Inventory Methods for Seabirds: cormorants, gulls, murres, storm-petrels, Ancient Murrelet, auklets, puffins, and Pigeon Guillemot

Standards for Components of British Columbia's Biodiversity No. 13

Prepared by
Ministry of Environment, Lands and Parks
Resources Inventory Branch
for the Terrestrial Ecosystems Task Force
Resources Inventory Committee

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Preface

This manual presents standard methods for inventory of Colonial-Nesting Freshwater Birds in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for group of species with similar inventory requirements. The series includes an introductory manual (Species Inventory Fundamentals No. 1) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The Species Inventory Fundamentals manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve either of these activities.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the Species Inventory Fundamentals No. 1 [Forms] (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at: http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve quickly over their initial years of use. Field-testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded by contacting:

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

Terrestrial Ecosystems Task Force

The current form of this manual was written by Alan E. Burger. The background information and protocols presented in this document are based on the unpublished draft manual, *An inventory manual for seabirds at-sea and at colonies in British Columbia*, prepared for the Inventory Resources Committee by Alan E. Burger with comments and assistance from Tony Gaston, Anne Harfenist, Scott Hatch, Gary Kaiser, Moira Lemon, Ken Morgan, Mike Rodway, Trudy Chatwin, and Andrea Lawrence. All decisions regarding protocols are the responsibility of the Resources Inventory Committee.

The Components of British Columbia’s Biodiversity series is currently edited by James Quayle with data form development by Leah Westereng.

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1. INTRODUCTION

Seabirds are the most conspicuous marine animals and studies of seabirds are important in understanding and monitoring marine processes and changes. For example, studies of population changes, breeding success and diets of seabirds have revealed the impacts of over-fishing in many parts of the world (Furness and Greenwood 1993). Colonial seabirds are among the few common vertebrates in which it is possible to get a reasonable estimate of global as well as regional populations. This makes them valuable for monitoring long-term changes in the marine environment, including the effects of global climate change, periodic El Niño events, over-fishing and pollution.

Accurate, replicated censuses are an essential component of seabird population monitoring. This manual recommends methods of censusing seabirds at-sea and at colonies (including birds which nest on the surface, on cliffs or in burrows) in British Columbia. Protocols for inventory at colonies and at sea are presented separately, because there is little overlap in methodology. The manual does not cover Marbled Murrelets (*Brachyramphus marmoratus)* for which a separate inventory manual has been produced (RIC 1995).

2. INVENTORY GROUP

British Columbia supports a rich seabird fauna, including 15 breeding species and a further 33 regular non-breeding migrants and wintering species (Campbell *et al.* 1990; Rodway 1991). There have been several censuses made of seabird colonies in B.C. (*e.g*., Drent and Guiguet 1961; Campbell *et al.* 1990; Rodway 1991). Comprehensive surveys to locate and census all colonies were undertaken by the Provincial Museum in 1974-1979 (Campbell *et al.* 1990). More intensive census efforts, covering most of the known colonies was completed in the 1980s by the Canadian Wildlife Service (CWS), (Rodway 1988, 1990, 1991; Rodway and Lemon 1990, 1991a, 1991b; Rodway *et al.* 1988, 1990a, 1990b, 1994; Vermeer 1992; Vermeer and Lemon 1986; Vermeer and Rankin 1984; Vermeer and Devito 1989; Vermeer *et al.* 1984, 1988, 1989a, 1992, 1993; Ewins *et al.* 1994). These CWS reports contain detailed descriptions of census methods, maps of colonies and locations of census transects and must be consulted by anyone attempting colony censuses in B.C.

At-sea surveys have also been undertaken on numerous occasions in B.C. waters (*e.g.,* Martin and Myres 1969; Vermeer *et al.* 1983, 1989b; Morgan *et al.* 1991; Hay 1992), involving both aerial and shipboard censuses. The methods used have varied somewhat, and there has been no recommended standard method suitable for B.C. conditions and avifauna. Marine surveys are the only way to determine the spatial distribution and densities of seabirds, and are particularly valuable in assessing the roles of breeding and non-breeding birds in local marine ecosystems, and in assessing their risks to oil spills (*e.g*., Ford *et al.* 1991; Burger 1993a).

The breeding species are grouped here according to their taxonomy and nesting habitats (5-letter codes follow Cannings and Harcombe 1990). Similar census methods apply within the colonies of each group.

Cormorants

Double-crested Cormorant (B-DCCO)	*Phalacrocorax auritus*
Brandt's Cormorant (B-BRCO)	*Phalacrocorax penicillatus*
Pelagic Cormorant (B-PECO)	*Phalacrocorax pelagicus*

Gulls

Glaucous-winged Gull (B-GWGU)	*Larus glaucescens*

Murres

Common Murre (B-COMU)	*Uria aalge*
Thick-billed Murre (B-TBMU)	*Uria lomvia*

Burrow and crevice-nesting birds

Fork-tailed Storm-petrel (B-FTSP)	*Oceanodroma furcata*
Leach's Storm-petrel (B-LSPE)	*Oceanodroma leucorhoa*
Ancient Murrelet (B-ANMU)	*Synthliboramphus antiquus*
Cassin's Auklet (B-CAAU)	*Ptychoramphus aleuticus*
Rhinoceros Auklet (B-RHAU)	*Cerorhinca monocerata*
Tufted Puffin (B-TUPU)	*Fratercula cirrhata*
Horned Puffin (B-HOPU)	*Fratercula corniculata*

Guillemots

These birds nest in crevices or burrows, but are only loosely colonial and require separate census methods. One species in B.C.

Pigeon Guillemot (B-PIGU) *Cepphus columba*

For information and references on the biology and distribution of these species in B.C. see Campbell *et al.* (1990) and Rodway (1991). Other useful references include: Harrison (1983), and Grant (1986) for identification; and Johnsgard (1987), Ehrlich *et al.* (1988), Ainley and Boekelheide (1990), and Gaston (1992) for general biology.

Northern Fulmars *Fulmarus glacialis* (B-NOFU) have been seen prospecting nest sites on Triangle Island, but have not been recorded to breed in B.C. (Campbell *et al.* 1990). Census methods for fulmars are described in Hatch (1989).

3. PROTOCOLS

3.1 Inventory Surveys

The table below outlines the type of surveys that are used to inventory seabirds at specified survey intensities. These survey methods have been recommended by wildlife biologists.

Table 1. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	*Intensity
At Sea Surveys		
Seabird Vessel Reconnaissance	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird Reconnaissance	• PN
Seabird Vessel Fixed-width Transects	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird Vessel Fixed-width Transects	• PN • RA • AA
Seabird Aerial Reconnaissance	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird Reconnaissance	• PN
Seabird Aerial Fixed-width Transects	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Formeral • Animal Observation Form- Seabird Aerial Fixed-width Transects	• PN • RA • AA
Stationary Counts	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird Aerial Fixed-width Transects	• PN • RA
Colony Surveys		
Nest Counts	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird	• RA • AA (most spp)
Adult Counts	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Formeral • Animal Observation Form- Seabird	• RA • AA (murre)
Aerial Photography	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Seabird Aerial	• RA

Beached Bird Surveys		
Beached Bird	• Wildlife Sighting Form (see No 1. Forms)	• PN
Any Survey Type	• Nest Site Description Form - used when nest is located.	• ANY

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

4. PROTOCOLS: Inventories At Sea

Table 2. Recommended inventory methods for seabirds at sea in British Columbia for the 3 levels of intensity.

Survey Type	Species	Intensity
Aerial Reconnaissance	All seabirds at sea	PN
Vessel Reconnaissance	All seabirds at sea	PN
Stationary Counts	All seabirds at sea	PN RA
Aerial Fixed-width Transect	All seabirds at sea	RA
Vessel Fixed-width Transect	All seabirds at sea	RA AA

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

There is no single method that will satisfy all inventory requirements at sea. The large variety of marine habitats in B.C. demands careful assessment of methods.

Recommended Survey Type for Marine Habitats in BC:

a) Confined waters (small bays, inlets etc.) - repeated Stationary Counts from land and complete count from a small boat, Aerial Reconnaissance for large areas;

b) Staging areas around colonies - Aerial Reconnaissance, repeated Stationary Counts from land, Vessel Fixed-width Transects to cover a fixed area;

c) Nearshore waters (within 1-2 km of shore) - repeated Vessel or Aerial Fixed-width Transects parallel to shore at fixed distances from shore, or point-to-point transects between islands;

d) Open water in straits or over the continental shelf - repeated Vessel Fixed-width Transects (300 m wide sample strip) with continuous counts of birds on the water and snapshot counts of flying birds;

e) Open ocean beyond the shelf-break or other situations with sparse bird densities - Vessel Fixed-width Transects as in (d) but also count all birds seen beyond the fixed-width boundaries.

4.1 Sampling Standards

The following standards are recommended to ensure comparison of data between marine surveys, and to mitigate several sources of bias common in surveys. Individual protocols provide more detailed standards applicable to the method(s) and design recommended.

4.1.1 Habitat Data Standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. As most, provincially-funded wildlife inventory projects deal with terrestrially-based wildlife, the terrestrial Ecosystem Field Form developed jointly by MOF and MELP (1995) will be used. However, under certain circumstances, this may be inappropriate and other RIC-approved standards for ecosystem description may be used. For a generic but useful description of approaches to habitat data collection in association with wildlife inventory, consult the manual, *Species Inventory Fundamentals*.

4.1.2 Time of Year and Time of Day

The optimal dates for various species differ. The dates and times of surveys will depend on the goals of the project, but should be selected so that they provide the best times to sample foraging birds. Many seabirds forage most actively in the morning; planktivores are often most active at dusk and dawn, and may not be associated with prey schools during the day. For long-term monitoring, the time and dates should be kept as constant as possible among surveys.

4.1.3 Weather Conditions

- Avoid surveys in heavy rain or in sea conditions exceeding 3 on the Beaufort scale (Table 2).
- Use the Beaufort scale for estimating wind and sea conditions during data collection.

Table 2. Beaufort scale for estimating wind and sea conditions.

Beaufort	Mariner's description	Wind Speed		Effect of Wind at Sea
		knots	m/s	
0	calm	0-1	0.0-0.5	like a mirror
1	light air	1-3	0.5-1.5	ripples form with the appearance of scales, but without foam crests
2	light breeze	4-6	2.1-3.1	small wavelets, crests appear glassy, no breaking
3	gentle breeze	7-10	3.5-5.2	larger wavelets begin to break, glassy foam, perhaps some scattered white horses
4	moderate breeze	11-16	5.7-8.2	small waves predominant but fairly frequent white horses
5	fresh breeze	17-21	8.7-10.8	moderate waves, distinctly elongated, many white horses, chance of spray
6	strong breeze	22-27	11.3-13.9	long waves with extensive white foam breaking crests begin to form, spray likely
7	moderate gale	28-33	14.4-17.0	sea heaps up, white foam breaking waves start to be blown in streaks, beginning of spindrift
8	fresh gale	34-40	17.5-20.6	moderately high waves with extensive crests, tops of crests break into sprindrift; foam blown into well-marked streaks, spray blown off crests
9	strong gale	41-47	21.1-24.2	high wave , rolling sea, dense streaks of foam, spray may affect visibility

Beaufort	Mariner's description	Wind Speed		Effect of Wind at Sea
		knots	**m/s**	
10	white gale	48-55	24.7-28.3	very high waves with long overhanging crests, foam in great patches blown in dense white streaks downwind; heavy rolling sea causes ships to slam, visibility reduced by spay, sea surface takes on whitish appearance
11	storm	56-66	28.8-34.0	exceptionally high waves, sea covered with long white patches of foam blown downwind, everywhere wave crests blown into froth, visibility impeded by spray
12	hurricane	above 66	above 34	air filled with foam and spray, sea entirely white, visibility seriously impaired

4.2 Vessel surveys

4.2.1 Vessel Reconnaissance

Recommendations: Useful to obtain a reconnaisance sample of seabirds present in a marine habitat that can adequately be covered by vessel.

An informal method for doing reconnaisance surveys of marine areas is outlined below. This method is of limited use beyond gathering reconnaissance information; for more meaningful conclusions, surveyors will be required to undertake more systematic surveys at a higher level of intensity. Surveyors should review procedures, personnel, and equipment as outlined for Vessel Fixed-Width Transect surveys, as reconnaissance vessels use many of these in a unsystematic fashion (no transects are required).

Unsystematic observations of birds from vessels have contributed to a large database of sight-record cards, archived in the Royal British Columbia Museum. These data were useful in plotting the general distributions of species (Campbell *et al*. 1990), but do not provide reliable measures of relative or absolute density, and tend to be biased by the geographic distribution of human observers and by a tendency to report unusual sightings (birds away from their normal range, or unusually large flocks). There is no standard protocol for this type of observation. When reporting numbers of birds or species composition it is useful to also report the type of vessel, observation effort (hours or days on watch), weather and sea conditions, names and addresses of all observers, and provide a map of the vessel's route and areas in which birds were observed. Observations can be submitted to the Ministry of Environment, Lands, and Parks using the Wildlife Sighting Form.

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant charts for the project area.
- Where possible, determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for survey areas from charts. Some Marine Ecosystem Classification has been completed by the provincial Land Use Coordination Office; this may be useful for selecting study areas.
- Delineate study areas in which surveys will take place on the charts. These should be areas of some logistical or ecological significance. For this *ad hoc* method of survey it would be wise to limit study areas to areas which can be completely surveyed in a maximum of one day.

Sampling Design

- Non-random non-systematic.
- Search the study area for seabirds, focussing effort based on knowledge of the area, points of interest, and immediate conditions.

Sampling Effort

- In general, surveyors should track time spent surveying and distance travelled as measures of survey effort.

4.2.2 Vessel Fixed-width Transect

Recommendations: Relative Abundance surveys in the following marine habitats: staging areas around colonies; nearshore waters; open water in straits or over the continental shelf; and open ocean beyond the shelf-break or for other situations with sparse bird densities.

Vessels have been used for counting seabirds for many decades, but there is still much to be learned, particularly with regard to the optimal width and orientation of ocean to be scanned. Tasker et al. (1984) and Gould and Forsell (1989) provided reviews of methodology, which were followed by many revisions and suggestions (Duffy 1983, Duffy and Schneider 1984, Broni et al. 1985, Haney 1985, Haney and Solow 1992, Gaston et al. 1987a,b, Van Franeker 1994).

Background Information

Transects are the most common method of estimating densities and species composition of seabirds at sea. These techniques involve recording birds seen from a vessel moving at a constant speed along a prescribed route. The count can include all birds seen within a fixed distance of the vessel (fixed-width or strip transect) or without reference to a fixed-width (encounter transect). Densities are reported as birds km^{-2} and birds km^{-1}, respectively. A third alternative is to use variable-distance transects (Buckland et al. 1993), in which the distance to each animal is recorded independently to estimate densities (birds km^{-2}). This method cannot effectively deal with flying birds and so is not recommended. Fixed-width transect is the recommended method, and the width of the sample strip must always be reported.

Duffy and Schneider (1984) compared fixed-width transects (all birds within a 90^{o} sector, ahead and to one side of the vessel with a radius of 300 m) with a bar-count (counting all birds crossing an imaginary line extending 300 m abeam of the vessel). Bar-counts method always gave lower estimates than fixed-width transects and underestimated flying birds. In both methods the faster flying birds were more likely to be included than slow birds. The bar method has not been widely used, and is not recommended.

Many vessel surveys off British Columbia have used encounter transects, usually following the PIROP (Programme Intégré de Recherches sur les Oiseaux Pélagiques) system (*e.g.*, Morgan *et al.* 1991). The advantage of recording all birds seen without reference to a fixed-width is that a larger area can be sampled, which is important when recording low densities. In deep ocean pelagic waters, where seabirds are rare, this method is possibly better than fixed-width transects; however, it is not recommended. Encounter transects allow comparisons of density within the same species (*e.g.,* seasonal trends), but because birds vary greatly in conspicuousness, this method does not allow accurate comparisons of density among species, nor does it provide estimates of density per unit of area. For these reasons, fixed-width transects are recommended over encounter transects. Observers doing fixed-width transects can record birds seen outside the transect strip separately and thereby make direct comparisons with encounter transect data.

Fixed-width transects

Fixed-width transects, usually with fixed-widths (strips) of 300 m, are the standard method for censusing most seabirds on the water (Tasker *et al*. 1984; Gould and Forsell 1989). A common practice is to have one observer scan the ocean ahead of the vessel and out to 300 m on one side, selecting the side with the best visibility (least glare, wind or spray). A major problem in using a 300 m fixed-width is that alcids and other inconspicuous seabirds are not reliably censused from a vessel beyond 150-175 m (Dixon 1977; Wiens *et al.* 1978; Tasker *et al*. 1984; Briggs *et al*. 1985a). Studies off California suggest that the detectability of Marbled Murrelets dropped off beyond 100 m in most sea and light conditions (Ralph *et al.* 1990; C.J. Ralph pers. comm.). Distant birds on the water will always be underestimated relative to flying birds. An alternative, used by Burger and Lawrence (1995; unpubl. data) in surveys off Vancouver Island from 1986-1995, and by Van Franeker (1994) in the Antarctic, is to observe 150 m on either side of the vessel, giving a total fixed-width of 300 m. Narrow fixed-widths can present problems if there is a high proportion of species which strongly avoids vessels, but this does not appear to be the case in B.C. A transect width of 150 m on either side of the vessel is therefore recommended.

Estimating perpendicular distances of birds or transect boundaries relative to the vessel route can be difficult. Heinemann (1981) and Tasker *et al.* (1984) describe simple rangefinders used for pelagic bird censusing. Heinemann provided designs for both fixed-width and continuous-scale estimation. Observers can be trained to estimate strip widths by towing a buoy at the required distance behind the vessel for part of the survey (it may slow the boat down), or by observing objects of known distance from the vessel using radar to determine the distance.

Recording Observation in Time Intervals

A traditional practice is to lump all bird sightings into 10-minute time blocks (Tasker *et al*. 1984; Gould and Forsell 1989). This time frame may be suitable for offshore pelagic surveys, but is too coarse to allow analysis of the fine-scale variations in bird densities and oceanic features experienced in coastal and shelf waters. At 10 knots a vessel will travel more than 3 km in 10 minutes, within which there could be many variations in bird densities, prey densities and physical ocean features. The bias towards flying birds is also increased with larger time frames (Gaston *et al.* 1987b). Use the finest time scale possible (maximum 1 minute intervals) to examine fine-scale variability. Data can always be pooled into larger time frames later. See Schneider and Duffy (1985), Schneider and Piatt (1986) and Haney and Solow (1992) for further reviews of this topic.

Counting Techniques

Measuring the densities of flying birds is a problem. Continuous counts of birds flying through the transect measure the flux of birds, and can overestimate densities by as much as five times (Van Franeker 1994). The problem has spawned several possible solutions, some of which involve quite complicated calculations, and detailed field measurements (Gaston *et al.* 1987a,b; Tasker *et al.* 1984; Spear *et al.* 1992). The **"snapshot method"** developed by Gould *et al*. (1978) and described by Tasker *et al*. (1984) and Van Franeker (1994) is recommended. This involves making instantaneous counts (or as close as possible to instantaneous) at repeated short intervals (1 min) of all the birds flying within the transect area that will be covered between snapshot counts (*e.g.,* 250 m ahead for a vessel travelling at 8 knots [14.8 km h^{-1}]). Birds which fly through the transect between snapshot counts, ship followers and birds crossing behind or well ahead of the vessel are ignored. Tasker *et al.* (1984) give a good graphical illustration of the method. **Continuous counts** can be made concurrently with snapshot counts to provide comparable data with other methods which use continuous counts of flying birds (Van Franeker 1994). Continuous counts may be acceptable if the goal is to provide relative densities of flying birds to correlate with habitat features and not derive absolute abundance (Spear *et al*. 1992).

Seabird Position - Flying or on the Water?

It is essential to count birds sitting on the water separately from those flying through the fixed-width strip. The former count is most valuable for assessing foraging habitat preferences or risks to oil spills, especially for diving birds such as loons, cormorants, grebes and alcids. These assessments might have to include flying birds when dealing with procellariiforms, gulls, terns and other birds which routinely search for food on the wing and, in the case of storm-petrels, feed on the wing. Birds that alight or take off during the observation period are counted as being on the water.

Counting Considerations

Birds which follow or avoid the vessel create special problems (Tasker *et al.* 1984; Gould and Forsell 1989). In B.C. Northern Fulmars and *Larus* gulls will occasionally follow ships for several minutes, but will usually leave if there is no food provided. Observers need to be alert for this problem and exclude any birds which follow or repeatedly "leap-frog" ahead. Special attention is also needed for birds which move away or dive at the vessel's approach (*e.g.,* Sabine's Gulls *Xema sabini* or Cassin's Auklets).

Species differ in their visibility, based on size, coloration and foraging methods. This makes comparisons of density among species difficult. Co-efficients of detection have been developed (*e.g.,* Wiens *et al.* 1978), but have not gained general acceptance (Tasker *et al.* 1984). Visibility is affected by many variables in addition to those listed above, including flock size, activity (flying, sitting, diving), sea and weather conditions, angle of the sun and vessel speed. Adjustments incorporating all these would be hopelessly complex. Most studies simply report the densities as seen in the field, along with the prevailing sea and weather conditions, and recognize that some groups will probably be over- or underestimated to an unknown degree.

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant charts for the project area.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for survey areas from charts. Some Marine Ecosystem Classification has been completed by the provincial Land Use Coordination Office; this may be useful for selecting study areas.
- Depending on the size of the project area, it may be desirable to subdivide it up into study areas and delineate these. on the charts. These should be areas of some logistical or ecological significance.
- Plot transects on the chart(s), and determine the co-ordinates of way-points and turning points.

Sampling Design

- Transect routes are usually selected to sample a defined (study) area (*e.g.,* around a colony) or to examine the effect of some oceanic feature (*e.g.,* across a shelf break). If a large tract of ocean is to be surveyed, transects should be laid out across this area so that all important features are equally sampled. This usually involves transects perpendicular to the coastline, evenly spaced throughout the entire area (*e.g.,* Briggs *et al.* 1987).

- Transects to sample coastal species can run at a fixed distance from the shore, or between conspicuous landmarks.
- Zig-zag routes can be used where the ocean features are either randomly spaced or relatively homogeneous. Plot the transect route on a chart, showing the coordinates of each turning point or oceanographic sample station.
- Satellite images of sea surface temperatures and chlorophyll concentration (indicating productivity) have proved useful in planning survey routes and interpreting seabird distributions (Haney 1986a, 1989a,b, Briggs et al. 1987).

Sampling Effort

- The duration, time and distance of sample transects will vary according to the goals of the survey and the vessel used.
- In general, transects should be at least 10 km long to incorporate fine-scale patchiness in seabird distributions.

Personnel

Vessel operator(s), plus 2 observers, and 1 person to record data.

Equipment

- Vessel
- Binoculars
- Stopwatch
- Charts
- Dataforms
- Field guide to birds
- Buoy
- 100 - 150 meters of line
- Radar (optional)
- GPS or LORAN (optional)
- Temperature and salinity sensors (optional)
- Echosounder (optional)
- Data recorder (optional)
- Tape recorder (optional)

Field Procedures

- Try to avoid surveys in heavy rain or in sea conditions exceeding 3 on the Beaufort scale (Table 2).
- Record the following at 30 minute intervals throughout the survey: wind and sea conditions (use Beaufort scale; Table 2); wind direction; choppiness; cloud cover and cloud type; precipitation. At any time in the survey, note visibility; whether sun glare, spray or rain affect visibility.
- Vessel speed should be kept as constant as possible and should ideally not exceed 10-12 knots. At 10 knots (18.5 km h^{-1}), the vessel will cover 308 m every 1 minute.
- Use a transect width of 150 m on either side of the vessel.

- Use two observers, each scanning one side of the vessel. A third person could record the data or drive the boat. The best position to stand is at the bow or a raised vantage point. Report the observer's eye level above sea level.
- Each observer should scan a 90^{o} arc from directly ahead of the vessel to one side of the vessel, with their eyes focused 100-150 m from the vessel.
- Practice estimating distances over water; use a range-finder (Heinemann 1981), or trail a buoy at 50 or 100 m behind the boat as a reference marker. The buoy may significantly slow the boat and so need be used for only 1-2 km two or three times per survey. Radar can also be used to measure distances to landmarks during training.
- Record separately birds seen beyond 150 m when possible (*i.e.,* with low densities).
- Binoculars should be used to confirm the identity of the bird or get details of moult or age, but should not be used to scan for birds, otherwise flying or diving birds could easily be missed.
- Count birds on the water and flying, and those inside or outside the designated transect width separately. A bird seen landing or taking off should be counted as being on the water.
- Use continuous counts for stationary birds (on the water or feeding). Count flying birds using the snapshot method (Tasker *et al.* 1984; Van Franeker 1994) to estimate absolute abundance. Instantaneous snapshot counts should be made at 1 minute intervals and include only those birds flying within the transect and within 1 minute of travel ahead of the vessel (see Tasker *et al.* 1984 for details).
- Continuous counts of flying birds may be useful for habitat assessment and comparison with other surveys which use that method.
- Ignore birds following or "leap-frogging" over the vessel.
- Record flock size: flocks are birds <5 m apart, andmay be mixed-species flocks. For large flocks (>200 birds), scan the flock for rare species, make a sample count to determine the proportions of common species and apply this to the estimated total flock size.
- Make notes on behaviour (*e.g*., feeding, kleptoparasitism, other interactions). Note the presence of vessels actively fishing or cleaning fish, and other vessels affecting the distribution of seabirds.
- Record all bird sightings and other relevant information in the smallest time unit possible. If the data can be recorded on a computer system, it should be programmed to tag each sighting with time to the nearest second. If recording the data on paper or tape recorder, note the time to the nearest minute. The data can be analysed later in larger time frames. When plotting very fine-scaled distribution patterns (e.g. at resolutions less than 100 m), use a stop-watch timed to the nearest second.
- Use Global Positioning System (GPS) or LORAN. Reasonably priced GPS systems which log directly into notebook computers at intervals as small as one second are now available. Be aware that GPS and LORAN coordinates are sometimes incorrect, and routinely check locations on a nautical chart. Navigation with reference to conspicuous landmarks is suitable for nearshore transects that follow the coast. Record the vessel position at regular intervals (*e.g.,* every 10-20 minutes) to keep track of drift due to currents, and to plot ocean features. You should be able to produce an accurate map of your route and plot bird densities (birds km^{-2}) on a fine scale (100s of m).

- In a small boat with no navigation aids, the position of birds along a transect of known distance can be plotted by traveling at a constant speed with a stop-watch running throughout the transect, and converting each timed sighting into a distance estimate.
- If possible, continuously or repeatedly record sea surface temperature (SST) and salinity (SSS) and run a recording echosounder (*e.g*., paper chart sounder) to determine sea depth and prey densities. Synchronize observers' watches with the data logging systems. Put time markers on the echosounder trace to record the beginning and end of each transect segment. A simple method for analyzing densities of fish schools from paper sounder traces is given by Piatt (1990). High frequency sounders (200 kHz) will detect small zooplankton (copepods etc.). Large zooplankton (euphausiids) and small fish can generally be adequately detected using 38 or 50 kHz sounders. If surveying from an oceanographic vessel, periodic CTD casts (to determine the vertical temperature-salinity profile), plankton tows or trawls, would provide useful supplementary data to help explain seabird distributions.
- Record sightings and plot the coordinates of schools of fish or zooplankton at the surface, all marine mammals and other organisms (e.g. sunfish *Mola mola* or marine turtles), but avoid being distracted from making seabird observations. Make notes on any interactions between birds and these animals.

Data Analysis

Haney and Solow (1992) made a detailed statistical examination of the assumptions and weaknesses of marine surveys of seabird densities. They suggest that the patchy distribution of the birds and stochastic nature of fixed-width sampling violate many of the requirements for parametric statistical tests, and recommend against complex parametric statistical analyses. This review must be read by all those undertaking marine surveys of seabirds, but appears to be too pessimistic. Many seabird studies have successfully applied rigorous statistical tests to survey data (e.g. Safina and Burger 1985, Schneider and Duffy 1985, Haney 1986b). Non-parametric tests may be more appropriate for some data (e.g. Hunt *et al*. 1990).

4.3 Aerial Surveys

4.3.1 Aerial reconnaissance

Recommendations: Useful to obtain a reconnaisance sample of seabirds present in a marine habitat that can adequately be covered by vessel. It can be used to determine a crude measure of seabird distribution; locate new areas for more detailed vessel surveys; locate staging areas and foraging concentrations.

Opportunistic or dedicated flights can be useful for spot checks in areas seldom visited or where more detailed censuses might not be possible. Opportunistic flights include those by Coast Guard helicopters visiting lightstations or investigating oil spills, low-level commuter flights, or those used to census seals at haul-outs.

An informal method for doing reconnaisance surveys of marine areas is outlined below. This method is of limited use beyond gathering reconnaissance information; for more meaningful conclusions, surveyors will be required to undertake more systematic surveys at a higher level of intensity. Procedures, personnel and equipment are generally the same as those for aerial transects (see below), except that data are collected in an unsystematic fashion (not transects are required).

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant charts for the project area.
- Where possible, determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for survey areas from charts. Some Marine Ecosystem Classification has been completed by the provincial Land Use Coordination Office; this may be useful for selecting study areas.
- Delineate study areas in which surveys will take place on the charts. These should be areas of some logistical or ecological significance. For this *ad hoc* method of survey it would be wise to limit study areas to areas which can be completely surveyed in a maximum of one day.

Sampling Design

- Non-random non-systematic.
- Search the study area for seabirds, focussing effort based on knowledge of the area, points of interest, and immediate conditions.

Sampling Effort

- In general, surveyors should track time spent surveying and distance travelled as measures of survey effort.

4.3.2 Aerial Fixed-width Transects

Recommendations: Presence/Not Detected and Relative Abundance of birds over a large sample area. Aerial surveys remain useful for reconnaissance, large-scale mapping of distributions, detecting areas of aggregations (such as staging grounds near colonies) and, with repeated surveys, for detecting seasonal or annual changes in relative abundance (birds per square km). They are also useful for rapid assessments of bird distributions and relative abundance (*e.g.,* at the time of an oil spill).

The general conclusion emerging from the studies reviewed is that aerial surveys underestimate densities of most birds, particularly small birds and alcids. Aerial surveys are not as reliable as vessel surveys for assessing densities and fine-scale habitat use. Aerial transects cannot provide simultaneous measures of ocean parameters (sea temperatures, prey densities etc.), which limits the ability to explain changes in population density and distribution. Aerial surveys remain useful for large scale mapping of distributions, detecting areas of aggregations (such as staging grounds near colonies), and, with repeated surveys, detecting seasonal or annual change in relative density. Aerial surveys alone are likely not appropriate to determine absolute abundance of seabirds.

Background Information

Low-flying aircraft are often used to count birds at sea. In British Columbia aircraft have been used in several censuses of wintering waterfowl and seabirds in coastal waters in sheltered inland seas (Savard 1982; Vermeer *et al.* 1983). Aerial surveys were an important part of the assessment of the impact of the *Nestucca* oil spill on birds off Washington and British Columbia (Rodway 1989; Rodway *et al.* 1989; Ford *et al.* 1991), and for monitoring marine birds in the Puget Sound Ambient Monitoring Program (Nysewander *et al.* 1993). They have also been used to census Marbled Murrelets, with variable degrees of success (RIC 1995, Ralph *et al.* 1995).

Aerial surveys have been extensively used in the Canadian Arctic, mostly with Thick-billed Murres, to compare colony-based studies with at-sea distributions and behaviour (Nettleship and Gaston 1978; Gaston and Nettleship 1981). Briggs *et al.* (1987) used both aerial and vessel surveys in a comprehensive 8-year study of seabirds over a broad swath of ocean off California, which could be used as a model for studies covering large areas and involving aerial surveys.

The major advantage of aircraft is their ability to cover large areas rapidly, thus providing a time-specific "snapshot" of a large sample area. Helicopters, being manoeuvrable and slower, allow better visibility than fixed-wing planes, but are considerably more expensive to operate and are generally not used over exposed open seas. Aerial surveys are expensive, particularly if twin-engined aircraft are needed over open seas, but could be cost effective relative to area covered. Single-engined planes could be used for inshore species, such as cormorants or Pigeon Guillemots.

Aerial Census Problems

Aerial census problems can be broken into two categories: those associated with counting and identifying the birds from the air; and, those associated with interpreting, modifying and applying the resultant survey data (Gaston and Smith 1984).

Problems associated with detection and identification of the birds are largely due to the high speed of aircraft, and fall into four categories (Gaston and Smith 1984; Briggs *et al.* 1985a,b):

a) Effects of weather, light and sea conditions on the detectability of birds. Adverse weather can restrict flying time, and slightly choppy water or glare of the sun off the sea can make it difficult to detect birds.

b) Variation in relative detectability among seabird species, depending on size, plumage, behaviour, and degree of aggregation. Large birds are easier to detect than smaller ones; under most light conditions dark birds are less visible than light-coloured ones; flocks are more visible than single birds; flying birds are easier to see than those sitting on the water. Overall, aerial surveys tend to greatly underestimate the densities of small, dark birds such as alcids, but are more reliable with pale, larger birds such as gulls.

c) Observer effects, including seating position, experience and fatigue. In aerial censuses of waterfowl, Savard 1982) found large differences in the results produced by experienced and inexperienced aerial observers, even if the inexperienced observers were qualified ornithologists experienced at other observation methods. Air-sickness is problem for many observers.

d) Effects of the aircraft's characteristics on the observer's field of view, and the effects of speed and altitude on the observer's abilities to detect the birds. High-winged aircraft and those that can maintain a slow ground speed are preferred.

Briggs *et al.* (1985a) compared shipboard and aerial surveys of seabirds off California. The two methods produced statistically similar estimates of densities under variable field conditions and with experienced observers. Aerial observers were able to identify the species of 77-96% of birds seen, while those on vessels identified 95-97%. Both methods produced similar measures of numbers of species and proportions of birds per species.

Experience in British Columbia suggests that aerial surveys report only half of the birds present and underestimate the importance of small birds and alcids (Savard 1982; Vermeer *et al.* 1983). There is no cadre of experienced aerial observers in B.C. such as that available to Briggs *et al.* (1985ab; 1987) and training observers would require many hours of flying. For these reason, several researchers with experience in aerial census of seabirds in B.C. recommend against using this technique as the **sole** method of determining seabird densities (Absolute Abundance) (A.J. Gaston in litt.; G. W. Kaiser pers. comm.; M. S. Rodway pers. comm.).

Interpreting Aerial Survey Data.

Gaston and Smith (1984) analysed some of the effects of behaviour on interpretations of aerial census data. Specifically, they identified five problems and made suggestions for improving interpretations. The problems were as follows:

a) Effects of colony attendance on at-sea distribution and densities. Numbers of birds at sea can vary with time of day or time of season. During incubation and brooding periods at least one adult is on the nest.

b) Effects of variable travel time between colony and feeding site on at-sea densities and distribution. Widely dispersed feeding areas will yield low at-sea densities, even around large colonies.

c) Distortions in interpreting flight paths of birds caused by relative motion of birds and aircraft. Because both aircraft and flying birds are moving rapidly, it is difficult to plot the flight direction of birds.

d) Underestimates of densities in diving birds related to the duration and frequency of dives. The probabilities of missing diving birds when they are underwater will be a function of the mean proportion of time spent underwater while at sea and the amount of time available for detecting them as the aircraft passes overhead.

e) Problems in interpreting the degree of aggregation in sociable birds. The intensity of survey coverage needed to estimate populations with the same degree of accuracy will increase with increasing flock size (see Gaston and Smith 1984 for details and proposed correction factors).

There is usually a large degree of variability in seabird densities, resulting from the movements of the birds and changes in prey distributions. This makes it difficult to detect changes in densities which might indicate population changes. Nysewander *et al.* (1993) calculated the likelihood of detecting significant changes in bird densities with replicated aerial surveys. For a medium-sized non-flocking bird (Red-necked Grebe *Podiceps grisegena*), they concluded that with five replicate surveys, there would have to be a 55% decrease in density to be detected with 95% probability. The likelihood of detecting change improved if repeated surveys were located optimally in the part of the census area where the most variability occurred, which was usually the areas with highest densities. In such cases a change in density of 25% could be detected with 95% probability after five replicate surveys. The probabilities of detecting changes in densities were even lower in some species (*e.g*., scoters). Reliable evidence of multi-year trends in population densities might require 5-20 years of data.

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant charts for the project area.
- Depending on the size of the project area, it may be desirable to subdivide it up into study areas and delineate these on the charts. These should be areas of some logistical or ecological significance.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for study areas from maps. Some Marine Ecosystem Classification has been completed by the provincial Land Use Coordination Office; this may be useful for selecting study areas.
- Plot the transect route, with careful reference to depth isobars, oceanic features and shoreline topography.

Sampling Design

- Sampling design is generally similar to that of vessel surveys, except that aircraft cover much larger areas per survey time and cannot make right-angle turns.
- Survey routes should be designed to sample adequately all marine habitats being investigated.
- Transects could run parallel with the coastline or at regular intervals perpendicular to the coast (*e.g.,* Briggs *et al.* 1987; Ford *et al.* 1991).

Sampling Effort

- The duration, time and distance of sample transects will vary according to the goals of the survey and the aircraft used.
- In general, transects should be at least 10 km long to incorporate fine-scale patchiness in seabird distributions.

- Note: observers in aircraft are likely to get fatigued more rapidly than on a vessel, because of the concentration required to detect and record rapidly passing birds.

Personnel

- Pilot (aircraft crew)
- 1 Timer/navigator
- 2 Observers. Observers should have 3-4 training flights to practice identification of seabirds from the plane. Test flights over known numbers of dummy birds can be used to gauge observer efficiency in various sea and light conditions. Practice estimating flocks larger than 20 by simulations (*e.g*., using beans scattered in clumps on a carpet).

Equipment

- Aircraft
- Maps/charts
- 2 or 3 watches or stopwatches with audible timers
- GPS
- 2 tape recorders
- Clinometer to measure appropriate angles of observations
- Polarized sunglasses (optional)

Field Procedures

- Aerial surveys should be undertaken only with experienced observers, when sea conditions are Beaufort scale 3 or less (see Table 2).
- Use a high-wing aircraft large enough to carry a pilot, navigator-timer, and two observers (one on each side). A twin-engined aircraft is needed for surveys going more than a few 100 m offshore.
- The plane is flown at 140-160 km per hour at an altitude of 60 m above the sea.
- The transect width is 50 m on either side of the plane (100 m in total). Use simple trigonometry to calculate the angles needed to get a 50 m transect width at 60 m altitude (Briggs *et al.* 1985b). For example, if the line of sight of the inner boundary is 30^{o} from vertically down (to eliminate looking immediately below the plane), the outer line of sight will be at an angle of 55^{o} from vertical. These angles may have to be adjusted to suit the shape of the aircraft. Use a clinometer (which measures angles) to determine the inner and outer boundaries of the transect, based on the required angles. The simplest way to mark the transect boundaries is to mark the wing struts with tape to show the correct angles when viewed from the observers' seats.
- When sun glare on the water restricts the visibility on one side of the plane, only the data from the other side should be used and the transect width adjusted accordingly to calculate densities. Polarized glasses might reduce the effects of sun glare.
- The navigator-timer records the plane's position to the nearest 0.1' of latitude and longitude at 1 minute intervals using a GPS. Computer-linked GPSs, which can log position every second directly to a computer database, are now available at a reasonable cost and can replace the navigator.
- The observers record all bird sightings in 1 minute intervals with their watches synchronised. Each observer should be equipped with a watch that beeps every minute,

so that the observers need not take their eyes off the water to look at their watches. All data are recorded on tape-recorders and later transcribed.

Data Analysis

- Haney and Solow (1992) made a detailed statistical examination of the assumptions and weaknesses of marine surveys of seabird densities. They suggest that the patchy distribution of the birds and stochastic nature of fixed-width sampling violate many of the requirements for parametric statistical tests, and recommend against complex parametric statistical analyses. This review must be read by all those undertaking marine surveys of seabirds, but appears to be too pessimistic. Many seabird studies have successfully applied rigorous statistical tests to survey data (e.g. Safina and Burger 1985, Schneider and Duffy 1985, Haney 1986b). Non-parametric tests may be more appropriate for some data (e.g. Hunt *et al*. 1990).

4.4 Stationary Counts

Recommendations: Presence/Not Detected; Relative Abundance in restricted areas.

Stationary counts are counts of birds within a confined area which has clearly defined boundaries and is clearly visible from the observation stations. They can be from land or at sea.

Background Information

For many years observations were made from the deep ocean weather ship at Station Papa (50^{o} N, 145^{o} W) about 1500 km west of Vancouver Island. These provided a valuable understanding of the seasonal changes in avifauna in a poorly sampled part of the ocean (Campbell *et al*. 1990). Stationary counts can be made of birds attracted to fishing vessels in order to gauge the impacts of these vessels (Gould and Forsell 1989).

Stationary counts made from shore can cover a larger area than stationary counts at sea, because the stable platform allows the use of spotting scopes. Nevertheless, the amount of information on densities and distribution which can be obtained from the shore is severely limited for most species of seabirds. For nearshore species, like cormorants or *Larus* gulls, shore-based observations can provide information on relative abundance, but even for these species, such counts might be misleading if the birds are feeding somewhat offshore.

Shore-based counts are most useful for censusing birds within well-defined, confined waters, such as bays, inlets or channels, using a spotting scope from one or more vantage points (Bibby et al. 1992). They might also be used for general reconnaissance, particularly if there is a road paralleling the shore from which observations can be made at regular intervals.

Fly-by counts are stationary counts to record birds that fly past a fixed point. They are most useful in showing diurnal and seasonal movements (*e.g.,* timing of migration), but have the same disadvantages as discussed for other stationary counts, and are also biased towards species which fly a lot (*e.g.,* gulls). If made from shore, they are also biased towards species which use the shore to roost (gulls, cormorants). Monthly fly-by counts have been made from Clover Point, Victoria (Shepard 1992).

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Consult maps and nautical charts to locate the optimal position(s) for repeated surveys within the project area.
- Plot count stations on the map.

Sampling Design

- To determine relative densities (birds km^{-2}), the area scanned must be accurately measured. Use conspicuous landmarks shown on charts, ship's radar, or optical rangefinder to determine distances and hence areas. Permanent buoys can be set up to mark specific areas for long-term monitoring.
- The area scanned, or “viewshed” may be considered to be a study area (using RIC terminology).

Sampling Effort

- Samples should be sufficiently frequent to show seasonal or diurnal patterns, tidal effects etc. (depending on the goals of the surveys).
- Time spent surveying must be recorded as a measure of effort.

Personnel

- A single observer, experienced in identification of seabirds.

Equipment

- Binoculars
- Spotting scope mounted on a tripod (for shore-based surveys)
- Dataforms
- Rangefinder (optional)
- Vessel (for counts ar sea)

Field Procedures

- These counts can be made from a stationary vessel using binoculars, or from fixed stations on land using a spotting scope.
- For repeated counts, such as those used to monitor seasonal or diurnal changes, the method, place and timing of surveys should be kept constant.
- In all instances record the details shown in the dataform. Use the same codes and measures as in vessel surveys.
- For tides report both height and state (flood, slack, ebb).

5. PROTOCOLS: Inventories At Colonies

Table 3. Recommended inventory methods for seabirds at colonies in British Columbia for the 3 levels of intensity.

Survey Type	Species	Intensity
Aerial Reconnaissance	All seabirds at colonies	PN
Vessel Reconnaissance	All seabirds at colonies	PN
Aerial Photography	Surface nesters only	RA
Nest Counts	All seabirds at colonies	RA AA*
Adult Counts	Murres; Pigeon Guillemots; cormorant & gull colonies if nest count on land not possible.	RA
Adult Counts (with applied K ratios)	Murres only	AA

* Obtainable for most species.

There are two primary goals for censuses of seabirds at colonies (Birkhead and Nettleship 1980):

- determining the numbers of birds in the colony at a particular time; and
- monitoring population changes over short- and long-term periods.

Secondary goals include:

- comparing distributions and densities of nests in various habitats;
- determining the proportions of breeding and non-breeding birds;
- monitoring changes in the parts of the colony used for nesting; and
- gathering information in support of studies of breeding biology.

5.1 Sampling Standards

Colony counts of seabirds are the standard method used to determine breeding populations and in some cases to estimate total (breeding + non-breeding) populations. Census methods have been refined over many years, and globally recognized techniques are available for most seabird groups, although these usually have to be modified for local conditions. Seabirds are among the few vertebrate groups where global populations can be estimated for most species (*e.g.,* Croxall *et al*. 1984; Croxall 1991).

Censuses at colonies are usually a compromise between the need for intensive counts, ideally repeated, to get the most accurate estimates, and the limitations imposed by time, number of personnel available, safety, and disturbance to the birds. Every burrow or nest might be counted, even in large colonies, if the population estimate has to be very accurate and there are sufficient personnel and time. This level of effort might be required to detect significant changes in seasonably variable breeding populations. For intensive studies it is advisable to consult a wildlife statistician for help in determining sample sizes and sampling design.

The two most important considerations in censusing seabird colonies are to reduce disturbance to the birds and maintain observer safety.

5.1.1 Reducing Disturbances to Colonies

Visits to seabird colonies are strongly discouraged. Even the most careful and experienced field biologist will cause disturbance to the birds. Seabird colonies are sensitive, very valuable places, and both surface- and burrow-nesting birds are easily disturbed (*e.g,.* Ellison and Cleary 1978; Gaston *et al*. 1988; Pierce and Simons 1986). Breeding success is invariably affected by investigator activities, and even the sight of distant humans can cause birds to leave their nests. Try to avoid walking over nesting burrows. Burrows are easily damaged underfoot, even if they don't collapse you are probably damaging the burrow structure and disturbing the birds within, and burrow-nesters may desert if disturbed at the nest. Surface-nesting birds usually leave their nests when humans approach, leaving eggs and small chicks vulnerable to predators like gulls, crows or eagles. Strictly limit the time spent on surface colonies, since most birds will stay off their nests while a person is present. Exposed eggs can overheat or cool, and unattended downy chicks are very susceptible to cold and rain.

The Canadian Wildlife Service Seabird (5421 Robertson Road, RR#1, Delta, B.C., V4K 3N2; Phone 604-940-4700) coordinates all work on seabird colonies in B.C.. Censuses should only be undertaken by trained observers working within established programs regulated by the Canadian Wildlife Service or the provincial Wildlife Branch. Most colonies are Ecological Reserves, Wildlife Management Areas or fall within National or Provincial Parks, and require permits to enter.

5.1.2 Safety of Personnel at Colonies

Seabird colonies are risky places for people, and are usually far from medical facilities. Many seabird biologists have been injured and several killed by falling off cliffs, slipping on rocks or steep grassy slopes, or in boating accidents when landing on islands. Aspergillosus (a fungal infection of the lungs) and other infections can be inhaled from dry guano, and a face-mask is recommended for extended visits to gull and cormorant colonies. Seabird burrows contain ticks, which might present some risk from contacting Lyme's disease (a spirochaete bacterial infection transmitted by tick-bites). Personnel required to reach into burrows will probably be scratched or bitten and should have a valid tetanus booster.

5.1.3 Time of Year

The optimal dates for various species differ. Table 4 summarises recommended census times for seabirds breeding in British Columbia. These times may vary with latitude and local ocean conditions, and should be confirmed by referring to previous reports from the target colony. There might also be considerable inter-annual variation which needs to be researched for each species before censusing. Refer to the protocol for each species group for more details.

Table 4. Recommended dates for colony censuses of seabirds in British Columbia.

Species	Recommended Censusing Dates	Comments
Fork-tailed Storm-petrel Leach's Storm-petrel	1 July - 1 August 1 August - 15 September	Census storm-petrels during chick-rearing. Mixed colonies are best sampled in late July.
Double-crested Cormorant Brandt's Cormorant Pelagic Cormorant	15 June - 31 August 15 June - 31 August 1 July - 15 August	Census cormorants during the peak of breeding
Glaucous-winged Gull	15 June - 15 August 1-30 June in QCI[1]	Census gulls during late incubation. Adjust for local variations.
Common Murre Thick-billed Murre	15 July - 15 August (both species)	Census murres between end of laying and before chicks fledge
Ancient Murrelet	1 - 30 June	Census after most chicks have fledged and while signs of occupation are still fresh
Rhinoceros Auklet Tufted Puffin Horned Puffin Cassin's Auklet	15 June - 31 July 10 July - 31 August 10 July - 31 August 1 June - 15 July	Census these alcids after most adults have stopped brooding , but before most chicks fledge.
Pigeon Guillemot	May-July	Census guillemots during egg-laying or incubation

[1] QCI = Queen Charlotte Islands

* Important note: For each species, the suggested dates might vary among colonies, with latitude, inter-annual changes in ocean conditions and local climatic features. Consult the literature on local colonies before planning censuses.

5.2 Common Protocol for all Colony Inventory

The following protocol applies to all colony surveys. Note: more detailed protocols are provided for each survey type and for each seabird group.

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant maps for study area (*e.g.,* Nautical charts , 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for study areas from maps.
- Review existing maps, photographs, sketches, reports and census data for the target colonies.
- Consult with previous census personnel to get details on how, when and where to do the censuses.
- Plot colonies in the project area on maps. Prepare maps of colonies and, if necessary, plot locations of sampled areas (transect routes, sample plots, etc.).

Sampling Design

- Follow specific protocols for each bird group.

Sampling Effort

- All sampling should be done in coordination with the Canadian Wildlife Service (see above)

Personnel

- All personnel should be experienced at working in and near colonies, aware of the risks of disturbance to breeding birds and the dangers of working in seabird colonies.

Equipment

- Maps and photographs of colonies
- Binoculars
- Notebook
- Dataforms
- Camera to photograph colony
- Click counter (optional)
- Face-mask (for extended visits to gull or cormorant colonies)

For all colony censuses, the following information should be recorded and filed with the census data. Where possible, this information has been indicated on the accompanying data forms.

- Date and time of the count. The number of active breeders usually changes continuously through the breeding season at most colonies. Colony attendance varies through the day and these daily patterns also vary with tides, latitude and local ocean conditions.
- Sketch maps and photographs, showing the size and habitat of the colony, and the location of observation points, transect lines or quadrat boundaries;
- Notes on other species seen at the colony (*e.g*., eagles, falcons, ravens, crows, marine mammals and potential predators such as rats, raccoons, mink, and river otters) or signs of their presence (scats, tracks, dens, predated birds or eggs).
- Confirmation of active breeding. Check the contents of a few accessible nests and, during the chick period, watch from a distance to see if adults are delivering food. Seabirds sometimes attend colonies, but fail to breed if oceanic conditions are unfavourable, and evidence for this needs to be documented. In addition, there are probably many small colonies in B.C., perhaps sporadically occupied, which have not been catalogued.
- The standard census unit for most seabirds is the number of breeding pairs, usually determined by counting or estimating the number of apparently occupied nest sites (Bibby *et al.* 1992). In small colonies all the nest sites can be counted, but in larger colonies these have to be estimated by extrapolation from sample quadrats or fixed-width transects. It is equally valuable to get counts of the numbers of birds in attendance at the colony, particularly for species in which pairs or nests are difficult to census (*e.g.,* murres). In some situations (*e.g,.* Pigeon Guillemots nesting among talus or boulders, or murres or cormorants nesting in caves) numbers of attendant birds are the only possible measure.
- Take photographs of the colonies. Comparisons of photographs are often useful in monitoring changes at colonies (Gaston et al. 1993).

All wildlife inventory data will become part of the provincial Species Inventory Database.

All census data should be archived as well. The Canadian Wildlife Service, 5421 Robertson Road, RR#1, Delta, B.C., V4K 3N2 (Phone 604-940-4700; Fax 604-946-7022) is the repository of seabird colony count data. Send sight record cards to the Vertebrate Division, Royal British Columbia Museum, 675 Belleville Street, Victoria, B.C. V8V 1X4 (Phone 250-387-2927). The Ad Hoc Working Group on Introduced Mammals should be notified of sightings of predatory mammals, especially raccoons and rats (c/o Canadian Wildlife Service - see above).

5.3 Nest Counts

Recommendations: Relative Abundance and Absolute Abundance (for most species).

5.3.1 Nest Counts - Cormorants

Brandt's Cormorants usually nest on flat or moderately sloping surfaces on small rocky islands. Double-crested Cormorants use similar places but also nest in snags and small trees on coastal islands. Pelagic Cormorants usually nest on cliffs, and sometimes inside caves. In all three species, the nests are usually clearly visible and easily counted, but all are very sensitive to disturbance from humans and should be viewed from as far away as possible. Census methods generally involve mapping the layout of the colony, preferably from photographs taken from the air or (for cliff colonies) from a boat, dividing the colony into recognisable sections with clearly delineated boundaries and then counting the nests in each section. Very few cormorant colonies in British Columbia contain 1000 or more nests, and so sampling with transects or quadrats should not be necessary. The contents of each nest are recorded (*i.e.* empty, number of eggs or chicks; see protocol below) where possible without flushing the birds.

Cormorants are particularly sensitive to disturbance from humans. They will temporarily desert nests when humans or boats are 100 m distant, leaving eggs or small chicks vulnerable to crows, gulls and other predators. Keep census visits to the minimum possible duration. To avoid walking through the colony, counts can be made from raised vantage points or blinds, with the aid of binoculars and spotting scope (Ainley and Boekelheide 1990:167), or from a boat at colonies on cliffs or small islands (Vermeer *et al.* 1989a, 1992). When it is necessary to enter the colony, the observers should have a co-ordinated plan to visit each section and leave the colony as quickly as possible.

Cormorants will shift colony sites between years and so an empty colony need not necessarily mean failed breeding. The birds might simply be using another island or cliff nearby.

Sampling Design

- Systematic count of all the nests (and their contents) at the colony. Colonies are usually divided into sections to make counting easier.

Sampling Standards

- **Time of year:** Cormorants are best censused at the time they have eggs or small chicks and the recommended time is therefore from the end of laying to the beginning of fledging (Table 4).

Equipment

See section 5.1.4. Additional equipment:

- Spotting scope
- Boat (for colonies on cliffs or small islands)

Field Procedures

- Counts should be made on foot at the colony, but colonies on steep slopes or less accessible islands could be censused from a boat. Aerial photographs can be useful for locating colonies and for making rough estimates of the number of nests.
- Map the colony. On an aerial photograph, or (less suitably) topographic map or field sketch-map, sketch the extent of the colony and highlight conspicuous landmarks that can be used in later years for orientation.
- Divide the colony into easily sampled sections, using natural boundaries and landmarks to delineate each section.
- Count the nests. Ideally observe the nests from raised vantage points that allow you to look into nests to check their contents. Use a spotting scope or binoculars to avoid flushing the birds. Walk through the colony only if necessary.
- Record the contents of each nest visible from the observation point, but do not flush the birds to see into nests.
- Estimate numbers of inaccessible nests. For example, Pelagic Cormorant nests under overhangs or in caves are often not visible from shore. They might be visible from a boat but if that is not possible, estimate the numbers of pairs from a count of the birds flushed from the nest, or seen entering and leaving the colony. Make detailed notes on how the estimate was derived.
- Make detailed notes and sketches of the islands, and parts of islands checked for nests. This is essential for comparing the count with previous and subsequent efforts, which might sample different areas.

5.3.2 Nest Counts - Gulls

Most gulls, including Glaucous-winged Gulls, nest above-ground in relatively dense island colonies. The nests are large, obvious cups of grass, algae and debris, usually well-spaced (>1 m apart) on grassy slopes, rocky boulders, scree or gravel beaches. Censusing at the colony involves counting the number of active nests and recording the contents of each nest (empty, number of eggs or chicks). In most cases this can be achieved by dividing the colony up into sections, with clearly delineated boundaries and then walking through each section counting the nests until the entire colony is counted. Some nests are placed deep within tall grass or other vegetation and require diligent searching. Few Glaucous-winged Gull colonies in British Columbia approach or exceed 1000 nests, and so sample quadrats or transects should not be necessary (Rodway 1991).

In general the methods are the same as for cormorants (above), except that observers will need to walk through the colony to locate nests.

Sampling Design

- Systematic count of all the nests (and their contents) at the colony. Colonies are usually divided into sections to make counting easier.

Sampling Standards

- **Time of year:** Gulls should be censused after clutch completion, preferably late in the incubation period. Most nests should be completed and easy to identify at this time. Counting gulls later in the season might underestimate productivity, because the chicks often wander several metres from nests and hide in cavities or vegetation.

Field Procedures

- Walk through the colony to locate nests.
- Record the numbers of active nests and their contents. Search carefully for chicks which might have wandered from the nest to hide in crevices or vegetation.

5.3.3 Nest Counts - Burrow-nesting Birds

Burrow-nesting birds

Burrow-nesting birds includes storm-petrels (B-FTSP and B-LESP) and auks (B-ANMU, B-CAAU, B-RHAU, B-TUPU, and B-HOPU). These species use burrows or cavities in a variety of habitats, including steep grassy slopes, under trees in old-growth forests or among boulders and scree (Campbell *et al.* 1990).

Counting occupied burrows

The sampling unit is the occupied burrow, indicating a breeding pair. Counting occupied burrows in a colony involves a three-step process:

a) determining the boundaries and area of the colony;

b) counting the total number of burrows for the species; and

c) determining the percentage occupancy

In small colonies (<1000 pairs) or larger colonies where sufficient time and personnel are available, it should be possible to do a complete count of all the burrows. The colony can be divided into easily recognized sections with clearly defined boundaries and the burrows in each section counted. In larger colonies it might be necessary to use sample quadrats to obtain a mean burrow density and then extrapolate this value to the estimated area of the whole colony (Rodway et al. 1994). Sample quadrats can either be placed at intervals throughout the colony or along transects running across the colony. Savard and Smith (1985) tested a variety of sampling methods in Cassin's and Rhinoceros Auklet colonies in B.C., which form the basis of the methods used by the Canadian Wildlife Service and recommended here.

Distinguishing species

Distinguishing species in mixed-species colonies is often difficult. Rodway *et al.* (1990b, 1994) derived a set of criteria for separating burrows of the storm-petrels and burrowing alcids based on size of entrance (5-7 cm in petrels; 10-12 cm in auklets and murrelets), odour (petrels have a distinctive musty odour), and distinctive feces, feathers, eggshell fragments and food remnants (see Rodway *et al.* 1994:6-7 and 1990b:7-8 for details). Cassin's Auklet burrows could usually be distinguished from those of Ancient Murrelets by their characteristic fishy odour and by whitish streaks of feces at the entrances (Gaston *et al.* 1988).

Burrow occupancy

Burrow occupancy (the percentage of burrows containing nesting birds) is determined by examining a sample of burrows. It is generally not feasible to examine all burrows in a sample quadrat for occupancy, and a constant sample size (e.g., 5 burrows per quadrat, including burrows outside quadrats if necessary) is preferred to simplify statistical analyses. Occupancy is usually determined manually, by reaching into the end of the burrow to check its contents, or with very long or obstructed burrows, making small excavations into the burrow. Occupancy is indicated by the presence of an adult, egg, chick, or freshly hatched egg membrane. Tests with Ancient Murrelets showed that burrow occupancy could be reliably identified by the presence of egg membranes after the chicks had fledged (at 1-2 days old), thereby avoiding disturbance to nesting birds (Gaston et al. 1988). Bibby et al. (1992) suggested using a fibre-optics scope to examine deep burrows, but tests in Ancient Murrelet burrows showed that the device was time-consuming, difficult to manipulate in contorted burrows and did not always reveal egg membranes or other evidence of nesting (Gaston et al. 1988, A.D. Lawrence, pers. obs.). Miniature remote video cameras are being tested for use in seabird burrows, and might be useful to minimise disturbance to birds.

Knock-down tags set in the entrances of burrows have been used as a crude estimate of occupancy, but they do not give absolute occupancy values because non-breeders and other species will enter burrows. Gaston et al. (1988) showed that knock-downs at occupied burrows were twice as frequent as at unoccupied burrows. They suggested that the method might be used to monitor annual variation in relative occupancy if the same areas were tested at the same time of year. The method is much quicker to perform and causes much less disturbance to birds than direct manual inspection.

Occupancy varies widely among colonies and within colonies (Gaston et al. 1988) and so the application of the mean or median values could lead to serious errors in population estimates. Wherever possible the local occupancy rate should be estimated.

Populations of Tufted and Horned Puffins, which visit burrows in daylight, can be crudely estimated from counts of adults at the colony or on the sea nearby (Bibby *et al.* 1992). Invariably, some non-breeders will be included and some breeders will be absent at sea, but if undertaken repeatedly at the same time of day at the same phase of breeding, these attendance counts can indicate relative population changes. This is not possible for other species which visit their nests at night, and is not a substitute for burrow-counts to estimate absolute densities.

Sampling Design

- Small colonies (<1000 pairs) and larger colonies (if possible): Systematic count of all burrows at the colony. Colonies are usually divided into sections to make counting easier. Burrow occupancy is determined by examining a sample of burrows at the colony.
- Large colonies: Systematic sample counts of the burrows at the colony using quadrats. Quadrats are placed at intervals throughout the colony or along transects running across the colony. Burrow occupancy is determined by examining a sample of burrows within each quadrat.

Sampling Standards

- **Time of year**: Burrow-nesting seabirds often nest in mixed-species colonies and it is usually most profitable to census all the resident species at the same time. This might not be possible if the species have very different breeding schedules (Table 4). Storm-petrels have a protracted incubation and chick-rearing period, when they can be censused. A problem arises in the many mixed-species colonies of storm-petrels because the Fork-tailed Storm-petrel nests about a month earlier than Leach's Storm-petrel and so the optimal time for the former is likely to cause desertions in the latter species. In mixed petrel colonies censuses are best made in late July. Burrowing alcids are very susceptible to nest-desertion if disturbed and should be censused late in the breeding season when there are few adults at the colonies during daylight. Ancient Murrelets are best counted after the chicks have left the colonies, and while there is still evidence of nesting, egg shells and membranes.

Equipment

See section 5.1.4. Additional equipment:

- Arm-protectors cut from the sleeves of old shirts reduce scratching and dirt when examining burrows.
- Measuring chain (if using transects)
- Measuring tape (if using sample plots for burrowing birds)
- Toothpicks or match sticks (optional, for knock-down occupancy estimates).

Field Procedures

- Reconnaissance on foot. Map out the extent of the colony on an aerial photo, topographic map or sketch-map. Most of the important seabird colonies in B.C. have been mapped (Rodway 1991; Rodway and Lemon 1990, 1991a,b; Rodway *et al.* 1988; 1990a,b, 1994), but the distribution of nests, and colony boundaries can change with time. Take copies of the relevant reports into the field to ensure comparable censusing. Do not attempt censuses where the substrate is steep or fragile and people are likely to damage burrows or be at risk to injury.
- Determine the colony area. The colony is defined as all portions of the site where burrows show signs of recent activity (droppings, feathers, regurgitated food, fragments of eggshell or egg membrane, worn entrances or tunnels, excavation or fresh nesting material). If estimating colony area from maps or air photos, adjustment must be made for slope to get actual ground area. This can be done by multiplying the length of the burrowing area (determined by following a contour line on a topographic map) by its width (determined by averaging the lengths of transects measured across burrowed ground) (Harfenist 1994, Bertram 1995). Rodway et al. (1994) provide an alternate, more complex method. If measuring directly on the ground no corrections are necessary for slope.
- For small colonies (<1000 burrows) count the entire colony if possible.
- If entire colony can not be counted layout sample quadrats:
    1. Lay out transects that run perpendicular to the shoreline and are spaced throughout the colony area. Transects should be 50-200 m apart, depending on the size of the colony and the time and personnel available to do the census.
    2. Lay out square quadrats at intervals of 5 to 40 m along the transects Quadrats size depends on burrow density and topography, ranging from 1x1 m or 2x2 m in dense storm-petrel or auklet colonies to 7x7 m for scattered, sparse burrows.
    3. Determine the compass bearing for each transect and use this to navigate across the colony, and a chain to measure distances between quadrats. Note: remember to remove all measuring chain when you are finished.
    4. Overall, the sample quadrats should cover at least 1% of the colony area. Where possible, the transects and sample quadrats already used in previous censuses should be re-sampled to improve inter-census comparisons.
- Make a quick assessment of the vegetation characteristics of the site and record distance from shore, slope and elevation. Changes in vegetation might help explain changes in bird densities. Do not spend too much time on this activity.
- Determine burrow density per quadrat.
- Count all the burrow entrances in the quadrat (an entrance leading to two burrows counts as one burrow), or in small colonies count all the burrows. Separate the likely occupants by species (see above and Rodway *et al.* 1990b, 1994, Gaston et al. 1988).

- Determine burrow occupancy. Manually search a sample of the burrows (at least five in or next to the quadrat) to determine the species of occupant, and evidence of occupancy (adult, egg, chick, fresh egg membrane). Where possible, delay any intrusions into the burrows until after incubation and the brood period, to reduce the chance of disturbing an adult and causing desertion. Beware of damaging the fragile eggs of storm-petrels and small alcids. Any excavations are likely to cause nest desertions and damage to burrows and should only be undertaken under the supervision of experienced personnel. Carefully repair any damage done to burrows during inspections. Knock-down tags set in burrow entrances give a crude estimate of relative occupancy, but are recommended only for comparisons within a colony (Gaston *et al.* 1988).

Note: Small colonies of Tufted and Horned Puffins are often inaccessible (on steep or fragile slopes) and so burrows cannot be counted or checked. In this situation attendant adults should be counted (repeatedly over a number of days, late in the day, early in the season) to provide relative densities, using the methods suggested for guillemots in the next section (Adult Counts).

Data Analysis

- Calculate the total number of burrows (B) by multiplying the mean burrow density by the estimated colony area.
- The total colony population (P) is then calculated using B and the mean occupancy rate (R): **P = B x R**. Rodway *et al.* (1994) give formulae and methods for calculating the variances of P and R .
- Always report and archive the raw data along with the final population estimate (e.g., the burrow count, area sampled, number of quadrats, occupancy).

5.4 Adult Counts

5.4.1 Adult Counts - Murres

Common Murres breed in dense aggregations on cliff ledges, on large boulders in scree slopes and on flat areas on top of cliffs or sea stacks. A few Thick-billed Murres breed in B.C., using cliff-ledges, often among the Common Murres. Both species incubate their eggs directly on the rock surface, and often breed with neighbours touching each other. These features make it extremely difficult to separate breeding birds from non-breeders, check on the breeding status (incubating, brooding or failed breeder) and make accurate counts of breeding populations.

For these reasons, special methods have been developed to count murres and determine their breeding status. These are outlined in detail by Birkhead and Nettleship (1980) and summarized here. The **Type I** method requires daily monitoring over a 6-week period (from before egg-laying through 10 days after laying ends) to record the position of each nest-site and the fate of each breeding attempt in sample plots. This method is most suited for studies focusing specifically on murre breeding biology and is not recommended for regular annual censuses. The **Type II** method requires daily counts of murres in sample plots over a selected 5-10 day period between the end of egg-laying and the start of fledging. This provides attendance numbers and this method has been widely used to monitor relative changes in populations over periods of years. Counts must be made at the same time of day to account for diurnal variations in attendance.

Estimates of breeding populations require derivation of a ***k* ratio** (number of breeding pairs divided by the number of individual birds counted; Birkhead and Nettleship 1980). The *k* ratio has to be determined from several clearly visible sample plots scattered throughout the colony. Each plot needs to be monitored for several hours per day for 5-10 days, to count the total number of birds present and to get a chance to see whether each pair has an egg or a chick.

The *k* values are colony specific, and are sensitive to seasonal and diurnal changes. Diurnal and seasonal patterns of attendance vary among colonies, among years and with weather and prey availability (*e.g.,* Gaston and Nettleship 1981; Hatch and Hatch 1989; Burger and Piatt 1990), but the best time to count murres is generally around mid-day between the end of egg laying and the start of fledging (mid-July to mid-August in B.C.). Rodway *et al.* (1990b) found least variability in numbers at Triangle Island between 1000 and 1300 h.

Sampling Design

- Follow the general procedures laid out by Birkhead and Nettleship (1980). Use either Type 1 or Type 2 to count murre populations and to determine their breeding status.
    - To focus specifically on murre breeding biology: use the Type I census method for intensive surveys where daily sampling is possible over the entire laying period (about 6 weeks).
    - To monitor relative changes in populations over periods of years: use the type II census method at sample plots from brief (5-10 day) visits to the colony.
- The method suggested here for B.C. has elements of both types I and II and follows Rodway (1990).

- To estimate the murre population on Triangle Island, Rodway (1990) took photographs from a boat, but because some parts of the colony were not visible from the boat, he made additional counts of the obscured sections from the cliff-top.
- The number of breeding pairs and the number of individual birds were counted in a sample plot. This was used to determine the *k* ratio:

$$\boldsymbol{k}\ \textbf{ratio} = \frac{\text{[\# breeding pairs in sample plot]}}{\text{[mean \# indiv. birds present per day in sample plot]}}$$

- The breeding population (P) was estimated as: $\mathbf{P = \boldsymbol{k}(T\boldsymbol{r} + C)}$

where k = defined above,

T = total mean count from photographs of the whole colony, r = ratio of telescope to photographic counts on the sample plot; C = additional count of parts of the colony obscured from the water.

- At most of the small murre colonies found in British Columbia, it should be possible to make counts of the complete colony, and apply a relevant *k* ratio determined from a sample plot [P = *k*(Mean count of individuals in Colony)].

Sampling Effort

- Multi-year censuses are generally required to detect statistically significant changes in murre populations, due to the high degree of variability in attendance and breeding attempts. The paucity of annual counts has made it very difficult to assess the impacts of major events which affect murres, such as oil spills, over-fishing or changes in local productivity (*e.g.,* Rodway 1990; Parrish and Boersma 1995). Systematic counts of murres at the few colonies in B.C. are thus extremely valuable and should be made whenever biologists visit these colonies.

Sampling Standards

- **Time of year**: Murres are best censused at the time they have eggs or small chicks and the recommended time is therefore from the end of laying to the beginning of fledging.
- **Time of day**: Birkhead and Nettleship (1980) recommend making counts of individuals within sample plots over the entire daylight period on at least two days, to determine the diurnal attendance pattern of the colony, and verify that mid-day is the most suitable (least variable) time for censusing.

Equipment

See section 5.1.4. Additional equipment:

- Observation blind (needed for prolonged observations to get *k* ratios)
- Camera (needed to document colony size and location)
- Boat (optional, for photographing and observing cliffs not visible from land)
- Binoculars or spotting scope are essential to separate breeders from non-breeders.

Field Procedures

- Map the colony. The murre colonies on Triangle Island have been mapped and photographed (Rodway 1990) and this publication should be taken into the field to ensure comparable censusing. Colonies might change with time.
- To determine the *k* ratio:
  1. Select sample plots. These are clearly visible parts of the colony which can be safely observed for 2-3 hours per day. There should be at least 50 clearly visible nest sites (100 birds) per plot and one plot per 1000 birds. Plots can be randomly or systematically spaced but should include both the centres and edges of large colonies. Plots should ideally be visible from above, not below, and from directly opposite, not at an angle (see sketches in Birkhead and Nettleship 1980). A temporary blind might be needed. Each sampling plot should be identified on the map and marked with a permanent marker (*e.g.,* labelled steel spike in the ground).
  2. Photograph each plot and mark the boundaries of the plot on the photograph. These are important for tracking changes to colonies (Gaston *et al*. 1993).
  3. Observe sample plots to determine the *k* ratio. These observations require about 2-3 hours per day, around mid-day (10:00-13:00 h) and should be repeated on 5-10 days.
  4. Complete a dataform for each visit to each plot. Calculate a mean value of *k* for the season by dividing the total number of active breeding pairs (seen with egg or chick) by the mean number of individuals present within a sample plot per day

     $$\textbf{\textit{k} ratio} = \frac{\text{[\# breeding pairs]}}{\text{[mean \# individual birds present per day]}}$$

- Count all the individuals at the entire colony. This might involve making counts, or taking photographs from vantage points on land or from a boat, or both. These counts should be made at mid-day (10:00-13:00 h) and repeated on 5-10 days during the census period. Calculate the mean and standard deviation of counts.
- Estimate numbers breeding in inaccessible or obscured parts of the colony. Murres in deep crevices or caves can be estimated by counting the numbers entering or leaving these areas. Add these estimates to the total counts of the colony, but clearly differentiate estimates from counts on the data sheets.

Data Analysis

- Estimate the breeding population (pairs) by multiplying the mean count of individuals for the entire colony by the *k* ratio.

  P = *k*(Mean count of individuals in Colony)].
- When reporting or archiving data include all counts, calculations, maps and photographs.

5.4.2 Adult Counts - Pigeon Guillemots

Nests of Pigeon Guillemots are often difficult to locate, situated under scree or shoreline boulders, deep within piles of logs, or in burrows. The normal procedures for sampling burrow nesters do not apply. Standardized counts of guillemots can be made of birds in adult (alternate) plumage at their loose colonies (Nettleship 1976; Cairns 1979; Bibby *et al.* 1992). In the field, breeding adults cannot readily be distinguished from immatures (*i.e.,* two-year old birds). Ratios of adult to immature numbers are likely to vary among local populations and with time of year (Cairns 1979; Ewins 1985; Nelson 1987).

Vermeer *et al.* (1993) analyzed attendance patterns of Pigeon Guillemots at colonies in Skidegate Inlet (Queen Charlotte Islands) and Mandarte Island (Strait of Georgia). Attendance was affected by time of day and tides to varying degrees at these colonies. They recommended making censuses only in the early morning and only at high tide. Drent (1965) and Ainley and Boekelheide (1990) report similar conclusions.

Maximum attendance at guillemot colonies usually occurs during the pre-laying period and some have recommended this as the best time to census (Nettleship 1976; Ewins 1985). Vermeer *et al.* (1993), however, found that counts of Pigeon Guillemots were more variable during pre-laying than later in the season, and recommended repeated counts during egg-laying, incubation and early-chick stages. Attendance declined significantly after fledging began (Ainley and Boekelheide 1990; Vermeer *et al.* 1993).

Sampling Design

- Systematically count all adult birds belonging to the colony.

Sampling Effort

- Attendance at colonies is variable and so repeated counts will provide more precise population estimates and a measure of variance.

Sampling Standards

- **Time of year**: Since nest contents are not checked, the birds can be censused throughout incubation or brooding (Table 4).
- **Time of day:** The recommended time of day is in the early morning (dawn to 08:00), preferably at high tide.

Equipment

See section 5.1.4. Additional equipment:

- Boat

Field Procedures

- Count the birds. Count the individuals in adult plumage on the shore or on the water within 200-300 m of the colony. Counts should be made in relatively calm seas (Beaufort scale 3 or less, Table 2).
- Make several counts and use the maximum value.
- Repeat the process 3-5 times, on separate days.
- Confirm breeding by checking a sample of accessible nest cavities.

Data Analysis

- Implicit within this method is the assumption that all birds are counted.
- When reporting and archiving data include all information on the date, time and number of birds from each sample count.

5.4.3 Adult Counts - Cormorants & Gulls

Counts of nests and adults from vessels can be used for cormorants and gulls in situations where it is either impossible to land, or landing would cause undue disturbance to the birds. Such counts provide relative densities and are not a substitute for nest counts.

Sampling Design

The procedures follow those outlined above for Pigeon Guillemots, except that it might be possible to count nest sites for some species (Glaucous-winged Gulls on small rocky islands, Pelagic Cormora

5.5 Aerial Photography

Recommendations: Relative Abundance for surface nesters only (when other methods are not possible).

Although aerial photography is not generally recommended as a census tool, it can be used on an opportunistic basis to sample remote or inaccessible colonies. Counts of birds and nests from aerial photographs are possible for surface nesters only, and since it is impossible to accurately separate breeding from non-breeding birds and some nests might be obscured, these counts provide relative and not absolute abundance. Every precaution must be taken to avoid disturbance by the aircraft to the breeding birds.

Office Procedures

- See section 4.1.4.
- Consult topographic maps and nautical charts to plan the best flight path over the colony.

Sampling Design

- Photography should be planned for the date at which most nests are complete (see Table 4). The numbers of off-duty birds (breeders not incubating or brooding) present at the colony will vary with time of day and weather conditions. For long-term monitoring the date, time and weather conditions should be standardized.

Sampling Effort

- Several photographs taken at intervals throughout the season will provide a better perspective on seasonal and annual variations than a single date.

Equipment

- Aircraft
- High quality camera (a medium telephoto lens, 100 mm or 150 mm focal length) loaded with fine-grained film. A motor-drive might be useful to get several successive pictures at a single pass over the colony. A polarizing filter to minimize reflections may also be required.

Field Procedures

- Aircraft passing over or near colonies are likely to disturb breeding birds and cause nest desertions. Use a medium telephoto lens and fine-grained film to get good photographs from a high altitudes (over 100 m) to minimize disturbance.
- If possible, open a window or remove a door to facilitate photography. If it is unavoidable to photograph through a window, use a polarizing filter to minimize reflections.
- The aircraft should be slowed to reduce engine noise and allow several photographs to be taken in a single pass.

Data Analysis

- Count birds and nests from the photographs. If using slides project them on a screen. Prints can be examined under a dissecting microscope to distinguish birds and nests.
- Include copies of photographs and all relevant information (e.g., date, time, altitude) when archiving or reporting the data.

6. Beached bird surveys

Surveys of dead, beached birds are a standard method of monitoring mortality patterns, causes of death, chronic and catastrophic pollution and seasonal occurrence of seabirds (e.g., Camphuysen and van Franeker 1992). The British Columbia Beached Bird program has run since 1990, covering 30-40 beaches and archiving data in standardized databases (Burger 1993b).

Office Procedures

- Review the section, Conducting a Wildlife Inventory, in the manual *Species Inventory Fundamentals*.
- Obtain relevant maps for study area (*e.g.,* 1:50 000 air photo maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for survey areas from maps.
- Register new survey routes with the co-ordinator (currently: Dr. Alan E. Burger, 5012 Old West Saanich Road, RR#3, Victoria, B.C. V8X 3X1; phone 250-479-2446) to avoid overlapping with an established route.
- Map out the route on a topographic map and determine the length of beach to be covered.

Sampling Design

- The protocol follows Ainley *et al.* (1980). Standardized dataforms have been developed for B.C.
- Select a beach. The beach should be easily accessed and the surveyor should be able to get to the beach once a month without a major effort. Sandy or gravel beaches are more reliably sampled than rocky shores. Ideally the beach should be at least 1 km long, but a combination of several smaller beaches will suffice.

Sampling Effort

- Do a complete beach survey once a month
- Try to sample on approximately the same day in the month.

Personnel

- Beach surveyors should be able to identify local seabirds and be committed to surveying beaches on an ongoing monthly basis.

Equipment

- Notebook or dataform
- Polythene bags for carcasses to be retained
- Labels
- Pencil

Field Procedures

- Search the beach on foot, focusing on the tide-line debris. Cover the same area with each survey.
- Count and identify each bird carcass found. On the dataform record for each carcass: species, age, gender, state of decomposition, estimated time since death, degree of scavenging etc.
- Remove the carcass. Intact, fresh carcasses should be kept frozen for use at museums and universities (contact the co-ordinator for details). Those incompletely identified should also be kept for later identification. All birds to be kept should be placed in polythene bags, with a label placed inside the bag showing the date and place of discovery and name and phone number of surveyor. Labels tied on the outside of bags tend to fall off. Use pencil not pen. All birds not kept must be removed from the beach to avoid re-counting; throw them well above the tide-line into vegetation.
- Complete the survey dataform. Even if no carcasses were found, the survey dataform must be completed and submitted (finding no carcasses is as important as finding them).
- Report any evidence of pollution (e.g., oil blobs, oiled logs) or unusual mortality of marine organisms.

Data Analysis

- Beach survey data provide long-term trends and are best analyzed over periods of 3-4 years or longer and covering as many beaches as possible (Burger 1993b).
- Carcass densities are expressed as birds per km of beach surveyed.

GLOSSARY

ALCIDS - birds belonging to the auk family (Alcidae), including murres, guillemots, puffins, auklets and murrelets.

ASPERGILLOSIS - a fungal infection usually caused by inhaling spores in dust and dried feces; found in many bird species, but usually rare.

BEAUFORT SCALE - scale of wind velocity ranging from 0 (calm) to 12 (hurricane), based on visual observations of the effects of wind on the sea surface and other movable objects.

CLINOMETER - optical device to measure angles and heights of objects.

CLUTCH COMPLETION - when the last egg of the clutch is laid.

CONTINENTAL SHELF - portion of the sea floor comprising part of the continent, generally considered to be the coastal area within the 200 m depth isobath.

CTD - electronic device which records conductivity (salinity), temperature and depth (and sometimes oxygen concentration) as it is lowered from a vessel.

DIVING BIRD - any species of bird which routinely dives below the surface to forage (e.g., loons, grebes, cormorants, alcids).

ECHOSOUNDER - device for detecting and measuring the depth and size of solid objects (fish, sea floor) below a vessel by reflection of sound waves.

ENCOUNTER TRANSECT - counting seabirds along a fixed route per unit of time or distance travelled without reference to any distance from the vessel (see Transect; Fixed-width transect; Variable width line transect)

FIXED-WIDTH TRANSECT - count along a transect line, including all birds within a defined width boundary.

GLOBAL POSITIONING SYSTEM (GPS) - system using signals from two or more satellites to determine the location (latitude and longitude) of the person, vessel or aircraft.

INSHORE WATERS - exposed coastal waters generally less than 40-50 m deep, and within 6 km of the shore (see Kessel 1979 for more details)

***K* RATIO** - ratio between the number of breeding pairs and the number of individuals counted; used in censusing murres where the number of breeding pairs cannot be readily determined (Birkhead and Nettleship 1980).

KLEPTOPARASITISM - robbing food from another individual

LORAN - navigation system using radio signals from two or three land-based transmitters to locate the position (latitude and longitude) of a vessel at sea.

LYME'S DISEASE - an uncommon infection by a spirochaete bacterium, transmitted via tick-bites; the bacterium has been found in a few seabirds but the risks of infection are low; symptoms are rash, headache, fever.

NEARSHORE WATERS - protected coastal waters, such as bays, fjords and inlets, generally fairly shallow and within 1-2 km of shore (see Kessel 1979)

OCEANIC FRONT - a comparatively sharp horizontal transition between two bodies of water, usually characterised by changes in temperature and/or salinity; fronts often provide important foraging areas for seabirds.

OFFSHORE WATERS - ocean seaward of the inner oceanic front, generally deeper than 50 m and seaward of 6 km; see Kessel (1979) for details and further subdivisions.

PELAGIC BIRD - bird which forages in open water, generally seaward of the inner oceanic front in offshore waters.

PROCELLARIIFORMS - tube-nose seabirds of the Order Procellariiformes; includes albatrosses, petrels, fulmars, shearwaters and storm-petrels.

STATIONARY COUNT - count of birds from one stationary location.

TRANSECT - pre-determined route along which the vessel travels to census birds.

VARIABLE WIDTH LINE TRANSECT - count along a transect line in which the distance to each bird is estimated to provide a density per square km; see Buckland et al. (1993) for details.

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