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A COMPARISON OF TWO METHODS OF COUNTING BIRDS AT SEA

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Investigators have used several methods for counting birds at sea. Early attempts to describe pelagic distributions of marine birds involved annotated lists of species with approximate daily totals (e.g., Murphy 1914, Jespersen 1924, Grayce 1950). Considerable progress has been made in the past decade toward developing techniques useful in measuring abundance and density. However, data collected by different methods have not been shown to be comparable.

In an effort to quantify observations, several authors have developed techniques that provide an index of relative abundance (numbers of birds seen per unit of time or distance traveled). Wynne-Edwards (1935), King and Pyle (1957), and Sage (1968) recorded the number of birds seen in 1-hour observation periods; Brown (1968) used 30-min periods; Brown et al. (1975), Brown (1977), and Powers and Rumage (1978) used 10-min periods. Data collected during the Pacific Ocean Biological Survey Program (POBSP) were reported as birds per nautical mile (nm) (Gould 1974), birds per sighting (Sanger 1974), and birds per square kilometer (Crossin 1974). The latter measurement assumed a reliable range of detectability for the species involved.

Estimates of density (number of birds per unit area) by strip or line transect procedures have been used by Cline et al. (1969), Wiens and Scott (1975), Gould et al. (1978), and Hunt et al. (in press). These estimates of density were more accurate than indices of abundance because (1) a distance was established to which detection was considered reliable for selected species or groups of species, and (2) ship-followers were excluded. Bailey and Bourne (1972) discussed some of the difficulties of counting birds at sea and recommended a uniform counting period (10 min) to ensure that observations are comparable by different observers and in different seas.

However, in spite of the above it is still not clear if estimates of density and abundance are comparable. Can either estimate be converted into the other by a conversion factor to allow comparisons of data from different oceans or investigators? How can one compare data gathered by different observers? Are these estimates biased when collected from fishing vessels? This paper suggests improvements in techniques for surveying marine birds by comparing methods to estimate relative abundance and density.

METHODS

I examined observation data from 15 research and 4 U.S. Coast Guard (USCG) cruises conducted in 1978–1979 to outer continental shelf waters from Cape Hatteras to Nova Scotia (Table 1). One cruise was made on a geodetic survey vessel in transit from Halifax, Nova Scotia to Hudson Bay in July 1978. The cruise objectives of the research vessels were hydrographic, zooplankton, or groundfish trawl surveys. The USCG cruises were law enforcement patrols. Observers were not able to determine or influence tracks followed during the cruise.

Observations were recorded in 10-min periods when the vessel proceeded on a constant course at a constant speed. Ship speeds among counting periods ranged from 4 to 12 knots. Therefore, duration was constant among counts, but area sampled varied and depended upon ship speed. Birds were recorded in 3 categories (Fig. 1): inside zone, outside zone, and recount, a subjective category based on ship-following behavior.

The observer counted all birds out to 300 m, on the side of the ship with best viewing conditions and forward of mid-ship to the projected end of the transect (Gould et al. 1978). The area censused was termed the "inside zone." The length of the inside zone decreased with time into the counting period (Fig. 1). The width of the strip was determined with a hand-held fixed-interval rangefinder described by Heinemann (1981). A ship-following bird that passed through the inside zone for the first time was counted; but in all transects thereafter, that bird was considered a "recount" and tallied separately. Birds only observed outside the boundary of the inside zone, but not ship-following, were counted in the "outside zone." Although no maximum visibility limits were established for this zone, a minimum visibility standard of 1 km was required for all transects.

In essence, 2 counting methods were employed simultaneously. One measured density from a fixed-area, the other measured abundance from a 360° scan to the horizon. Estimates of density (birds per km^2) were calculated by dividing bird counts in the inside zone by the area sampled for each transect. Area sampled (A) per transect was calculated as:

$$A = \frac{\text{speed (knots)}}{60\ \text{min/h}} \times 10\ \text{min} \times \frac{1852\ \text{m}}{1\ \text{nm}} \times 300\ \text{m} \times \frac{1\ \text{km}^2}{1 \times 10^6\ \text{m}^2}$$

Estimates of abundance (birds per 10 min) were calculated by summing all birds recorded in the "inside" and "outside" zones and "recounts." This method of estimating abundance is equivalent to that described by Brown et al. (1975).

In the analyses I considered 10 bird species and one species group which were seasonally common to abundant in the western North At-

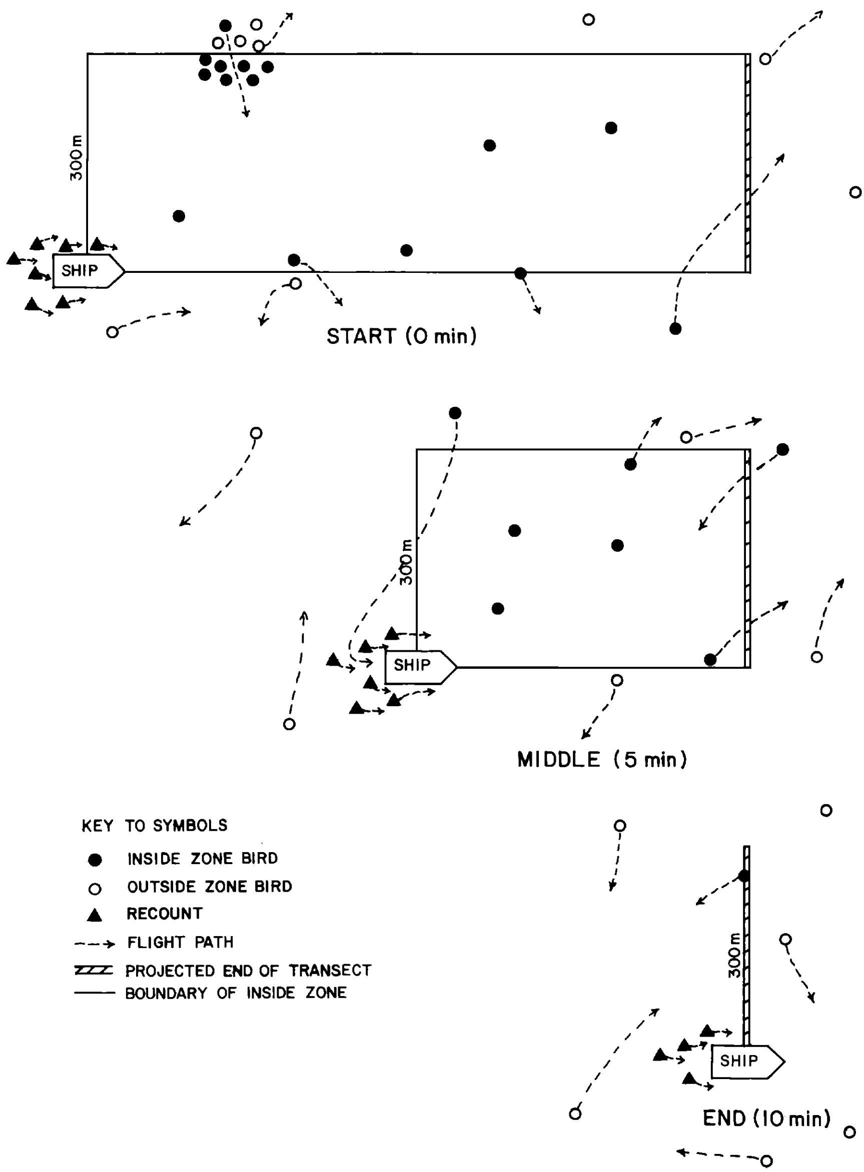

FIGURE 1. Illustration of bird counting categories used to obtain estimates of relative abundance and density from shipboard observations.

lantic: Northern Fulmar (*Fulmarus glacialis*), Cory's Shearwater (*Calonectris diomedea*), Greater Shearwater (*Puffinus gravis*), Wilson's Storm-Petrel (*Oceanites oceanicus*), Gannet (*Morus bassanus*), Red Phalarope (*Phalaropus fulicarius*), Great Black-backed Gull (*Larus marinus*), Herring

Gull (*L. argentatus*), Black-legged Kittiwake (*Rissa tridactyla*), Razorbill (*Alca torda*), and murres (*Uria* spp.).

In an examination of the qualitative and quantitative relationships between estimates of density and abundance, I used Spearman's coefficient of correlation test (Sokal and Rohlf 1969) first to determine if there was a significant association between the estimates, and if so for which species. If a significant correlation was found for a given species or species group, a linear regression analysis was performed to examine the quantitative relationship of the 2 estimates.

Bias in estimates of density and abundance from fishing activity on the observer's ship was examined with Fisher's exact test (Siegel 1956). The percent of the abundance estimate comprised by recounts for each cruise and the mean recount percentage for all cruises were calculated for each bird species. Cruises were then separated by objective: fishing or nonfishing (Table 1). Recount percentages were further separated as occurring above or below the overall mean recount percentage for that species. Frequencies of each group were compiled in a 2 × 2 contingency table and tested for significant differences between fishing and nonfishing cruises. Density estimates were examined for significant differences between fishing and nonfishing cruises in the same fashion as previously described for abundance estimates.

A paired t-test was used to determine differences and variability in estimates of density and abundance between observers for each species and species group. Paired density estimates were examined from 2 cruises and abundance estimates from one cruise. Only observers with at least one yr of field experience were used in this analysis and one observer (Powers) was the same for all paired tests. Observers recorded birds on the same side of the ship and did not compare or discuss notes until after the cruise.

RESULTS AND DISCUSSION

Density and abundance relationships.—Highly significant associations (relative ranking) between density and abundance estimates of fulmars, Cory's and Greater shearwaters, Wilson's Storm-Petrels, Gannets, Red Phalaropes, kittiwakes, and large auks indicated that the 2 methods correlated at both high and low density levels. The correlation coefficient for estimates of density and abundance of large gulls was not significant ($r = .26$, df $= 86$) in one oceanographic survey. Chronic ship-following by Great Black-backed and Herring gulls caused substantial differences in the ranking of density and abundance estimates. Zero density values were recorded in 25 transects, whereas abundance estimates inflated by recounts ranged from 1 to 165 large gulls per 10 min for the same transects.

The density estimate is derived from a strip census on one side of the ship using line transect methodology (Burnham et al. 1980). The abundance estimate is derived from a 360° peripheral scan, which includes both sides of the ship. Thus, one might expect a minimum 2:1 relation-

TABLE 1. List of cruise numbers, dates, objectives, and data analyses used for this study. Data from all cruises were used in fishing bias analysis.

Cruise number	Cruise dates	Vessel	Cruise objective	Linear regression	Observer differences
7809	17 Apr–03 May 1978	RV ALBATROSS IV	Groundfish		
7818	16–25 Jul 1978	CGC NARWHAL	Geodetic	X	
7819	14–28 Aug 1978	RV ALIOT	Zooplankton	X	
7822	01–19 Oct 1978	RV ANTON DOHRN	Groundfish	X	
7901	02–12 Jan 1979	CGC DECISIVE	Law enforcement		
7904	01–09 Feb 1979	CGC VIGILANT	Law enforcement		
7905	10–23 Feb 1979	RV ANTON DOHRN	Groundfish		
7906	15–24 Feb 1979	RV MT. MITCHELL	Zooplankton	X	
7907	24 Feb–12 Mar 1979	RV ANTON DOHRN	Groundfish		
7908	27 Feb–20 Mar 1979	CGC VIGOROUS	Law enforcement		
7909	16–28 Mar 1979	RV SUBSIG II	Hydrography		
7910	27 Mar–17 Apr 1979	CGC TANEY	Law enforcement		
7911	12–17 Apr 1979	RV ALBATROSS IV	Groundfish		
7914	02–12 May 1979	RV ALBATROSS IV	Groundfish		
7918	29 May–07 Jun 1979	RV SUBSIG II	Hydrography		
7922	30 Jun–14 Jul 1979	RV ALBATROSS IV	Zooplankton		
7927	15–30 Aug 1979	RV ALIOT	Zooplankton		X
7932	27 Sep–19 Oct 1979	RV ANTON DOHRN	Groundfish		
7936	13–21 Nov 1979	RV WIECZNO	Zooplankton	X	X

ship between estimates of abundance and density from these data given the following assumptions. (1) Individual birds and flocks are not influenced by the observer or the observer's vessel. (2) The probability of detection of a species is uniform to either side of the ship. And (3) birds do not move. That is, the frequency of any species observed within the inside zone on one side of a ship should be equivalent to that observed on the other side; hence, a minimum 2:1 relationship between estimates of abundance to density.

Slope (*m*) values from the linear regression analysis indicated little support for the expected 2:1 relationship between estimates of abundance and density (Table 2). Estimates of abundance were more than twice those of density in only one model (murres) (Table 2). Slope values in the other models were 0.5 to 1.7 with a considerable range in the coefficients of determination, 0.2 to 0.9.

The assumptions, from which the 2:1 relationship was based, were not valid. Some seabirds were influenced by the observer's vessel, e.g., ship-following recounts. Flocks had a higher probability of detection than single birds, especially as sighting distance increased. Most birds were usually observed flying.

Furthermore, differences in ship speeds among transects affected the relationship between the estimates. Ship speed was included in the calculation of density, but not in the estimate of abundance. This problem was critical at slower ship speeds (4–7 kn) where area sampled ranged from 0.37 to 0.65 km^2, as opposed to speeds of 9–11 kn where 0.93 to 1.11 km^2 was sampled. Therefore, density estimates from transects made at 4 and 9 kn for the same number of birds would be considerably different, since the number of birds is divided by the area sampled. There would be no difference in estimates of abundance regardless of ship speed, as both counts were of 10-min duration. Mean densities of fulmars, Greater Shearwaters and Gannets in cruise no. 7936 were greater than average estimates of abundance (Table 2), because bad weather during part of that cruise caused 20% of the transects to be conducted at 4–6 kn, instead of the typical cruising speed, 9–11 kn.

Two adjustments were made in the regression analyses to minimize problems with the assumptions. First, the number of birds counted in the inside zone, not the density calculation, was compared with the sum of counts from the inside and outside zones. This reduced problems from ship-following recounts. Also a count of birds from the inside zone, instead of the density calculation, prevented discrepencies in area sampled from various ship speeds. Second, separate regression models were derived for sitting and flying birds of each species and cruise (Table 3), to correct for behavioral differences.

The modified regression model for sitting birds supported the expected 2:1 relationship between estimates of abundance and density, slope (*m*) values were 2.0 and 4.3 (Table 3). The degree of the relationship is dependent upon the sighting distance of a given species. Sighting distances are affected by a number of factors and conditions: species

TABLE 2. Results from preliminary linear regression analyses used to predict abundance estimates (birds/10 min) from density (birds/km^2) values for bird species by cruise.

Species	Number of transects (n)	Mean density count (±SD)	Mean abundance count (±SD)	Slope (m)	Coefficient of determination (r^2)	y-intercept (b)	Cruise number
Fulmar	127	12.2 (±17.9)	18.4 (±34.8)	1.7	0.8	−2.2	7818
Fulmar	64	20.9 (±29.6)	33.1 (±46.7)	1.5	0.9	1.9	7906
Fulmar	45	9.2 (±13.9)	8.2 (±15.4)	1.0	0.9	−1.3	7936
Greater Shearwater	125	10.8 (±25.8)	10.9 (±21.5)	0.8	0.9	2.3	7819
Greater Shearwater	156	29.1 (±49.0)	63.5 (±108.8)	1.2	0.3	27.8	7822
Greater Shearwater	62	8.1 (±11.9)	7.6 (±10.0)	0.7	0.7	1.8	7936
Wilson's Storm-Petrel	204	10.9 (±19.0)	13.3 (±25.5)	1.2	0.9	−0.3	7819
Gannet	67	5.3 (±6.2)	4.7 (±4.3)	0.5	0.4	2.3	7936
Kittiwake	41	7.5 (±9.1)	13.6 (±31.6)	1.6	0.2	1.9	7818
Kittiwake	71	27.4 (±98.2)	42.4 (±175.7)	1.7	0.9	−4.8	7906
Murres	150	8.3 (±11.4)	15.4 (±36.4)	2.5	0.6	−5.7	7818
Large auks[a]	27	4.1 (±6.4)	6.7 (±10.3)	1.4	0.7	0.9	7906

[a] Large auks = Razorbill and murres.

TABLE 3. Results from modified linear regression analyses based on behavior used to predict abundance estimates (birds/10 min) without ship-followers from density counts (birds/inside zone) for bird species and cruise.

Species	Number of transects (n)	Mean density count (±SD)	Mean abundance count (±SD)	Slope (m)	Coefficient of determination (r^2)	y-intercept (b)	Cruise number
FLYING MODEL							
Fulmar	114	10.0 (±9.5)	14.0 (±15.5)	1.5	0.9	−1.5	7818
Fulmar	63	20.5 (±27.1)	28.0 (±38.6)	1.4	0.9	0.9	7906
Fulmar	40	4.1 (±3.2)	5.0 (±3.8)	1.1	0.8	0.5	7936
Greater Shearwater	114	7.2 (±10.6)	8.5 (±12.1)	1.2	1.0	0.3	7819
Greater Shearwater	100	13.7 (±39.3)	16.4 (±46.9)	1.2	1.0	0.1	7822
Greater Shearwater	59	5.3 (±8.0)	6.9 (±9.7)	1.2	0.9	0.7	7936
Wilson's Storm-Petrel	192	9.2 (±15.2)	11.9 (±22.8)	1.4	0.9	−1.1	7819
Gannet	57	3.0 (±3.1)	4.2 (±4.1)	1.1	0.7	0.9	7936
Kittiwake	37	6.5 (±8.2)	10.4 (±15.1)	1.2	0.5	2.4	7818
Kittiwake	67	31.2 (±113.1)	43.6 (±180.7)	1.5	0.9	−4.4	7906
Large auks[a]	26	3.2 (±3.9)	5.5 (±7.5)	1.3	0.5	1.2	7906
SITTING MODEL							
Fulmar	38	5.1 (±17.5)	15.9 (±44.3)	2.0	0.6	5.6	7818
Murres	74	5.4 (±9.9)	17.9 (±48.1)	4.3	0.8	−5.2	7818

[a] Large auks = Razorbill and murres.

TABLE 4. Contingency table by species indicating frequencies of fishing and nonfishing cruises in relation to mean percent of recounted or ship-following birds ($\bar{x}$) in estimates of abundances. Probability of significant differences between recounts from fishing and nonfishing cruises is indicated.

Species	Overall mean % recounts ($\bar{x}$)	Number of fishing cruises		Number of nonfishing cruises		Probability of significance (P)
		$>\bar{x}$	$\leq\bar{x}$	$<\bar{x}$	$\leq\bar{x}$	
Large gulls[a]	29.2	4	3	3	9	0.15
Fulmar	15.6	5	1	0	9	0.01**
Kittiwake	13.0	2	0	0	6	0.04*
Gannet	8.0	3	3	0	3	0.24
Greater Shearwater	7.5	2	0	0	6	0.04*
Wilson's Storm-Petrel	1.8	0	2	4	0	0.07
Cory's Shearwater	1.5	1	1	0	3	0.40
Red Phalarope	0	(n = 5)				
Large auks[b]	0	(n = 7)				

[a] Large gulls = Great Black-backed and Herring gulls.
[b] Large auks = Razorbill and murres.
* Significant difference ($P < 0.05$).
** Highly significant difference ($P < 0.01$).

size and color, angle of wave front, cloud cover, and height of observer above water (Briggs et al. 1981, Dixon 1977, Wiens et al. 1978).

The modified regression models for flying birds approximated a 1:1 relationship between estimates of abundance and density, slope (m) values ranged from 1.1 to 1.5 with less variability in the coefficients of determination, 0.5 to 1.0 (Table 3). One explanation is apparent. These birds were moving and they may have been detectable in both the inside and outside zones; however, they would have been recorded only in the inside zone. My experience in the field indicates that this possibility is most likely, and that flying birds usually cross at least one boundary of the inside zone during a transect.

Bias from fishing activity.—Estimates of abundance of several species were significantly inflated when the observer's vessel was fishing. Larger portions of abundance estimates consisted of recounts for fulmars ($P <$ .01), Greater Shearwaters ($P < 0.05$), and Black-legged Kittiwakes ($P <$ .05), when observed from fishing vessels than from vessels not fishing (Table 4). Such species are often found in greatest abundance in fishing areas because of their attraction to offal (Wahl and Heinemann 1979). However, I also recorded high counts of these species in feeding assemblages devoid of fishing activity.

In the estimate of abundance, twice the mean percentage of recounts was found for large gulls as compared to any other species considered (Table 4), but there was no significant difference between estimates of abundance derived from fishing or nonfishing vessels. Yet, I observed

TABLE 5. Contingency table by species for frequencies of fishing and nonfishing cruises in relation to mean density (birds/km²). Probability of significant differences between estimates from fishing and nonfishing cruises is indicated.

Species	Overall mean % density ($\bar{x}$)	Number of fishing cruises $>\bar{x}$	Number of fishing cruises $\leq\bar{x}$	Number of nonfishing cruises $>\bar{x}$	Number of nonfishing cruises $\leq\bar{x}$	Probability of significance (*P*)
Red Phalarope	46.4	1	1	1	2	0.60
Fulmar	17.3	3	3	1	7	0.16
Kittiwake	11.3	1	1	2	4	0.54
Large gulls[a]	9.9	5	2	3	9	0.06
Greater Shearwater	9.7	1	1	2	4	0.54
Wilson's Storm-Petrel	8.2	0	2	3	1	0.20
Cory's Shearwater	5.5	1	1	2	1	0.60
Large auks[b]	4.0	0	2	4	1	0.14
Gannet	2.4	1	5	2	1	0.21

[a] Large gulls = Great Black-backed and Herring gulls.
[b] Large auks = Razorbill and murres.

a predominant influence by fishing activities on the pelagic distribution of large gulls. The counts of large gulls in the outside zone made up an average 70% of the abundance estimate in 4 nonfishing cruises. These cruises were USCG patrols with objectives to seek and identify fishing vessels. On the USCG patrols highest counts of large gulls were recorded around fishing vessels in the outside zone. Since this outside zone count greatly reduced the percentage that recounts would have contributed to the overall estimates of abundance, the statistical test failed.

Gannets were often noted in association with fishing vessels. The percentage of the abundance estimate of gannets contributed by recounts, for all but one cruise, was greater in the presence of fishing activity than in its absence; but the difference in recounts between fishing and nonfishing cruises was not significant (Table 4).

No significant difference was found in estimates of abundance for Cory's Shearwaters, Wilson's Storm-Petrels, Red Phalaropes, and large auks in the presence or absence of fishing activity on the observer's ship. Although Cory's Shearwaters and Wilson's Storm-Petrels were sometimes recorded as ship-followers, the average contribution of recounts to the estimate of abundance never exceeded 2% of the total estimate (Table 4). In addition, no large flocks of Cory's Shearwaters or Wilson's Storm-Petrels were noted in association with fishing vessels on any cruise. Red Phalaropes and large auks were never recorded as ship-followers nor found in association with fishing activity.

No significant differences were found between density estimates derived from vessels fishing and those from vessels not fishing (Table 5). Although a fishing vessel may attract various bird species, density estimates were not increased because the method excluded recurring ship-

TABLE 6. Means and differences between observer estimates of density (birds/km²) by bird species from paired observations of observer X and Y. No differences were significant.

Species	Number of transects (n)	Observer means (±SD) X	Observer means (±SD) Y	Mean difference (±SD)	Maximum single estimate X	Maximum single estimate Y
Wilson's Storm-Petrel	91	27.1 (±168.4)	17.2 (±94.9)	11.1 (±74.2)	1600	901
Large gulls[a]	44	24.0 (±90.2)	26.9 (±134.4)	2.9 (±51.8)	588	893
Fulmar	28	8.3 (±16.7)	11.1 (±25.8)	2.7 (±17.2)	88	102
Greater Shearwater	35	8.5 (±11.9)	7.4 (±9.9)	1.2 (±11.5)	69	53
Kittiwake	28	4.8 (±9.9)	3.8 (±9.2)	0.9 (±12.8)	52	49
Greater Shearwater	59	3.8 (±12.7)	2.8 (±5.1)	1.0 (±10.6)	13	36
Gannet	36	7.0 (±16.3)	7.5 (±17.9)	0.2 (±5.6)	18	49
Large gulls[a]	48	3.5 (±9.2)	3.4 (±6.3)	0.1 (±4.8)	57	38
Cory's Shearwater	65	2.7 (±3.7)	2.6 (±4.5)	0.3 (±3.1)	21	33

[a] Large gulls = Great Black-backed and Herring gulls.

followers. However, as a caution two points must be made. (1) The influence of fishing activity in attracting birds was not measured, and (2) neither census method could adequately sample large gulls. The propensity of large gulls to follow ships demonstrated an inflationary bias of recurrence in estimates of abundance and a violation of the assumption of nonattraction needed for estimates of density.

Observer differences.—No significant difference in estimates of density between observers was found for 6 bird species and one species group (Table 6) or in abundance estimates of 4 bird species and one species group (Table 7). Although no significant difference was found, considerable variability was noted between observers with both counting meth-

TABLE 7. Means and differences between observer estimates of abundance (birds/10 min) by bird species from paired observations of observer X and Y. No differences were significant.

Species	Number of transects (n)	Observer means (±SD) X	Observer means (±SD) Y	Mean difference (±SD)	Maximum single estimate X	Maximum single estimate Y
Large gulls[a]	51	42.8 (±119.3)	32.9 (±127.2)	10.0 (±41.7)	800	911
Fulmar	29	8.9 (±19.1)	14.1 (±36.6)	5.2 (±21.3)	104	177
Kittiwake	31	6.7 (±17.2)	8.3 (±22.4)	1.7 (±9.3)	95	118
Greater Shearwater	42	8.6 (±11.5)	7.7 (±10.3)	0.9 (±9.8)	68	54
Gannet	39	4.4 (±4.7)	5.0 (±8.5)	0.6 (±6.7)	20	50

[a] Large gulls = Great Black-backed and Herring gulls.

ods. This variability was attributed to several factors: (1) differences in ability to estimate large numbers of birds, (2) differences in the conspicuousness of birds, (3) differences in separating recounts from initial ship-followers, and (4) differences in determining the boundaries of the inside zone.

Differences and variances were greatest when the estimate of density or abundance was largest (Tables 6 and 7). When one observer estimated the density above 100 birds/km^2 for any species, differences between observers ranged from 13 (88–101) to 699 (901–1600). Similarly, when one observer estimated abundance above 100 birds/10 min, differences in counts between observers ranged from 22 (78–100) to 111 (800–911). Problems in counting birds were evident in dense concentrations of mixed species, e.g., birds associated with fishing vessels. In these instances little time was available to carefully examine species composition and abundance of each flock; hence, some species were underestimated while others were overestimated.

Differences in the detectability and conspicuousness affected estimates of abundance. Generally small dark species were less detectable than large light species; sitting birds were less conspicuous than flying; single individuals were not as obvious as flocks (Briggs et al. 1981). The method of estimating density has an advantage in this regard because the observer's field-of-view is focused to a quadrant, as opposed to the method of estimating abundance that requires a constant peripheral 360° scan of the horizon.

Differences occurred in observer judgments as to include or exclude ship-followers from the inside zone. During one cruise, such discrepancies were noted with large gulls and fulmars in 36 and 3% of the transects, respectively. Although ship-followers were not always in sight of the observer's vessel, confusion arose because they were suspected of being in the vicinity of or circling back to the ship.

Differences between observers in judgment of the boundary limits of the inside zone were found, but they were not a major source of variation in density estimates between observers. Differences between observers occurred in 4 and 13% of the transects for sitting and flying birds, respectively. The use of a standardized rangefinder minimized variability in judgment of the inside zone boundaries.

CONCLUSION

Quantitative relationships exist between estimates of relative abundance and density for most marine bird species. Estimates of abundance can be derived from values of density by regression models when the following factors are considered: bird behavior (flying, sitting, and ship-following), duration of the count, and ship speed. My data suggest a minimum numerical relationship of 2:1 between estimates of abundance and density for sitting birds and 1:1 for flying birds.

Neither method of counting birds at sea eliminates the problem of ship-followers. However, the density method minimizes an inflationary effect caused by ship-followers that is apparent with the abundance estimate, especially when the observer's vessel is associated with fishing activities.

Differences in abilities of observers to count birds is a principal, but unavoidable, source of variability with both counting methods. The density method also minimizes this problem by focusing the observer's view in an area with known boundaries. This standardization decreases variability in bird detection due to weather, size and color differences between species, flock sizes, and bird behavior. These factors are not controlled in estimates of abundance.

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