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The "Snapshot" Count for Estimating Densities of Flying Seabirds During Boat Transects: A Cautionary Comment

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Most early surveys of seabirds from shipboard were designed to collect information on distribution and relative abundance (see Tasker et al. 1984). More recently, several investigators have attempted to translate observations at sea into absolute densities and, in some cases, estimate standing crop biomass and energy transfer (Wiens et al. 1978, Schneider and Hunt 1982, Powers 1983, Ainley et al. 1984, Blake et al. 1984). This practice is likely to grow as interest increases in the impacts of seabirds on marine ecosystems.

Most investigators have estimated densities by means of strip transects, usually 300 m wide and lasting from 10 to 30 min. The methodology and biases of strip transects have been investigated extensively for terrestrial situations (Hayne 1949; Anderson and Pospahala 1970; Emlen 1971, 1977; Eberhardt 1978; Burnham and Anderson 1984), but in all of these studies the birds censused were regarded as stationary objects. At sea a high proportion of birds counted are flying, and the majority move faster than the shipborne observer (Gaston et al. 1987). This causes a problem in deriving instantaneous densities because most of the birds seen are in flight and, hence, the chance of their entering the observer's field is a function of their speed relative to the ship.

Some investigators have ignored this potential source of bias (Powers 1983, Ainley et al. 1984), while others have discussed it without correcting for it (Wiens et al. 1978). Recently, Tasker et al. (1984) suggested a technique to eliminate the bias caused by bird movements. They suggested that birds in flight should be counted by means of a series of instantaneous "snapshots." Hence, if the ship covers 2.5 km in the course of a 10-min watch, and if flying birds are visible up to 0.5 km away, then five "snapshot" counts will be made of the area within the transect up to 0.5 km ahead to provide an estimate of the density of flying birds on the transect.

Under ideal conditions the method outlined by Tasker et al. (1984) should yield results unbiased by bird movements. Any snapshot count, however, is bound to involve a finite time period (Haney 1985). To investigate how the time taken to complete the "snapshot" might affect the bias caused by bird movements, we developed a simulation model based on a simplified transect of fixed width. The model is based on formulae 8 and A9 of Gaston and Smith (1984):

$$N = Dt(w|S - s \cos r| + as|\sin r|),$$

where N = number of birds counted within the transect, D = true density of flying birds (birds/km^2), t =

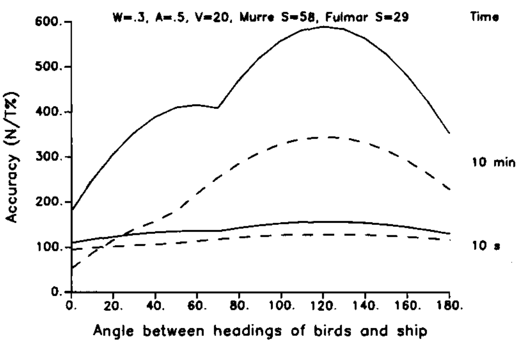

Fig. 1. Accuracy of density estimates for flying birds in relation to the angle between the headings of birds and ship. Solid lines = fulmar, broken lines = murre. Times at right are watch durations. At $r = 0$ birds and ship are moving in the same direction.

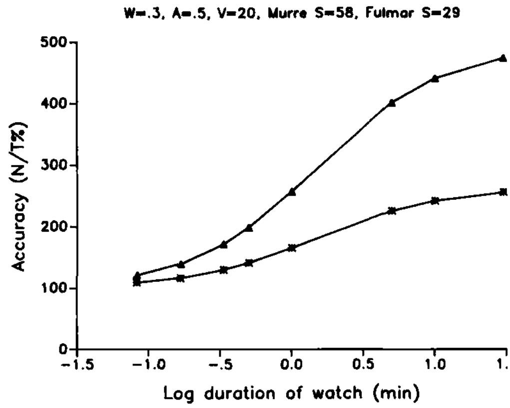

Fig. 2. Accuracy of density estimates for flying birds in relation to the length of the watch. Triangles = murre, stars = fulmar.

duration of transect (h), w = width of transect (km), S = speed of ship (km/h), s = speed of birds (km/h), r = angle between heading of bird and ship, and a = the distance at which flying birds are counted ahead of the ship (km).

For our simulations we assumed that $S = 20$, $w = 0.3$ (observer watches 300 m on one side of the ship), and $a = 0.5$. Whether the observer watches one side or both sides does not affect the results. We used two example cases: murres (*Uria* spp.), which fly at 58 km/h more or less in a straight line (Bradstreet 1982), and Northern Fulmars (*Fulmarus glacialis*), which fly at 43 km/h (Pennycuick 1960) but zigzag considerably in flight, reducing the average forward velocity by a factor of about 1.5 (Gaston et al. 1987).

We compared N computed for various values of t with the actual number of flying birds present on the transect at any instant (T), estimated by:

$$T = D(tSw + aw).$$

We found that the ratio N/T was very sensitive to the angle between the heading of the birds and the ship (Fig. 1), as pointed out by Wiens et al. (1978). The dip in the curve between $r = 40°$ and $80°$ occurs because the area being scanned is rectangular. The number of birds entering the area is proportional to its maximum chord at right angles to their path (Gaston and Smith 1984). Hence, as r changes from 0° to arctan a/w, the length of this chord increases from w to $\sqrt{w^2 + a^2}$ (the diagonal of the rectangle under observation) and then diminishes again to a at $r = 90°$.

To estimate the ratio N/T for a situation where the birds are heading in all directions relative to the ship, we calculated N/T for each degree and took the mean value over 180°. This mean was then plotted as a function of the duration of the watch period (Fig. 2).

Our estimates of accuracy (N/T) suggest that, for a fast-flying species such as a murre, a snapshot count must be very brief to avoid any bias due to the movement of the birds. Even a 5-s watch results in an average bias of +25% in the number of flying birds counted. For the slower-flying fulmar, however, this level of bias is reached only by watching for 20 s. A more satisfactory prediction of the model is the demonstration that for watches of 10 min and above the bias is very similar, making density indices derived from watches in this range reasonably comparable.

Tasker has pointed out (in litt.) that by counting flying birds continuously as well as in snapshots, the observer can keep track of them so that the snapshot is genuinely instantaneous. This was the method used by Tasker et al. (1984). The need to monitor flying birds continuously, however, reduces the amount of attention that can be devoted to birds on the water, which are normally harder to detect. Compromise is inevitable if only a single observer is present.

Snapshot counts usually are performed by panning around the arc of observation. Hence, even when the total scan takes 10 s, the time taken to scan each field of vision is probably much less (P. J. Gould pers. comm.). If there is a preferred direction of movement among seabirds in the area, then possible bias can be reduced further by panning in the same direction the birds are flying (i.e. if most birds are flying from left to right across the ship's bow, then begin on the left-hand side of the field and scan across to the right). Clearly, experienced observers are likely to be much better at coping with these details than inexperienced observers.

Our results should not be construed as a criticism of the method proposed by Tasker et al. (1984), which remains an imaginative response to a problem that has confronted everyone who has tried to census birds at sea. Rather, we present our results to caution those wishing to adopt this technique. The "snapshot" has to be precisely that—as instantaneous a count as possible. Otherwise, there is a risk of producing results not directly comparable either to true density estimates or to the density indices derived from counting all birds during a 10-min watch.

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Avian Play: Comparative Evolutionary and Developmental Trends

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Play is an important behavior in higher vertebrates (Byers 1981, Fagen 1981, Bekoff 1984, Bekoff and Byers 1985, Martin and Caro 1985). Most quantitative studies of animal play are limited to mammals (for reviews see Bekoff and Byers 1981, 1985; Fagen 1981; Martin and Caro 1985), whereas descriptions of play in birds are mainly anecdotal (Ficken 1977, Fagen 1981). Recent reviews of avian play (see especially Ficken 1977, Fagen 1981: 244–246) have allowed us to determine whether individuals of a particular species played and the type of play exhibited. Play was defined broadly as "all motor activity performed postnatally that appears to be purposeless, in which motor patterns from other contexts may often be used in modified forms and temporal sequencing" (Bekoff and Byers 1981: 300; other definitions in Fagen 1981 and Martin and Caro 1985). Typically, play is most common in the young of a species. Types of play (Bekoff and Byers 1981: 300–301) also were classified as locomotor play, "frantic flight about (the) environment"; object play, "activity directed toward an inanimate object"; and social play, "activity directed toward another living object."

We classified extant avian orders as having species with either primarily altricial or precocial young (Van Tyne and Berger 1971, Reid and Williams 1975, Welty 1982). Thirteen (48.1%) of the 27 orders we consid-

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