MARINE BIODIVERSITY MONITORING

Protocol for Monitoring Seabirds

A REPORT BY THE MARINE BIODIVERSITY MONITORING COMMITTEE (ATLANTIC MARITIME ECOLOGICAL SCIENCE COOPERATIVE, HUNTSMAN MARINE SCIENCE CENTER) TO THE ECOLOGICAL MONITORING AND ASSESSMENT NETWORK OF ENVIRONMENT CANADA

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Table of Contents

Rationale

Seabirds are particularly appropriate candidates for monitoring the biodiversity of marine ecosystems for a variety of reasons:

P there are relatively few species of seabird in any particular marine ecozone;
P they are mostly fairly large, diurnal, and, in contrast to species which occur only below the water surface, are easily identified;
P many nest in colonies which are easy to locate and relatively straightforward to count;
P within any one ecological region, different species exploit prey at different trophic levels, allowing changes to different parts of the food-web to be detected within a single community;
P most importantly, techniques for estimating population size (a crucial component of any biodiversity index) are well established, both for breeding birds at colonies and for non-breeding populations at sea.

Seabirds are widely recognized as potentially powerful indicators of changes in marine environments (Croxall *et al*. 1988, Kushlan 1993, Furness *et al*. 1993). They respond dramatically to El Niño events (Duffy 1993) and to less extreme large-scale oceanographic changes (Myers 1979, Schumacher and Ried 1983, Royer 1993); for example, the growth rate of nestling Rhinoceros Auklet *Cerorhinca monocerata* responds to small changes in sea temperature (Bertram *et al*. 1991), and Black-legged Kittiwakes *Rissa tridactyla* have shown demographic responses to long-term climate changes in the North Sea (Aebischer *et al*. 1990).

Seabirds also offer considerable potential as cost-effective samplers of young year-classes of commercial fish stocks which may otherwise be difficult to sample. Diet samples from seabirds provide early indications of year-class strength in a variety of fish stocks in many parts of the world, including Alaska (Hatch and Sanger 1992), B.C. (Bertram and Kaiser 1993), California (Anderson *et al*. 1980), eastern Canada (Montevecchi and Berruti 1991), southern Africa (Crawford *et al*. 1983), Norway (Barrett 1991) and Scotland (Monaghan and Zonfrillo 1986, Hislop and Harris 1985). The incorporation of these relationships promises to improve some fishery-stock assessment models (Cairns 1992).

Through their diversity of feeding methods, seabirds exploit and are influenced by virtually all components of marine food-webs. They therefore offer the potential for not only detecting changes, but also explaining those changes through known linkages among component organisms and populations in the marine food-web. In particular, their strong interactions with commercial fish stocks (which often depend on the same keystone prey species as seabirds) offers practical possibilities for enhancing the understanding of changes in the diversity of marine populations of direct and immediate economic interest (e.g. Atlantic Cod).

This protocol proposes the use of well established techniques for measuring (a) the size of breeding populations of seabirds, through censuses at breeding sites; and (b) the density of populations at sea, from on board ship and from aircraft. These methods are well accepted by the international community and can be applied immediately; in some places, and for some species, they are already in use off Canada's coasts.

General Principles

The number of species present in a region (the species richness component of biodiversity) is established simply by observation by capable ornithologists, both at colonies during the breeding season, and at sea throughout the year. Pelagic surveys are needed as well as colony censuses because most marine ecoregions of Canada support large numbers of species which breed elsewhere and visit Canadian waters outside their breeding season; they do not come to land in Canada and so would not be detected by colony surveys.

Biodiversity indices generally go beyond species richness to include measures of the relative abundance of different species (species diversity). Thus it becomes necessary to provide estimates of the population size of each species present. This protocol presents the methods available for censusing seabirds. At breeding sites it is feasible to estimate total numbers because the population is concentrated, during the breeding season, within a relatively small geographic area. At sea, populations are mobile and dispersed over large areas, so can only be sampled; here, total population estimates are rarely feasible, but estimates of relative abundance can be achieved.

At breeding sites, the ideal unit of measurement is the *breeding pair*; in many cases the best approach to counting breeding pairs is to count *occupied sites* or nests. Calibration of either of these indirect measures, to convert them to actual breeding pairs, requires collecting information on the stage of the breeding cycle and attendance patterns of adults. Most seabird colonies include not only the nests of breeding pairs, but also 'loafing sites' used by substantial numbers of non-breeding birds. Since seabirds are long-lived, and often delay breeding for several years, a population may contain a high proportion of non-breeding birds. Distinguishing between actual breeding sites and numbers of breeding birds, on the one hand, and loafing sites of non-breeding birds on the other, is important if trends in numbers are to be predicted or interpreted (the 'assessment' component of a monitoring program). Only if trend information *per se* is required, with no need to assess the significance of those trends through demographic changes in the population concerned, might it be possible to dispense with these distinctions.

The ideal monitoring method should (a) provide an accurate index of population trends, (b) be quick to carry out, (c) be readily transferable between different observers, and (d) cause negligible disturbance (Gaston *et al.* 1988). Criteria (a) and (b) involve a trade-off because accuracy and precision of a sample usually increase with the sampling effort used. Established techniques involve a range of methods from 'quick and dirty' surveys when time is short or people are few, to intensive high-precision methods when conditions and resources allow. The important point for a long-term monitoring program is that the same methods should be used throughout; this requires careful identification of the objectives of the program (to estimate the precision required) and the resources available.

Contributions of Current Activities to a Seabird Biodiversity Monitoring Program

Two well-established inventory programs already contribute significantly to seabird biodiversity monitoring in Canada. These programs have developed the techniques necessary for a monitoring program (see also Hatch *et al*. 1994), but provide single measures of diversity and abundance rather than the repeated time-series required for monitoring. *Seabird colony catalogues* are lists of all known seabird colonies in a region, with the best available information on species composition and population sizes. Such catalogues have been produced for Canada by the Canadian Wildlife Service and others (Cairns *et al.* 1986, Vermeer *et al*. 1983, Vermeer and Sealy 1984, Lock *et al*. 1994). These inventories provide the best current information on breeding populations, and are widely used for impact assessment. The need for such catalogues was the primary impetus for the development of the colony census techniques which are now available to provide the repeated measurements required in a monitoring program. *Pelagic seabird databases,* usually presented in the form of an atlas, include at-sea censuses of seabirds, usually from ships but sometimes also from aerial or ground-based surveys. These serve a similar purpose to colony catalogues but for pelagic habitats rather than breeding colonies, and cover the whole year rather than just the breeding season. Techniques for pelagic censuses are less widely agreed than those for breeding colonies but nevertheless are reasonably standardized. Canada has good coverage of the western, and arctic and eastern, offshore regions (Morgan *et al*. 1991, Brown 1986, respectively).

In contrast to these two inventory programs, a *seabird biodiversity monitoring program* is designed specifically to replicate selected population parameters over time. Only a selection of colonies would be included in such a monitoring program, and data will usually refer to sample plots rather than entire colonies, or to selected samples of transects at sea.

Clearly there is no need to develop new techniques for counting seabirds. Existing inventory programs provide the basic methodology for a monitoring program. *Therefore, biomonitoring of seabirds can proceed most effectively by repeating inventories of selected colonies, and providing trend analyses of existing pelagic seabird surveys, at frequent intervals.*

Proposed Protocol

(a) Monitoring the biodiversity of seabirds at breeding sites

The procedure for moving from colony catalogues to a monitoring program within a particular ecoregion is as follows (Figure 1, and Birkhead and Nettleship 1980):

> i) From the colony catalogue, select colonies and species for routine monitoring: *colonies* should support a variety of species and be reasonably accessible, allowing both aerial survey/photography and ground counts, and should include colonies in vulnerable areas as well as 'control' colonies not currently at risk; *species* selected should represent the full range of taxonomic and ecological variety of the region;
>
> ii) Within selected colonies, identify representative study plots in which birds will be counted in detail to assess changes in status. These plots are marked permanently in the field, and on good-quality photographs, for future reference and re-location.

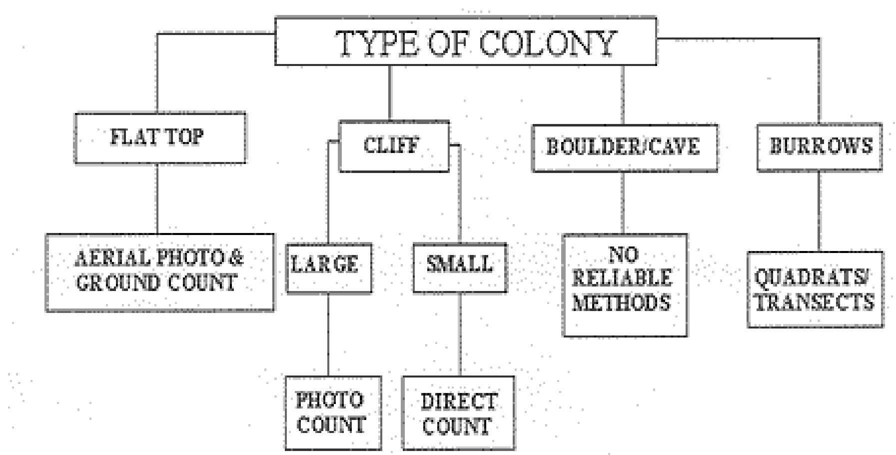


Figure 1. Relationship between type of colony and census method (from Birkhead and Nettleship 1980)

Methods are based primarily on Nettleship (1976), updated as appropriate from Birkhead and Nettleship (1980) and Gaston *et al*. (1988).

In small colonies (< 2,000 pairs) direct counts of birds and/or nests should be carried out; in larger colonies, a proportion of the total population is sampled and the results extrapolated multiplicatively. Procedures 1-2 (below) apply to all colonies or sites included in the monitoring framework; step 3 (census) differs according to the nesting pattern of the target species, and may also vary somewhat between species within a nesting pattern.

1) **Colony description.** Each colony is described in as much detail as possible, and the description attached to sketch maps and photographs. A *general sketch map* shows the location of each colony, or area sampled, in enough detail to allow precise re-location in future years by different observers (Figure 2). For large areas, where the bird distribution is small or highly aggregated, an inset map is drawn to show nesting sites in relation to distinct natural features. A *detailed sketch map* shows the limits of the colony being censused, as well as the precise method used to determine population size (Figures 3,4,5). Limits of the colony or area chanciest are shown in relation to distinct features of the environment, such as gullies, streams, rock falls etc.; these permanent landmarks are essential reference points for re-locating sites in future years. Where possible, photographs of the colony or census area are taken at the time of census to provide a permanent record, preferably using a Polaroid camera to allow direct notation, in the field, of colony areas onto the print. A film producing both a negative and a print should be used. The photographer's name, location, direction of photograph, date, time, camera, lens and film types, shooting distance and weather conditions, are all recorded at the time.

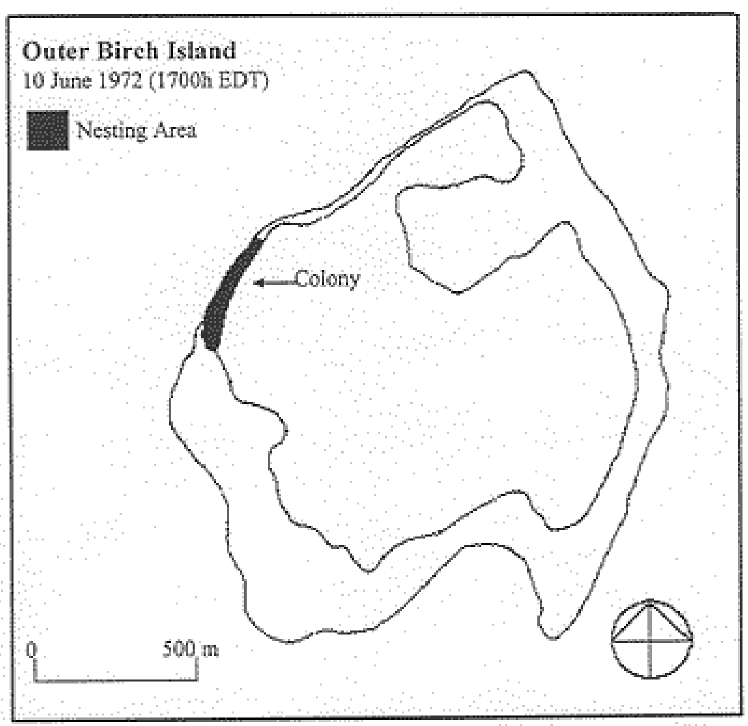


Figure 2. Example of a general sketch map showing position of a Black-legged Kittiwake colony on an island in the Gulf of St. Lawrence

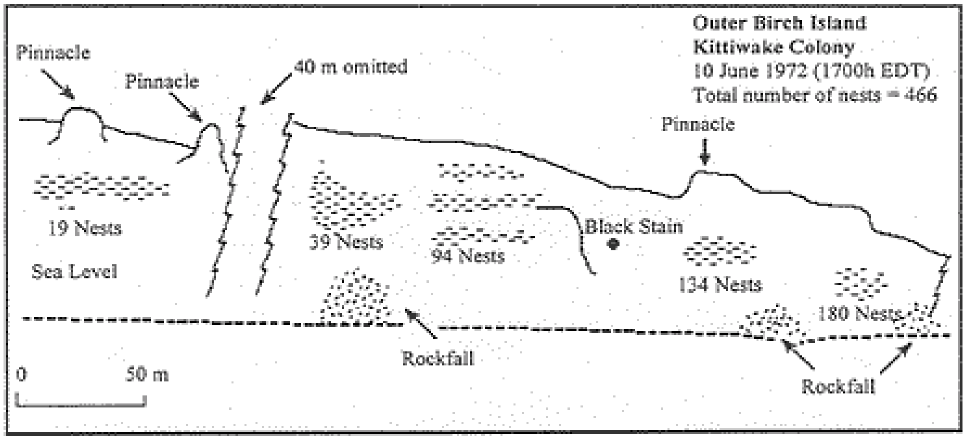
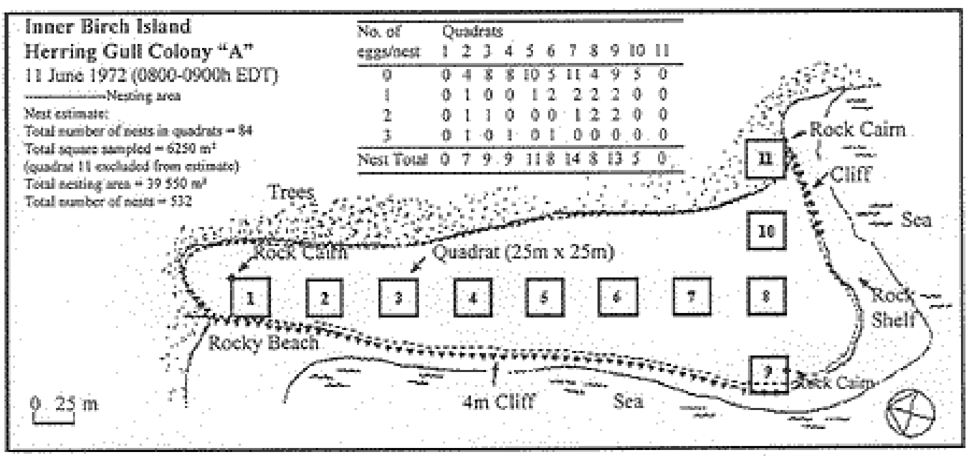


Figure 3. Detailed sketch map showing the distribution of nests on the cliffs in the same colony as in figure 2 (from Nettleship 1976)



No. of eggs/nest	Quadrats 1	2	3	4	5	6	7	8	9	10	11
0	0	4	8	8	10	5	11	4	9	5	0
1	0	1	0	0	1	2	2	2	2	0	0
2	0	1	1	0	0	0	1	2	2	0	0
3	0	1	0	1	0	1	0	0	0	0	0
Nest Total	0	7	9	9	11	8	14	8	13	5	0

Figure 4. Detailed sketch map showing line-transect method (distribution of quadrats and nests) on a colony of ground-nesting seabirds (from Nettleship 1976)

Legend:

------ Nesting area

Nest estimate: Total number of nests in the quadrats = 84

Total square sampled = 6250 m^2

(quadrat 11 excluded from the estimate)

Total nesting area = 39 550 m^2

Total number of nests = 532

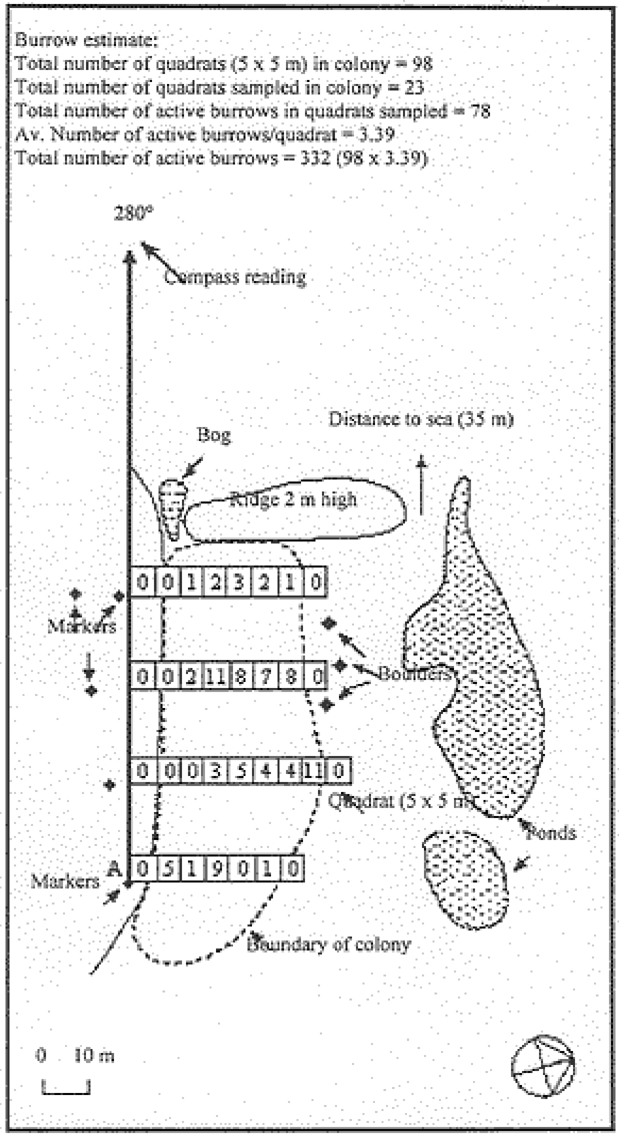


Figure 5. Detailed sketch map showing the application of the line-transect method to a colony of burrow-nesting puffins (from Nettleship 1976)

2) **Weather conditions.** The attendance of birds at breeding colonies may be influenced significantly by weather. Temperature, precipitation, wind strength and direction, and visibility must all be recorded at the time of the count in order to correct for these sources of variation.

3) **Phase of breeding cycle.** Censuses of breeding birds are normally conducted during the middle and latter half of the incubation period. However, since the timing of

breeding can vary according to environmental conditions, it is important to record the stage of breeding of the species at the time of census. This is done by recording the contents of a sample of nests, as in Figure 6.

4) **Census techniques.** These vary according to the nesting behaviour of the species. There are essentially three main patterns, each requiring a different technique:

P above-ground ('flat-top' (Birkhead and Nettleship 1980) nesting (gulls, gannets, terns, cormorants);
P underground (burrow) nesting (storm-petrels, puffins);
P boulders, scree slopes and caves (black guillemots, razorbills, dovekies);
P cliff-nesting (fulmars, kittiwakes, murres).

(i) Above-ground nesting

(a) Northern Gannet *Morus bassanus*. Gannets build large nests in dense colonies both on the flat tops of islands or peninsulas, and on steep cliffs. Both types of colony are best censused by aerial photography, usually from a fixed-wing aircraft (Barrett and Harris 1963, Nettleship and Chapdelaine 1988). Overlapping photographs are taken during the incubation period from about 550-600m; individual nests can be counted from enlarged prints using a plastic overlay and a hand lens. Nests are identified by the presence of one or two adults, so the count is of *occupied sites* rather than breeding pairs. Ground counts of nest contents can be used to correct the aerial survey for the proportion of adults occupying sites but not breeding.

(b) Common murres *Uria aalge*. Murres usually nest on cliffs (see below) but occasionally (e.g. Funk Island, NF) in dense colonies on flat ground. In these situations, colony limits are marked on vertical aerial photographs, and the density of breeding birds checked by ground counts. Birds are first counted carefully (and photographed if possible) in specific groups, without disturbance; then they are driven slowly and carefully from their eggs, the eggs are counted, and the area occupied by the counted birds measured using 1m x 1m or 2m x 2m quadrats. Eggs not being incubated (abandoned, cold, broken, addled, or wedged in cracks) are distinguished from those being incubated. Densities of breeding birds (1 pair per incubated egg) can then be applied to the total area occupied to derive a total population estimate.

(c) Gulls and terns (family Laridae). These species often nest in mixed-species colonies, so in addition to a total or sample census, the species composition must be determined. This is achieved by counting (from a distance) adults of each species attending nests in several sample plots (delineated on photographs and/or maps) throughout the colony.

Full nest counts can be achieved on the ground at small colonies. Nests should be marked non-intrusively (e.g. with tongue depressors) to avoid omission and duplication. At larger colonies, line-transects or quadrats are marked on the ground, and delineated on maps, and all nests and their contents counted (a nest is any structure more elaborate than a simple scrape, i.e. with some built-up edge).

Numbers of breeding pairs can be estimated less reliably (e.g. when nests are not visible, or time is short) by (i) a boat count of adults standing on or flying over the colony, multiplied by the ratio of nests to adults counted on control areas selected prior to the boat count; (ii) boat count of adults alone; (iii) estimation or photography from the air. Visual estimates and aerial counts are generally inaccurate (Kadlec and Drury 1968, Drury 1973-74) and provide no more than an indication of the size of colonies and an estimate of the number of gulls in a geographic region.

Some gulls nest on cliff ledges; here, direct counts of nests are made from a boat. Nests must not be confused with whitewashed loafing sites.

(ii) Cliff-nesting

(a) Northern Fulmar *Fulmarus glacialis*. Prospecting non-breeders may occupy sites for several years before breeding. Also, attendance at breeding ledges fluctuates irregularly within wide limits over periods of several days. Single counts of birds on ledges are therefore subject to very wide confidence limits. The recommended method is to count all apparently occupied nest sites in the colony, or in study plots, daily over 3 to 7 consecutive days around the middle of each day, when attendance tends to be highest, and in the middle of the incubation period.

(b) Black-legged Kittiwake *Rissa tridactyla*. This species builds a conspicuous nest on cliff faces and so is relatively easy to census providing the cliff face is clearly visible. The only difficulty incurred is in distinguishing nests from whitewashed loafing sites. The middle and latter half of the incubation period is the preferred time for censusing.

(c) Common Murre *Uria aalge* and Thick-billed Murre *U. lomvia*. These species habitually breed in enormous colonies on steep cliffs. Census methods using photographs of study plots have been developed to a greater degree of sophistication than for any other seabird species (Gaston and Nettleship 1981, Birkhead and Nettleship 1980). The method consists of careful counts of birds, eggs and chicks on sites numbered on photographic prints of carefully chosen study plots. Plots contain 80-100 sites; each plot is observed for about 3 hours per day for 5-40 days, beginning before egg-laying. Birkhead and Nettleship (1980) described two survey methods of differing intensity; the Type I method takes 6 weeks per colony and is not described further here because it is too demanding of resources to be adopted for biodiversity monitoring. The Type II method may require as little as 6 days, and is the more widely used method (e.g. NERC 1977). The difficulty with both species is in relating the number of birds counted to the number of eggs laid; this ratio (the *'k'* value) varies from colony to colony and from year to year, so must be established each year for each colony. Observers use large-scale photographs of study plots, with the limits of the plot clearly drawn. The observation point from which counts are made is identified by a permanent marker on the ground, and photographed with an observer *in situ*. Counts of individual birds are conducted at the same time each day for 5-10 consecutive days; on at least two days, counts are made every 2 hours over the entire daylight period. A.J. Gaston (*in litt*.) advocates counting a set of study plots between 1700h and 1800h daily for 10 days early in the chick-rearing period, assuming a fixed value of 'k' for each colony.

(iii) Boulders, scree slopes and caves

Seabirds nesting in these habitats are essentially impossible to census accurately. Many Black Guillemots *Cepphus grylle*, and some Razorbills *Alca torda*, Atlantic Puffins *Fratercula arctica* and Common Murres breed in such habitats. In all except Black Guillemot, relatively small numbers are likely to breed here compared with cliff sites or burrows. The census method recommended for Black Guillemots is to count birds displaying in pairs on the sea, early on calm mornings, before egg-laying. Counts can be made from a boat or from the land, and locations of pairs observed are marked on a detailed map.

(iv) Underground burrows

Burrow-nesting species are time-consuming to count. Counts are of occupied burrows. The general method involves detailed examination of potential burrows within intensively-counted quadrats or transects set up to cover the entire range of densities exhibited within a colony and extending beyond its borders. Burrow densities tend to vary with topography, usually in relation to distance from the coast, so transects containing plots for detailed counts should be run perpendicular to the coast (Harris and Murray 1981, Savard and Smith 1985).

Once study plots have been established, each burrow within each plot is found and scored as occupied or unoccupied. Signs of occupation include presence of an egg (or eggshell or egg membrane), chick, nest material, or dropped food; signs that the burrow has been entered (e.g. soil scrapings, defecation) are not reliable because non-breeding birds may leave identical signs. Gaston *et al.* (1988) used plastic tags placed at the entrance to burrows of nocturnal Ancient Murrelets *Synthliboramphus antiquus* and recorded whether or not the tag was knocked down overnight; they suggest that using the proportions of knockdowns in the same area on comparable dates would provide an index of occupancy. The advantage of this method is that it minimises disturbance to the breeding birds. This is a potentially serious problem in monitoring burrow-nesting birds, which may desert if they are handled in the burrow, especially while incubating (Nettleship 1976).

(b) Monitoring the biodiversity of birds at sea

Current values for the diversity of seabirds in the pelagic ecoregions of Canada can be computed from existing pelagic seabird databases (Morgan *et al.* 1991 for western

Canada, Brown (1986) for arctic and eastern waters). Population estimates are much more difficult with pelagic than colony data, so a simple and consistent index such as 'birds per linear kilometre' (Brown 1986) should be adopted as the trend indicator. Attempts to convert survey data into absolute populations by counting birds seen within a fixed-width transect (e.g. Briggs *et al.* 1987, Tasker *et al.* 1984), or from transects of undefined width (Diamond *et al.* 1986) are fraught with difficulties, and are not necessary for a monitoring program, where trends (rather than absolutes) are the required outputs. Method I described by Tasker *et al*. (1984), in which all birds seen per 10 minutes within a 300m transect either side of the vessel are counted, is probably the best suited to a biodiversity monitoring program.

Pelagic seabird survey programs will be more difficult to incorporate into biodiversity monitoring, because generally (e.g. Brown 1986) such programs rely on 'ships of opportunity' rather than using dedicated ship time. As a result, an ideal procedure such as selecting and repeating a sample of transects chosen to represent marine habitats in the region (using a randomised or stratified-random design) is unlikely to be practicable.

The standard Canadian technique for pelagic seabird surveys is as follows:

P count all birds identified in a 180° field forward from the observation point of the ship, normally about 15m above the surface, on the bridge (adoption of Tasker *et al*. (1984)'s method I would limit this to birds within 300m of the ship);

P the ship's speed should be at least 5 knots (9.25 $km.h^{-1}$);

P observations are confined to daylight hours, and are suspended in heavy rain, fog, or rough seas;

P latitude and longitude are recorded at the beginning and end of each 10-minute count;

P individuals following the ship (large gulls, albatrosses) are counted only once;

P the presence of fishing boats within the survey area is recorded, as it may affect the behaviour of the birds;

P data are accumulated in blocks of 10 minute periods, and are available in that form, but can be aggregated into degree or other spatial cells as required (Brown 1986, Morgan *et al.* 1991).

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