIPBOARD SURVEYS

4.1 Methodology

Surveys from ships almost exclusively involve line transect sampling methodology. Two assumptions of conventional line transect sampling may be particularly problematic with respect to cetacean surveys:

(1) all animals on or close to the trackline are detected (i.e. the probability of seeing animals on the trackline, $g(0)=1$); and
(2) animals do not move in response to the vessel prior to detection.

Estimates of abundance from surveys using conventional line transect sampling may be biased to an unknown extent as a result of violation of these assumptions. The amount of bias depends primarily on the whale species/stock and the survey protocol. The majority of shipboard estimates of abundance accepted by the Committee for use in the RMP have been obtained from conventional line transect sampling surveys assuming $g(0)=1$ and no responsive movement. An updated table of accepted abundance estimates and methods used is available on the IWC website (*http://www.iwcoffice.org*).

However, a number of methods have been developed to account for animals missed on the trackline and, in some cases, responsive movement. These methods require the use of two teams of observers on independent platforms on the same vessel and the identification of groups, animals or cues seen from both platforms (duplicate identification). Methods that require two teams of observers on independent platforms include:

- the independent observer (IO) method (Butterworth and Borchers, 1988; Palka, 1995);
- the tracking method (Borchers *et al.*, 1998; Buckland and Turnock, 1992); and
- the hazard probability method (Schweder *et al.*, 1997; Skaug *et al.*, 2004).

The cue counting approach used on aerial surveys (Section 6) has been attempted on ship surveys but no estimates of abundance accepted by the Scientific Committee for ship surveys have used this methodology (but see Buckland *et al.*, 1993).

Those proposing a survey to generate estimates of abundance for use in the RMP need to determine which method will be used, taking into consideration the target species and the resources available, among other things. For example, if resources are limited and violation of conventional line transect assumptions is not believed to be serious for the target species, it may not be worth the additional complexity and expense of conducting a two-platform survey. The chosen methodology will determine data collection and analytical procedures.

4.2 Methods used by the Committee

This Section gives a brief description of the methods that have been used to obtain estimates of abundance that the Committee has accepted for use in the RMP.

4.2.1 IO method

The use of data collected by observers on two platforms on the same vessel to account for animals missed on the trackline was first explored by Butterworth and Borchers (1988) in the context of estimating the abundance of Antarctic minke whales in the Southern Hemisphere. Palka (1995) developed the direct duplicate method in estimating the abundance of harbour porpoises in the Gulf of Maine. In IO surveys, teams of observers search independently for groups of animals from two visually and aurally isolated platforms. Sightings detected from both platforms (duplicates) are determined in the field or in analysis based on position and time data. Data on observations from each platform and the duplicate data are then analysed to estimate $g(0)$ as part of the abundance estimate.

Collecting data from two independent platforms is considered by the Committee to be a standard method and estimates of abundance have been obtained from these data e.g for Antarctic minke whales (Branch and Butterworth, 2001). However, in estimates of abundance used by the Committee in the RMP, the duplicate sightings data have not been used to correct estimates of abundance for animals missed on the trackline, primarily because of concerns about bias resulting from unmodelled heterogeneity.

4.2.2 Tracking method

Buckland and Turnock (1992) proposed a method to account both for animals missed on the trackline and responsive movement. The method is based on one team of observers (the Tracker team) searching sufficiently far ahead of the vessel to detect groups/animals before they may have responded to it. This team then tracks detected groups/animals until they are lost or pass abeam of the vessel. A second team (the Primary team) searches independently as if conducting a conventional line transect survey and relays information on sightings to the Tracker team via radio. A judgement is then made by a 'duplicate identifier' on the Tracker team on whether or not each sighting made by the Primary team has already been seen by the Tracker team. The analysis of data from the two teams and of the duplicate data generate an estimate of abundance that accounts both for animals missed on the transect line and, if animals are seen before they respond, for responsive movement. This method has been extended by Borchers *et al.* (1998) and used to estimate the abundance of harbour porpoises, white-beaked dolphins and common minke whales in the North Sea and adjacent waters (Hammond *et al.*, 2002).

4.2.3 Hazard probability method

The hazard probability method takes as its starting point that because minke whales surface for very short periods they are observable only at discrete points in time. The method treats the sighting process as a point process in space (representing the locations of individual whales), time (representing the surfacings of the whales), and a sequence of Bernoulli experiments representing whether or not a whale was observed at a given surfacing. The probability of success in these Bernoulli experiments is called the hazard probability and is the conditional probability of detecting a whale given that the observer was previously unaware or it.

In practical terms, the method requires that teams of observers searching from two independent platforms track sighted whales and record data on the time, angle and radial distance of each surfacing in a track. Because neither team is aware of the others' sightings, duplicate identification is not undertaken in the field.

The hazard probability depends on the position of the whale relative to the observer and on other covariates such as Beaufort sea state, visibility, observation team, etc. Parameters of the hazard probability are estimated by maximum likelihood methods, with the likelihood function evaluated partially by stochastic simulation, incorporating dive-time data from radio-tagged whales. The likelihood function consists of two parts, one based on the recorded initial position of the sighted whales, and the other based on the double platform data. Before calculating the likelihood function, the double platform data are processed through a duplicate identification routine incorporating a measurement error model.

The method is analytically complex and computationally intensive. Schweder *et al.* (1997) and Skaug *et al.* (2004) describe the application of this method to the estimation of common minke whale abundance in the northeastern North Atlantic.

4.3 Common considerations

A number of important considerations are common to all shipboard line transect methods. A good source of detailed information on these and other aspects of conducting sightings surveys is the document providing Information for Researchers on the IWC SOWER Circumpolar Cruises (available from the IWC Secretariat and the IWC website).

4.3.1 'Passing' versus 'closing' mode

When a sighting is made by an observer, either (i) data on the sighted group can be collected and recorded as searching continues (passing mode) or (ii) searching can cease while the group is approached to confirm species identification and estimate group size (closing mode). There are advantages and disadvantages to both methods.

Closing mode results in a low proportion of groups unidentified to species or without group size estimates but can result in an under-representation of searching effort in areas of high whale density. This is because the time taken to close with sightings may substantially reduce the time left for searching and because primary sightings may be missed that would otherwise have been seen. Conversely, passing mode eliminates possible bias as a result of this, but can result in a higher proportion of sightings unidentified to species or without group size estimates.

The most appropriate method for a particular survey will depend on the species and region to be surveyed. Many surveys now use 'modified closing mode', whereby sightings are only closed with where necessary to confirm species and/or school size (this applies only to target species - passing mode is always applied to non-target species). In other surveys, a combination of both methods has been used at different times.

On two-platform surveys, the procedures for using closing mode depend on the particular method (see Section 4.3.6).

4.3.2 Searching effort data

Searching effort data should be collected and recorded in a disaggregated form to allow the recalculation of estimates of abundance if boundaries of Management Areas are altered. Changes in Beaufort sea state and other indicators of sighting conditions should be recorded to allow the data to be stratified by these variables where appropriate.

4.3.3 Estimates of angle and distance to a sighted group of whales

Line transect sampling assumes that data are accurate. Distance and angle data are particularly important and training observers in the collection of these data should be conducted, preferably at the start and during surveys, in the interests of obtaining the most accurate positional data possible.

It is essential that angles to sightings are recorded accurately, to the nearest degree. Angles should be determined using a form of 'angle board' or equivalent equipment to avoid the tendency to round angles to convenient values.

The estimation of distance at sea is particularly difficult. Subjective estimation by eye of distance to sighted groups may be used provided that adequately documented experiments are conducted on each vessel to enable corroboration or calibration of the distance estimates. If a practical technology for objective distance estimation or for aiding subjective distance estimation is available and can be demonstrated to be appropriate (e.g. distance 'sticks', reticule binoculars, video range-finding equipment (Leaper and Gordon, 2001), it should be used in preference or in addition to subjective distance estimation.

Angle and distance experiments should be carried out, if possible, before, during and after the survey. Methods that allow accurate determination of the angles and distances to the target objects, simultaneously with the estimated angles and distances, should be implemented. Estimates of angles and distances should be made on command and not in the observers' own time.

The observer making the estimates should be identified both in the calibration experiment data and in the survey data. Determination of the best design and conduct of these experiments will depend on the application. One factor to be considered is obtaining a sufficient range of combinations of angles and distances, bearing in mind typical distributions of angles and distances obtained during the survey.

4.3.4 Species identification and estimation of group size
For a sighting to be used in calculating estimates of abundance, the species must be identified with certainty and the number of whales in the group must be counted or estimated. To ensure that these data are recorded accurately, survey personnel must include scientists or observers experienced in conducting sightings surveys for whales (Section 3.3).

If a large group of whales is encountered it may be unclear whether it consists of one or more groups for the purposes of recording sightings data. The field instructions should include guidance notes on how such cases should be handled.

4.4 Independent observer data
Estimation of *esw* on surveys where $g(0)$ is not assumed to be one involve the collection of data by observers searching simultaneously from two platforms on the same vessel. These data are known as independent observer (IO) data because the observers on the two platforms search with one-way or two-way independence, depending on the method employed. IO data should be collected as an integral part of the survey; this ensures that they are representative and may also improve sighting efficiency.

If independent observer data are collected to allow the estimation of $g(0)$, these data and documentation of the data collection methods shall be submitted to the Secretariat (Section 2).

Estimates of abundance from IO data corrected for animals missed on the trackline are biased by unmodelled heterogeneity in detection probability. It is important, therefore, that data on variables that affect detection probability be recorded as far as possible, and for all sightings.

4.4.1 Duplicate identification
Analysis of IO data depends critically on the ability to identify duplicate sightings of the same group, animal or cue made by observers on different platforms. Judgements on duplicate identification can be made in the field during data collection or later during analysis. In the latter case, recording the time at which a group or cue was made is essential. Use of electronic recording devices is critical for obtaining accurate sighting times of individual groups or cues, and hence reliable duplicate identification. In some circumstances it will not be possible to record accurate times, even when electronic recording devices are used. It is important that there is a facility for identifying which sighting do not have associated accurate times.

If duplicate identification is undertaken during analysis, it should be done on the basis of an objective rule and not by subjective judgement. The criteria used for duplicate judgement should be specified as explicitly as possible, the object being to make each duplicate decision intelligible to someone not involved in the actual decision making.

4.4.2 Tracking procedures
Where the survey protocol and analysis requires tracking of groups/animals after their initial sighting, tracking teams should consist of more than one observer. When one member of a team starts tracking, the operational procedures for the other observer(s) should be explicit.

Data records for each group/animal tracked should contain some information on the level of certainty that the resightings are of the same group/animal. For example, if there were uncertainty whether or not a particular cue in the series was from the group/animal being tracked, this should be indicated.

There may be a trade-off between obtaining complete tracks from both platforms for reliable duplicate identification on the one hand, and maximising sighting efficiency by not diverting search effort into tracking sightings on the other hand. The problem is more severe when survey procedures are such that animals remain in the field of view for long periods of time than when they are potentially (re)sightable for a short period only. More work needs to be done before the nature of this trade-off is properly understood.

4.4.3 Direction of movement of detected animals
Information on the direction of movement of groups/animals can help in duplicate identification and can also allow investigation of bias resulting from responsive movement (e.g. Palka and Hammond, 2001). This information should be recorded for each detected sighting of a group, animal or cue. The recorded direction can be with respect to either the trackline (possibly using a pointer mounted on an angle board) or to line of sight.

4.4.4 Group fragmentation and formation
When tracking, group fragmentation (when a previously detected group splits into more than one group/animal) and group formation (when more than one previously detected group/animal join together to form a single, larger group) should be explicitly recorded. Data forms should be designed to accommodate the recording of these data. The number of animals associated with a (re)sighting should always be recorded. Where cues are recorded rather than groups/animals, explicit criteria for recording more than one cue as a single (re)sighting should be specified and used in recording data. For example, cues from different animals in a single group should be recorded as a single (re)sighting if they occurred within a specified small time period of each other.

4.4.5 Additional data
Each (re)sighting record in the data forms should have field for additional data, such as details of group/animal behaviour.

4.4.6 Closing with IO mode surveys
If animals are closed on, this should be done in a way that does not compromise the collection of IO data. For example, if analysis is group-based rather than cue-based, closing should be delayed until either the group has been detected by observers on both platforms (2-way independence) or the primary platform (BT method), or it has passed abeam. If analysis is cue-based then closing need only be delayed until observers on both platforms have had sufficient opportunity to detect a cue seen from one of them.

5. AERIAL SURVEYS

5.1 Methodology
Although conventional line transect methods used on shipboard surveys can also be used on aerial surveys, the high searching speed of aircraft means that the probability of missing a sighting on the transect line is much greater than for a shipboard survey. Even if $g(0)$ can be estimated without bias, it is likely to increase the estimate of abundance several-fold so that the variance of the estimate will be dominated by the variance of the estimate of $g(0)$.

A preferable method for some species is cue counting. This approach assumes that every cue (e.g. blow, dive) directly below the aircraft is seen, not that every animal on the track line is seen as for line transect surveys. A cue is, by definition, at the surface so the problem of submerged animals is removed. The density of cues per unit of time is estimated and converted to an estimate of whale abundance using an estimate of cue rate. The approach is thus dependent on a good estimate of cue rate. Cue counting relies on the distance to every cue sighted being recorded. It is therefore unsuitable for species that are regularly found in groups of three-four or more (i.e. where many cues may occur in quick succession).

Aerial survey cue counting estimates accepted by the Scientific Committee are all from the North Atlantic. A full account of the analyses of the data is given in Hiby *et al.* (1989).

5.2 Searching effort data

The same guidelines apply here as for shipboard surveys (Section 4.3.2), irrespective of whether the cue counting or line transect approaches are adopted. Most aircraft employ GPS equipment to determine position (this is recommended for safety as well as scientific reasons) and it is possible to download position and time information directly onto a computer.

5.3 Position of the cue/sighting relative to the trackline

Distance can be accurately determined using an inclinometer to measure the angle from the horizontal to the sighted cue or group. In line transect sampling this is typically done when the sighting comes abeam of the aircraft to give perpendicular distance directly.

Cue counting does not require perpendicular distances to be determined; it is the radial distance to each cue that must be accurately recorded. The observer must record the exact time the cue is sighted and the exact time the inclinometer angle is obtained (to the nearest second). The most appropriate data recording method to achieve this is to use a voice activated tape recording system with an in-built time signal. The altitude, speed and drift angle of the aircraft are also required to estimate the position of the cue. Angles from the trackline need only be recorded approximately (to the nearest 10°) to determine if the cue falls within the scanning sector (usually 90° from the trackline on either side of the aircraft) and to aid in separating one cue from another if seen simultaneously. In most cases, the time of the cue (to the nearest second) is sufficient to distinguish between cues.

5.4 Species identification and estimation of group size

The same guidelines apply here as for shipboard surveys (Section 4.3.4). Although estimation of group size is not necessary if cue counting methods are used, the general value of such information makes it useful to record, especially given the relative ease of its collection.

5.5 Independent observer data

As noted in Section 5.1, estimation of $g(0)$ is essential if line transect sampling is used in aerial surveys. Methods have been developed for aerial surveys (Section 7) but there are no estimates of abundance accepted by the Committee that have used these methods.

In the cue counting method, independent observer data are used to estimate the probability of sighting a cue directly beneath the aircraft, to assess the accuracy of estimates of radial distance and to help evaluate observer differences.

5.6 Estimation of cue rate

The estimation of cue rate is essential to the use of the cue counting approach for assessment purposes. This must be obtained separately as it is impractical to collect such data during the survey. Such experiments have usually been carried out from vessels either relying on visual observations or using radio tags. It is important that efforts be made to minimise any effects of vessel presence on the 'cueing' behaviour of the animals. In some cases it has been possible to carry out such experiments from land.

The following factors potentially affecting cueing rates need to be considered in any such experiments:

(1) time of day (e.g. morning, evening);
(2) behaviour of animals (e.g. feeding, travelling);
(3) group size;
(4) effect of vessel (e.g. avoidance, curiosity);
(5) sea state/weather conditions (these may affect the sightability of the cue and/or the behaviour of the animal(s) - use of radio tags will minimise this); and
(6) geographical location/stock identity (it is important to try to carry out experiments in the locality of the survey).

6. ANALYTICAL CONSIDERATIONS

The methods described in Sections 3-5 are based on robust statistical analysis of specific data that are required to be collected in the field. It is imperative, therefore, that those planning surveys to provide estimates of abundance intended for use in the RMP involve experienced analytical scientists from the beginning of the process. Surveys that are designed and conducted based on a full understanding of how the data are to be analysed will be much less likely to suffer from analytical problems when abundance is estimated.

6.1 Variance estimation and the *CLA*

Simulation trials show that the performance of the *CLA* can be degraded when the abundance estimates have high true coefficients of variation (e.g. CV>0.8) but the estimates of the CV of the abundance estimates have themselves a very high variability so that estimated CVs may be low. The latter situation can arise when survey effort has been very small, which may result in very few transects upon which to base a CV estimate. Under these circumstances the *CLA* may be misled if a time-series of estimates is input whose true CVs are high but whose estimated CVs are either substantially negatively biased or have themselves very high variances.

It is therefore important that underestimation of the CV of abundance estimates be avoided and that the estimator for the CV of an abundance estimate should not have an excessively high variance.

Accordingly, a CV estimate should take into account, to the extent possible, all major sources of observation error[6]. A CV estimate should never be less than that which would be obtained by treating the number of sightings (of groups of animals) as a random variable with a Poisson distribution whose mean is equal to this number of sightings. In most cases it will be considerably more than this. A CV estimate based on the observed inter-transect variance should not normally be calculated from less than four transects. In cases of doubt one should err on the side of overestimating the CV of an abundance estimate to be used with the *CLA*.

[6]Observation error is the sampling error arising from the survey methods and design. The level of observation error is inversely related to the amount of survey effort, provided that the survey is well designed.

These guidelines do not apply to zero estimates, which occur when no sightings are made on primary effort during a survey. This should not occur often, but zero estimates should not be ignored when they do occur. It is not normally appropriate to attempt to estimate the variance or CV of a zero estimate, but an alternative variance-related statistic can be calculated for use with the *CLA* of the RMP. In the case of zero estimates, a statistic that errs on the side of underestimating the variance of the estimate is acceptable, such as the one described in annotation 29 to the RMP (this volume, p. 493).

6.2 Simulation techniques

The Committee has noted the importance of using simulation techniques to evaluate the performance of any abundance estimator (IWC, 1996a, p.58). Simulations should be carried out to provide sufficient information to indicate the basic statistical properties (e.g. bias and precision) of the abundance estimators and their variance. Generic simulation testing can provide an indication of satisfactory performance, but it is important to conduct simulations that are appropriate for specific applications. A number of factors relevant to the design and conduct of simulation testing have been identified (IWC, 1996b, pp.180-1).

In 1996, the Committee considered the application of simulation testing to hazard probability methods in the estimation of northeast Atlantic common minke whale abundance (IWC, 1997). Since then, the Committee has overseen the development of a substantial number of simulated datasets suitable for evaluating the performance of a variety of abundance estimators. The current simulated data are designed to represent features of minke whales in the North Atlantic and the Southern Hemisphere and the protocols used on surveys of these species (Palka and Smith, 2004).

7. OTHER METHODS NOT YET REVIEWED BY THE COMMITTEE

Methods for estimating abundance are continually developing. The Committee encourages the presentation of new methods that could be used for obtaining estimates of abundance suitable for use in the *CLA*. Methods that have been developed in recent years include spatial modelling (e.g. Hedley *et al.*, 1999), accounting for responsive movement (Palka and Hammond, 2001) and the tandem aircraft and circle-back aerial survey methods (Hiby, 1999; Hiby and Lovell, 1998).

Before estimates of abundance obtained from such new methods can be accepted for use in the RMP, the properties of such estimates and the implications for their use in the *CLA* may need to be examined by the Committee.

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Appendix 1

Outline of data to be submitted to the Secretariat for each survey

The following list illustrates the types of data and level of detail that need to be reported. The exact data items may vary depending on the type of survey.

Cruise information for each survey platform:
(1) vessel/aircraft name and characteristics;
(2) dates of survey;
(3) location of survey;
(4) description of sighting platform(s); and
(5) description of sighting teams and observation schedule(s).

Searching effort records for each transect (or part transect as determined by events and/or sighting conditions):
(1) beginning date, time and position;
(2) ending date, time and position;
(3) geographic stratum;
(4) platform speed and course;
(5) Beaufort sea state (and any other measure of sighting conditions considered appropriate - e.g. glare); and
(6) number and identity of primary observers searching.

Sighting record:
(1) date, time and position when sighting made;
(2) location from which sighting made (e.g. barrel, bridge, co-pilot seat);
(3) identity of observer making sighting;
(4) sighting cue;
(5) distance or inclinometer angle and bearing to sighting, or inclinometer angle and calculated radial or perpendicular distance;
(6) species (and species breakdown if more than one species); and
(7) number of animals in group.

Ancillary data for use in estimation of abundance:
(1) data from experiments to estimate $g(0)$ and other correction factors;
(2) data from dive-time experiments, including those for estimation of surfacing rates for cue-counting estimates of abundance; and
(3) data from experiments to corroborate and/or calibrate visual estimates of range to sightings.

Appendix 2

Documentation of data and analysis to be included with estimates of abundance intended for use in the *CLA*

It is not possible to provide a comprehensive list of the data and analysis documentation needed to cover all issues related to assessing whether abundance estimates are acceptable for use in the *CLA*; this will vary according to the nature of a particular survey or surveys. This Appendix therefore simply lists the minimum information the Committee would normally expect to receive for estimates from conventional line transect surveys in which $g(0)$ is assumed equal to 1 (in addition to documentation listed under Item 2.4). Substantial additional documentation would be expected for estimates in which $g(0)$ is estimated or for novel methods; this will depend upon the methods used. The Committee will provide advice on the required level of information for such cases at the beginning of the *Implementation* process or when preparing for an *Implementation Review*.

(*i*) *Basic data*
(1) Tables of survey effort and frequency histograms of perpendicular distance broken down by covariates that appreciably affect detection probability (e.g. survey block, passing/closing mode, sea state, vessel, as appropriate) including, where appropriate, combinations of covariates used in analysis.
(2) Plots showing the realised coverage, by survey mode, in each survey block relative to the planned coverage.
(3) Documentation of the causes of uneven realised coverage within a survey block, if this has occurred.
(4) Tables or figures showing the distribution of school sizes.
(5) Plots showing the distribution of radial distances and angles.
(6) Documentation of sighting rates for individual observers if observer is found to be a significant factor affecting estimation of abundance.

(*ii*) *Data analysis*
(1) Results of analyses of data from experiments used to correct angle and distance measurements and documentation of how estimates of observer bias were incorporated into abundance estimation.
(2) Results of analyses to correct for bias in estimates of school size.
(3) Tables of effective strip half width (*esw*), with SE and/or CV, for stratifications of the data and any covariates used in analysis (e.g. survey block, passing/closing mode, sea state, vessel).
(4) Documentation of the rationale for the choices made in calculating the final estimates presented (e.g. form of the detection function, choice of covariates).
(5) Plots comparing the fitted detection function with the frequency distribution of observed perpendicular distances for stratifications of the data and any covariates used in the final abundance estimates.

When *esw* or mean school size (mss) is calculated from data pooled over survey blocks and/or over a period of years, additional documentation would be expected. In particular, analyses motivating the selected pooling of data for the final abundance estimates and the sensitivity of the results to alternative pooling/stratification should be provided.