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Aerial Surveys for Cetaceans in the Former Akutan, Alaska, Whaling Grounds

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ABSTRACT. Randomized aerial surveys were flown between 26 July and 26 August 1984 to search for cetaceans in two areas of southwestern Alaska: one on both Bering Sea and Pacific Ocean sides of the Aleutian Islands near the defunct Akutan shore-whaling station, which operated from 1912 through 1939, the other overlapping continental slope and shallow continental shelf waters between the Aleutians and the Pribilof Islands. Surveys were made at altitudes between about 150 m and 245 m from a Partenavia P68 Observer with a plexiglass nose bubble, which permitted center-line viewing. Searches covered about 3940 nautical miles (nm), including some 2403 nm of random transects. Sightings were made of gray whales (10 sightings, 14 individuals), fin whales (3, 11), minke whales (1, 1), unidentified beaked whales (1, 6), Dall's porpoises (47, 131), killer whales (8, 26), and harbor porpoises (4, 7). A Fourier series model was used to estimate density of Dall's porpoises as 115 individuals (CV = 0.263) per 1000 nm^2 on the whaling grounds and 16.6 individuals (CV = 0.0) per 1000 nm^2 in the Bering Sea north of the whaling grounds. These estimates are comparable to those previously reported for the same general areas (97.2 animals per 1000 nm^2, SD = 49.5). There were too few sightings of other cetaceans to permit calculation of meaningful density estimates. At least four species of great whales (blue, fin, humpback and sperm) were sufficiently abundant during the first four decades of this century to support significant whaling activities within about 100 nm of Akutan (more than 5300 whales were caught during 23 years of whaling, 1912-39). Although previous studies of the fisheries showed a downward trend in catch per unit of effort and an increase in distance traveled to take whales, whales were still being taken at relatively high rates (0.28-0.51 whales per gross catcher day) at the end of the fishery in 1939. Populations of fin, humpback, blue and sperm whales were probably significantly reduced by shore and pelagic whaling conducted widely in the North Pacific since 1939. The low number of sightings on the present surveys probably means that populations on and near the whaling grounds remain depressed from such activities.

Key words: aerial surveys, cetaceans, Bering Sea, North Pacific Ocean, historical whaling

RÉSUMÉ. Des relevés aériens ont été effectués au hasard entre le 26 juillet et le 26 août 1984, afin de déterminer la présence de cétacés dans deux régions du Sud-Ouest de l'Alaska: l'une située des deux côtés des îles Aléoutiennes (du côté de la mer de Béring et du côté de l'océan Pacifique), près de ce qui fut jadis le port baleinier d'Akukan qui resta en opération de 1912 à 1939; l'autre couvrant à la fois les eaux du talus continental et celles, peu profondes, de la plate-forme continentale, entre les îles Aléoutiennes et les îles Pribilof. Les relevés furent effectués à des altitudes comprises entre 150 et 245 m, d'un appareil d'observation Partenavia P68, muni d'un nez de plexiglas, permettant de voir dans l'axe de déplacement. Les recherches ont été effectuées sur environ 3940 milles nautiques (mn), y compris 2403 mn de recoupements au hasard. On a relevé la présence de baleines grises (10 relevés, 14 individus), de rorquals communs (3, 11), de petits rorquals (1, 1), de baleines à bec non identifiées (1, 6), de marsouins de Dall (47, 131), d'épaulards (8, 26) et de marsouins communs. On a utilisé un modèle en séries de Fourier pour déterminer approximativement la densité de marsouins de Dall à 115 individus (CV = 0.263) aux 1000 mn^2 dans les zones de pêche à la baleine, et à 16.6 individus (CV = 0.0) aux 1000 mn^2 dans la mer de Béring au nord des zones de pêche. Ces évaluations sont comparables à celles rapportées précédemment pour ces mêmes zones en général (97.2 animaux aux 1000 mn^2, DS = 49.5). Trop peu d'autres cétacés ont été aperçus pour justifier le calcul des densités approximatives. Durant les quarante premières années de ce siècle, il y avait au moins quatre espèces de grandes baleines (rorquals bleus, rorquals communs, rorquals à bosse et cachalots) en quantité suffisante pour alimenter une industrie baleinière dans un rayon d'environ 100 mn d'Akutan. (Plus de 5300 baleines furent pêchées durant les 23 années que dura la pêche à la baleine, de 1912 à 1939). Bien que des études précédentes sur la pêche aient montré une tendance à la baisse du nombre de prises par rapport au nombre d'unités d'effort et une augmentation de la distance à parcourir pour capturer les baleines, celles-ci étaient capturées à un taux relativement élevé (de 0.28 à 0.51 baleine par unité d'effort brute par jour) à la fin de la pêche en 1939. Les populations de rorquals communs, de rorquals à bosse, de rorquals bleus et de cachalots ont probablement été réduites de façon significative par le pêche côtière et la pêche pélagique, qui ont été pratiquées à grande échelle dans le Pacifique Nord depuis 1939. Le petit nombre de cétacés aperçus durant les présents relevés porte à croire que les populations dans les zones de pêche et dans leur vicinité, restent peu élevées en raison de ces activités.

Mots clés: relevé aérien, cétacés, mer de Béring, Pacifique Nord, ancienne pêche à la baleine

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INTRODUCTION

Between 1912 and 1939 whaling operations were conducted from a shore station on Akutan Island, in the eastern Aleutian Islands, Alaska (Fig. 1). Between May and October in the years 1912, 1914-20, 1922-30 and 1934-39 two to seven vessels hunted whales within an approximately 100 nautical mile (nm) radius of the station on both Bering Sea and Pacific Ocean sides of the Aleutian Islands and in Unimak Pass. Catches consisted mainly of fin (*Balaenoptera physalus*) (at least 2498), humpback (*Megaptera novaeangliae*) (1510), blue (*B. musculus*) (835) and sperm (*Physeter catodon*) (482) whales, with occasional takes of right whales (*Eubalaena glacialis*) (9) and other species (Reeves *et al.*, 1985). Trends in availability to the whalers of the four key species within and among years (Leatherwood *et al.*, 1985), interpreted in the context of other data available for the area (Leatherwood *et al.*, 1983), suggest that: 1) Fin whales formerly were present on both sides of the Aleutian Islands chain from April through early September. In July and August they were found primarily in the Bering Sea, where they were relatively abundant near Unalaska and Akutan islands. The southeast Bering Sea apparently was an important spring-summer feeding ground. By August or early September, the population center had shifted to the North Pacific. Migration between the two areas apparently concentrated in Unimak and Akutan passes. 2) Humpback whales were present in greatest numbers from June through August, in the Pacific, in Unimak Pass and in the Bering Sea just north of the pass. 3) Blue whales were most abundant from June through August, almost exclusively on the Pacific side of the islands. 4) Sperm whales, all adult males, were found in the Pacific near Akutan Island and rarely in the Bering Sea, largely in July.

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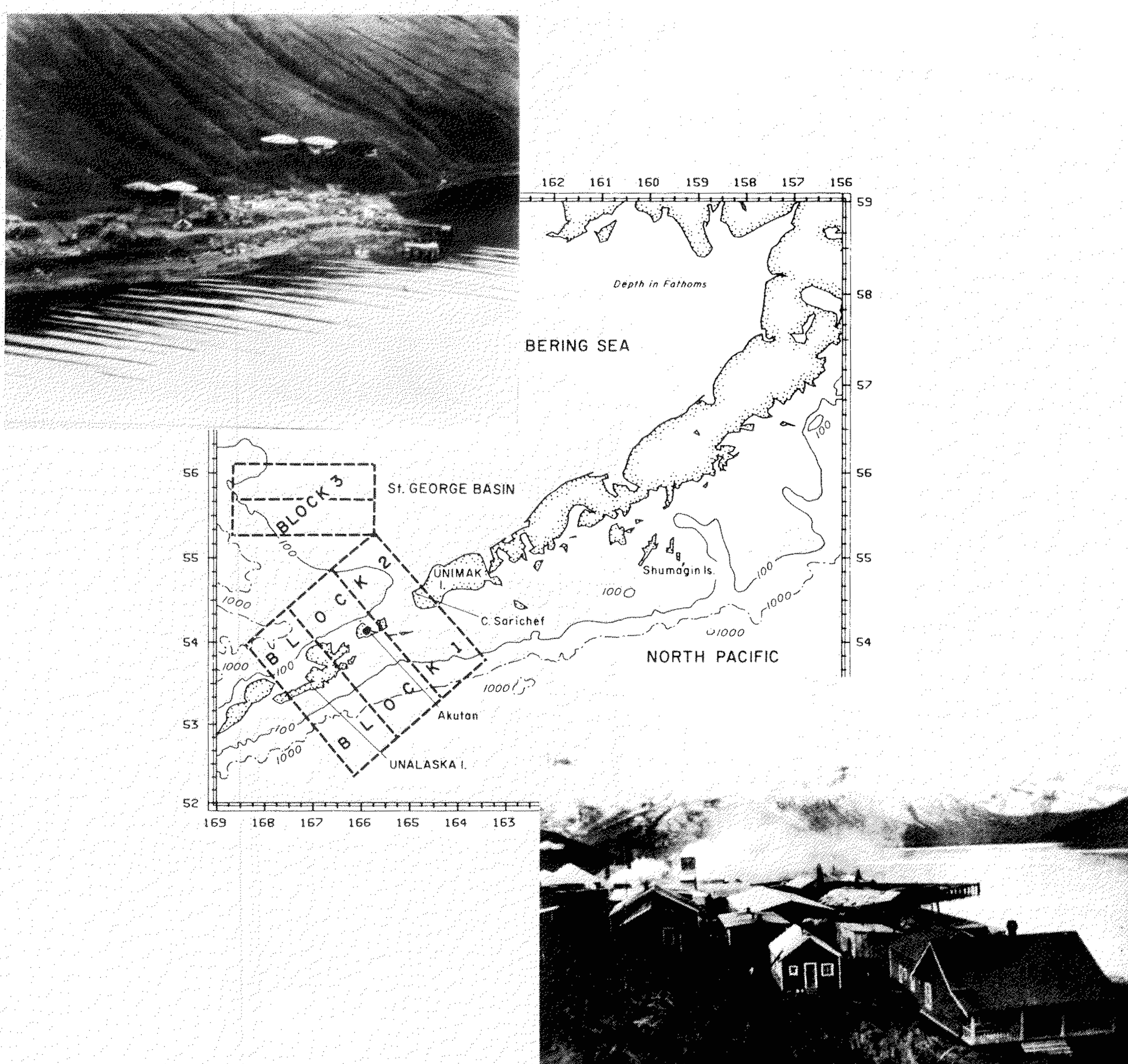

FIG. 1. Southwestern Alaska and the eastern Aleutian Islands, showing the location of the shore whaling station on Akutan and the three blocks in which transects were flown. The adjoining photos show the station in about 1920 (lower right) and the site in early August 1984 (to left). (Photos courtesy of Alaska Historical Library, Juneau, bottom, and by S.A. Karl, top.)

Analysis of trends in the Akutan fishery (Leatherwood *et al.*, 1985) indicated some depletion of the stocks. Both fin and humpback whales were taken at greater distances from the station in later than in earlier years, indicating reduced availability. Overall, there was a downward trend of catch per unit of effort, also taken to mean stocks were declining somewhat. Nevertheless, significant numbers of whales apparently were still available to the whalers between 1935 and 1939, as 0.28-0.51 whales per gross catcher day were taken in the last five years of operation. Whaling continued in the North Pacific after the closure of the Akutan station in 1939, and it is generally accepted that subsequent intense episodes of whaling in the northeastern Pacific from shore stations and pelagic fleets left most great whale stocks in the broader area depressed (e.g., Rice, 1974; Tillman, 1977; Braham, 1984).

In 1982 and 1983, a series of eight aerial surveys of the southeastern Bering Sea and Bristol Bay (*ca.* 185 000 nm^2) was flown to determine geographic and seasonal distribution and relative abundance of cetaceans. The transect lines in this enormous area were widely spaced and covered only about 1.93% of the areas during each survey. Furthermore, surveys were often flown in less than ideal survey conditions (see Leatherwood *et al.*, 1983:Table 2, p. 9 and Table 4, p. 42). With the exception of gray whales (*Eschrichtius robustus*), for which it was possible to estimate density in portions of the southeastern Bering Sea in May and June (Leatherwood *et al.*, 1983:Table 10, p. 67), few great whales were seen (Leatherwood *et al.*, 1983:Table 7, p. 57). Several hypotheses were proposed to explain the apparent low density of whales in the area overall, and particularly in the portions of the surveyed area where some species formerly occurred in much greater abundance: 1) it was an artifact of sparse coverage and generally poor survey conditions; 2) whale distribution was highly localized near the Aleutian Islands where previous whaling effort had concentrated, but where aerial survey coverage was low; and 3) there were few great whales present in the eastern Bering Sea during survey periods in 1982 and 1983.

To test these hypotheses, in 1984 we flew intensive low-altitude aerial surveys of the former Akutan whaling grounds at precisely the time of year when the greatest abundance of whales was expected on the grounds, as determined from historical whaling records (see Reeves *et al.*, 1985). We also flew a smaller number of transects in an area straddling the continental slope between the whaling grounds and the Pribilof Islands, near scheduled oil and gas exploration and developments.

FIG. 2. The Partenavia P 68 Observer used in the surveys. Note the clear plexiglass nose, permitting unobstructed viewing of the transect center line, and the side bubble window at the starboard observer station. (Photo by S. Leatherwood.)

METHODS

Survey Design, Transect Selection and Placement

Surveys were designed using a stratified random sampling scheme to balance the need for a random sample with practical logistical and operational constraints. The former whaling grounds, defined by reference to Reeves *et al.* (1985:Figs. 11 and 12), were divided into two blocks, one south (block 1) and one north (block 2) of the Aleutian Islands chain but with a common southwest to northeast oriented boundary between them (Fig. 1). Blocks 1 and 2 covered about 14 400 nm^2. Each block was subdivided into three zones of equal width. The sizes of blocks and zones were defined such that the amount of searching in each zone or combination of zones for which density estimates were to be reported (i.e., blocks 1 and 2 collectively and block 3 alone) was roughly proportional to its area. This feature permitted blocks and zones to be combined for density estimates.

The boundary between blocks 1 and 2 was scored at 0.25 nm intervals. Before beginning surveys, eight sets of three numbers each were selected at random and without replacement. These represented the starting points of 48 transects (24 in each block, 8 in each zone) to be flown northwest to southeast or southeast to northwest, parallel to the zones' long boundaries.

A third block (block 3) was defined between Unimak Pass and the Pribilof Islands, in waters overlapping coastal, continental shelf and pelagic areas (Fig. 1) in which at least fin, sei (*B. borealis*), minke (*B. acutorostrata*), humpback, gray, right and bowhead (*Balaena mysticetus*) whales and various other smaller cetaceans had been reported recently (Leatherwood *et al.*, 1983). This rectangular block, which covered 4000 nm^2, was divided into two zones, each approximately 20 × 100 nm. The western margin of each zone was scored at 0.25 nm intervals, and eight sets of transects were selected for each, as described above. Transects were to be flown east to west, parallel to the long block and zone boundaries.

Conduct of Surveys

All surveys were flown in a Partenavia P68 Observer (Fig. 2), a high wing, twin engine aircraft with a clear plexiglass nose (which afforded a clear and continuous view of the transect center line) and a 61 cm plexiglass bubble window on each side adjacent to the observer's seat. There were three observers. The forward observer, seated in the co-pilot's position, was dedicated to observing along the transect center line. Two side observers, who could also see the center line, searched outward from the line. Flights were sufficiently short that rotation of observers was unnecessary.

Surveys were flown at altitudes between about 150 m and 245 m and at a ground speed of 100 knots (kts). As in our previous aerial surveys of cetaceans (e.g., Leatherwood, 1979; Leatherwood and Reeves, 1983; Leatherwood *et al.*, 1987), transects were only initiated in sea surface conditions of Beaufort 3 and below, as rougher conditions are considered to significantly affect the probability of seeing cetaceans (e.g., Leatherwood and Show, 1980; Scott and Gilbert, 1982:Tables 6 and 7). If conditions deteriorated during a survey to Beaufort 4 or higher and remained so for five minutes or more the transect was terminated. If possible, such transects were resumed when conditions improved or were reflown on subsequent days.

Data on effort and sightings were collected from transects (the randomly selected lines that provided the basis for density estimation; such periods were logged as "on effort") and during transits (straight lines connecting transects with one another or with the shoreline, routes flown along land masses and between the base of operations, Dutch Harbor, and starting or ending points of transects and any survey lines completed under unacceptable conditions; such periods were logged as "off effort"). Data were also recorded during the ferry flights between Anchorage and Dutch Harbor. All data were logged using an Epson HX-20 computer linked to the aircraft navigation system (Loran-C, Model AVA-100A, ARNAV Systems, Inc.) by means of an RS-232 connection. Location (latitude and longitude), local time, magnetic heading and ground speed were recorded automatically once each minute and whenever a report of a sighting was entered. Environmental conditions, including sea state (as Beaufort number), sun glare and characterizations of weather and visibility, were entered periodically, as they changed and when sightings were entered.

For each marine mammal sighting the following information was recorded: the angle (γ) formed between the horizon and a line to the animal(s) when the aircraft was perpendicular to the sighting (measured, to the individual or to the center of the group of individuals, with a hand-held Suunto clinometer, and later used to calculate perpendicular sighting distance); species; the cue prompting the sighting; behavior; total number of animals; swimming direction; and observer making sighting. Once the sighting angle was measured, we left the transect and circled the animal(s) to confirm species identification, search for calves and count individuals. The time spent circling was considered "off effort." Data were stored on microcassettes and later transferred to a WICAT computer at Hubbs Marine Research Center for analysis.

Perpendicular distance to each sighting was calculated as

$$x = H \tan(90 - \gamma) \qquad \text{(Equation 1)}$$

where H is aircraft altitude, in feet.

Data Analysis

Density and abundance estimates were calculated using line transect techniques (following Burnham *et al.*, 1980) and program TRANSECT (Laake *et al.*, 1979). Highlights of the method as applied in this instance are summarized below.

The probability density function (pdf) of the perpendicular distances, f(x), was estimated from calculated distances and evaluated at zero (f(0)). The result was used in the following expression for density

$$D = \frac{n\,f(0)}{2\,L} \qquad \text{(Equation 2)}$$

where n is the number of observations and L is the length, in nautical miles, of the line(s) (i.e., the distance searched). The value of L was calculated from recorded positions and verified by comparison with time and speed calculations. In fact, distances calculated by the two methods differed by only three percent.

Following Burnham *et al.* (1980), we selected a Fourier series model, a linear combination of cosine functions, which has proven generally useful and has been applied to a variety of recent survey data (e.g., Ratti *et al.*, 1983; Hammond and Laake, 1983; Leatherwood *et al.*, 1983; Leatherwood *et al.*, 1987). It can be expressed as

$$f(x) = \frac{1}{W} + \sum_{k=1}^{m} a_k \cos(k\pi x/W) \qquad \text{(Equation 3)}$$

where W is the half-width of the transect, in this case the largest observed perpendicular distance, m is the number of cosine terms used in the model, and a_k is the k^{th} parameter estimated from the data. The estimate of f(0) is

$$f(0) = \frac{1}{W} + \sum_{k=1}^{m} a_k \qquad \text{(Equation 4)}$$

because when it is evaluated at x = 0 the cos (0) = 1.

For marine mammals that occur in groups (herds), the group (herd), rather than the individual animal, must be treated as the observation (Hayes, 1977; Burnham *et al.*, 1980; Quinn, 1980). Therefore, the number of sightings (n) is the number of groups observed. The estimate of density, therefore, is

$$D = \frac{n\,f(0)\,\bar{C}}{2\,L} \qquad \text{(Equation 5)}$$

which is the product of the density of groups and an average group size ($\bar{C}$).

An estimate of the sampling variance for density, given by Burnham *et al.* (1980), is

$$\mathrm{Var}(D) = D^2\,(CV^2(n) + CV^2(f(0)) + CV^2(\bar{C})) \qquad \text{(Equation 6)}$$

where

$$CV^2(n) = \mathrm{Var}(n)/n^2, \qquad \text{(Equation 7)}$$

$$CV^2(f(0)) = \mathrm{Var}(f(0))/(f(0))^2, \text{ and} \qquad \text{(Equation 8)}$$

$$CV^2(\bar{C}) = \mathrm{Var}(\bar{C})/\bar{C}^2 \qquad \text{(Equation 9)}$$

The variance of f(0) is from Equation 4; the variance of $\bar{C}$ is the standard sampling variance; and the variance of n, based as it is on replicate lines, can be expressed as

$$\mathrm{Var}(n) = \frac{L}{R-1} \sum_{i=1}^{R} \ell_i \left[\frac{n_i}{\ell_i} - \frac{n}{L}\right]^2 \qquad \text{(Equation 10)}$$

where R is the number of replicate lines, L is the total line length, and ℓ_i and n_i are the length and number respectively of observations for the i^{th} replicate.

The validity of estimates of density from line transect sampling depends on how well the following underlying assumptions are satisfied: 1) the area of interest is sampled randomly or the population is distributed randomly within the area; 2) all animals on or near the transect center line are seen; 3) all measurements are made without error; 4) the animals do not move or sampling occurs instantaneously with respect to any movement; 5) sightings are independent events; and 6) the size of a group (herd) of animals does not affect its probability of being observed. For a detailed review of line transect theory and methodology see Burnham *et al.* (1980). For details on the use of such techniques in censuses of cetaceans see contributors to Chapman (1982).

RESULTS

On flights made between 26 July and 26 August 1984 we collected data along 3040.0 nm of survey track, including 2403.1 nm "on effort," i.e., during random transects (Fig. 3, top; Tables 1 and 2), and 1819.5 nm "off effort" (Fig. 3, bottom; Tables 1 and 2). A total of about 23.6 hr was spent searching while on transect (i.e., "on effort"), at an average speed of 100 kts. The vast majority of effort on transect was

TABLE 1. Distance searched by Beaufort class

Areas	Transects (on effort) Beaufort 0-2	3-5	Total	Transits (off effort) Beaufort 0-2	3-5	Total	Total Beaufort 0-2	3-5	Total
Blocks 1 & 2 combined	1284.7 (58.6%)	908.4 (41.4%)	2193.1	1026.6 (68.6%)	470.3 (31.4%)	1496.9	2311.3 (62.6%)	1378.7 (37.4%)	3690.0
Block 3	183.8 (87.5%)	26.2 (12.5%)	210.0	40.0 (100%)	0.0 (0%)	40.0	223.8 (90%)	26.2 (10%)	250.0
Ferry flights	0.0	0.0	0.0	269.3 (95%)	13.3 (5%)	282.6	269.3 (95%)	13.3 (5%)	282.6
Total	1468.5 (61.1%)	934.6 (38.9%)	2403.1	1335.9 (73.4%)	483.6 (26.6%)	1819.5	2804.4 (66.4%)	1418.2 (33.6%)	4222.6

Effort was assigned to the category "0-2" if whitecaps were absent, "3-5" if whitecaps were present. Ferry flights are those flights between Anchorage and Dutch Harbor.

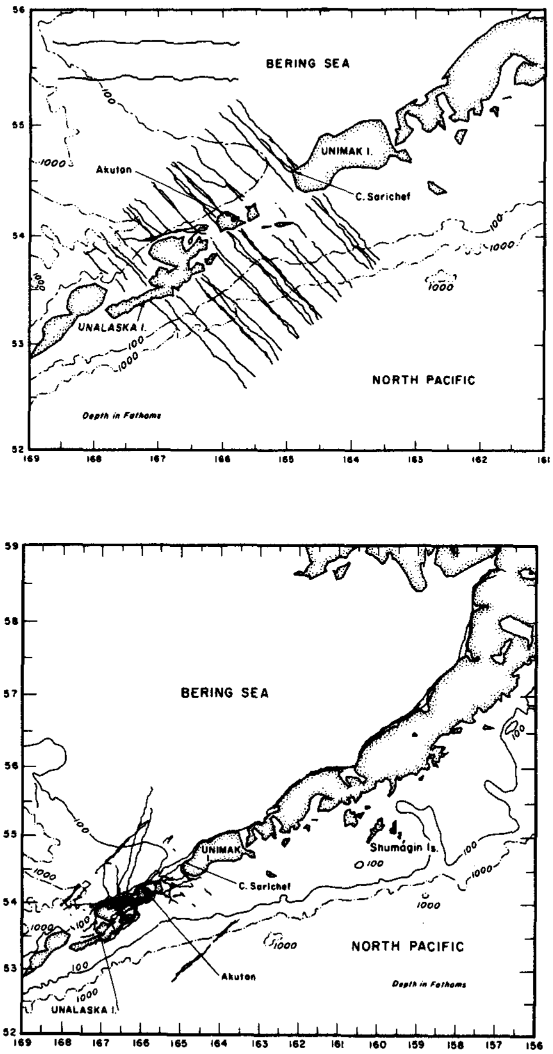

FIG. 3. The distribution of transects (top) and transits (bottom). Transects were logged as "on effort" and transits were logged as "off effort."

spent in blocks 1 and 2, where 47 of 48 planned transects were completed. Inclement weather, mostly persistent low clouds and fog, which significantly affected survey conditions and safety, permitted us to complete only 2 of 8 transects planned for block 3.

Overall, we saw 77 groups (199 individuals) of cetaceans (Fig. 4). The only identified baleen whale seen on transect was a single minke whale located off western Unalaska Island (Fig. 4). The 11 fin and 14 gray whales recorded were all seen "off effort," during transit or ferry flights. So also were 20 of the 26 killer whales (*Orcinus orca*) seen (Table 3). Only one species, Dall's porpoise (*Phocoenoides dalli*), was observed with sufficient frequency to permit estimates of density (Table 4). Three such estimates were made: for blocks 1 and 2 combined; for block 3; and for blocks 1, 2 and 3 combined.

There were too few "on effort" sightings of Dall's porpoises to estimate f(0) reliably; so we combined "on" and "off effort" sightings, as described below, to derive the sightability function. Such an approach is valid if the factors affecting f(0) are not significantly different between the two sets of sightings. The factors most likely to affect f(0), and their characterizations for the present surveys, are: 1) sea state — the proportions of distance flown under various sea states were relatively consistent between all effort in blocks 1 and 2 combined and effort on transect in block 3. Sightings from remaining flights — i.e., those "off effort" in block 3 and those during ferries — were excluded from calculations to estimate f(0) because they were made almost entirely in the one category of good sea state conditions (Table 1); 2) visibility conditions — the proportions of distance flown under various visibility conditions were relatively consistent among all flights in blocks 1 and 2 combined and block 3 (Table 1), so all sightings from them were included in calculations to estimate f(0); 3) altitude — nearly all (91.8%) transects were flown at altitudes between about 225 m and 245 m; therefore, sightings from "off effort" were included in calculations to estimate f(0) only if they were made while flying within this range of altitudes; and 4) effects of group size on sightability — group sizes were not substantially different between sightings "on effort" ($\bar{x}=2.5$) and sightings "off effort" ($\bar{x}=3.8$) and no differences were apparent between the sightability functions from the two circumstances. Proceeding in this manner, we were able to use 42 sightings of Dall's porpoises to estimate f(0).

All of these 42 sightings of Dall's porpoises resulted in recording of clinometer angle. The distribution of distances calculated from those measured angles indicates little bias due to rounding. This does not imply that measurements are free from error, only that such error is random. Therefore, rather than being grouped into distance intervals, the calculated perpendicular distances were used as exact distances to estimate f(0)

TABLE 2. Distance searched (in nautical miles) by visibility class

	Blocks 1 and 2 combined		Block 3		
Visibility class	Transects (on effort)	Transits (off effort)	Transects (on effort)	Transits (off effort)	Ferry flights between Anchorage and Dutch Harbor
Mostly obscured <1 nm	144.9 (6.6%)	129.0 (8.6%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
Partially obscured 1-10 nm	706.6 (32.2%)	530.4 (35.4%)	50.2 (23.9%)	29.6 (74.0%)	0.0 (0.0%)
Unlimited with some to strong glare	704.1 (32.1%)	487.0 (32.5%)	111.5 (53.1%)	6.24 (15.6%)	0.0 (0.0%)
Unlimited with no glare	637.5 (29.1%)	350.5 (23.5%)	43.3 (23.0%)	4.16 (10.4%)	282.6 (100.0%)
Total	2193.1	1496.9	210.0	40.0	282.6

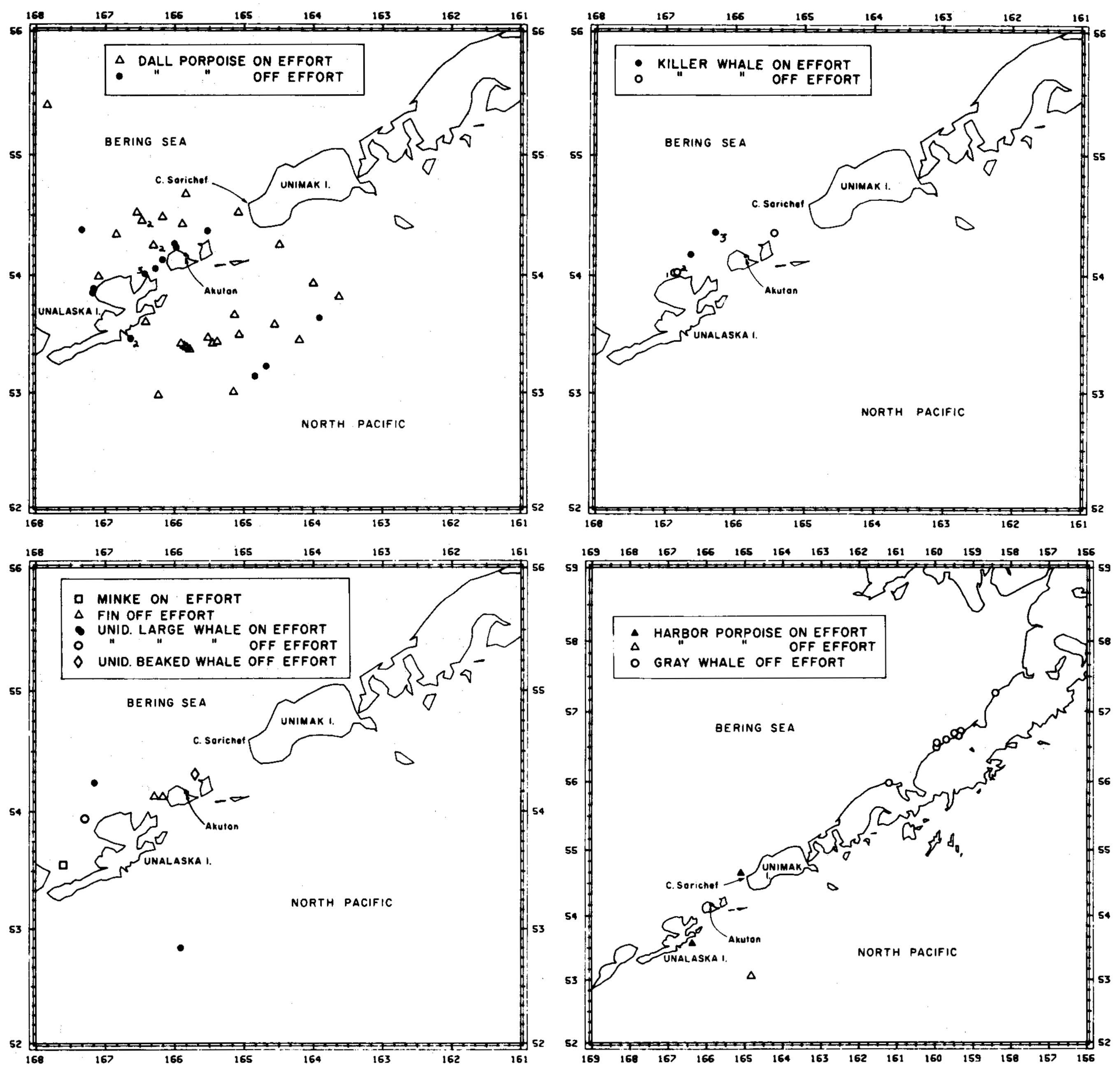

FIG. 4. Locations of sightings of cetaceans during transects ("on effort") and during transits ("off effort"). The numbers by the symbols indicate the number of sightings at that location.

and to derive a Fourier series fit for sightings of Dall's porpoises (Fig. 5).

Density estimates were made using the above described estimates of f(0), the number of "on effort" sightings (n), and the average group size ($\bar{C}$) in all "on effort" sightings (Fig. 6). We calculated an estimate for blocks 1 and 2 combined and a separate estimate for block 3 because there was considerably more effort in proportion to area in the former than in the latter.

To construct an overall density estimate, we weighted the individual block estimates by the relative sizes of the areas as

$$D = \frac{(A_1 + A_2)\,(D_1 + D_2) + A_3 D_3}{A_1 + A_2 + A_3} \qquad \text{(Equation 11)}$$

where A_1, A_2 and A_3 are the areas (in nm) and D_1, D_2 and D_3 are the densities for blocks 1, 2 and 3 respectively.

DISCUSSION

The eastern North Pacific gray whale stock appears to have recovered from the effects of the most recent episode(s) of whaling, earlier this century, and is believed to be at or near its pre-exploitation size of 15 000-20 000 (Reilly, 1984). The vast majority of that population is north of Unimak Pass annually from April-June through November-December (Jones *et al.*, 1984). With respect to our survey areas and times, gray whales are peripheral, moving through Unimak Pass and then eastward close along the shores of Unimak Island and the Alaska Penin-

TABLE 3. Number of sightings of marine mammals (number of individuals is shown in parentheses)

	Transects (on effort)		Transits (off effort)			
Species	Blocks 1&2	Block 3	Blocks 1&2	Block 3	Ferry Anchorage to Dutch Harbor (all transits)	Total
Fin whale			3(11)			3(11)
Minke whale	1(1)					1(1)
Gray whale					10(14)	10(14)
Unid. large whale	2(2)		1(1)			3(3)
Killer whale	4(6)		4(20)			8(26)
Unid. beaked whale					1(6)	1(6)
Dall's porpoise	30(71)	1(1)	16(59)			47(131)
Harbor porpoise	2(4)		1(2)		1(1)	4(7)
Total	39(84)	1(1)	25(93)		12(21)	77(199)

sula during migrations. Gray whales were not taken by Akutan whalers (Reeves *et al.*, 1985). All of our sightings were "off effort" and during transit along the north shore of the Alaskan peninsula, where gray whales were expected to be at this time of year. We did not expect to see many in our survey area.

Minke whales of the northeastern Pacific have never been substantially exploited (a few were taken at Akutan — Reeves *et al.*, 1985). They are at present regarded as an Initial Management Stock (IMS) and believed to be abundant overall (IWC, 1983:97). They were the balaenopterids seen most frequently on recent aerial and vessel surveys in southeastern Bering Sea and Bristol Bay (Leatherwood *et al.*, 1983). Their population size is not known.

TABLE 4. Summary of statistics used in density estimates of Dall's porpoises and their coefficients of variation (CV) in parentheses

Area	A	n	f(0)	$\bar{C}$	D
Blocks 1&2	14 400	30	6.957	3.30	115.0
	(0.209)	(0.121)	(0.450)	(0.263)	
Block 3	4 000	1	6.957	1.00	17.0
	(0.862)	—	(0.0)	—	

Density (D) is expressed as number of animals per 1000 nm^2; A = the size of the area in nm; h = the number of sightings; f(0) = the probability detection function evaluated at zero (see text for additional details); $\bar{C}$ = the average group (herd) size.

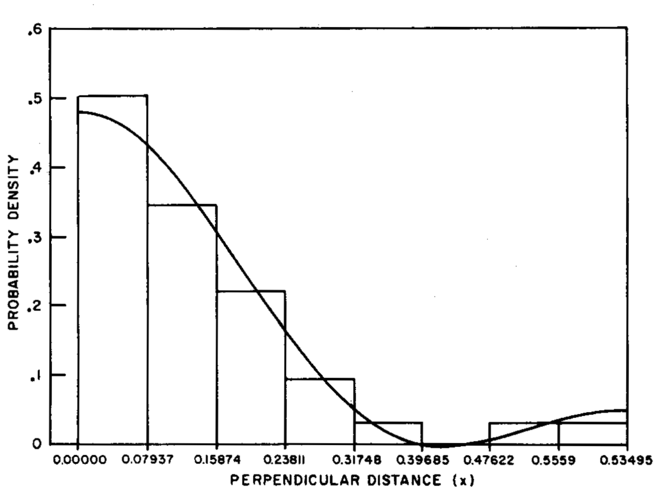

FIG. 5. Illustrations of the fit of the Fourier series to the perpendicular distances of the sightings of Dall's porpoises ($f(x) = 1/W + 2.994 \cos(1\pi x/W) + 1.289 \cos(2\pi x/W)$ and $W = 0.374$).

The pre-1905 humpback whale population in the North Pacific has been estimated as about 15 000, but the population was subjected to extreme modern whaling through the 1960s (Rice, 1978). Johnson and Wolman (1984) estimated the current population at about 1200, including 550-790 that winter in Hawaiian waters (Rice and Wolman, 1984). There are data suggesting the population is much larger. Darling and McSweeney (1985) estimated that there are a minimum of 1500 humpback whales in the northeastern Pacific, and Darling (1983) has photoidentified as many as 2100 individuals in the Hawaiian population alone. Rice (1978) reports that humpbacks, though present in the Asian winter grounds, are now scarce in that area. Apparently, animals from both populations occur in Alaskan waters (Nishiwaki, 1966), but there are still only sporadic records in the southeastern Bering Sea and along the Aleutians near Unimak Pass (Leatherwood *et al.*, 1983). Humpbacks were the second most important species to the Akutan whalers

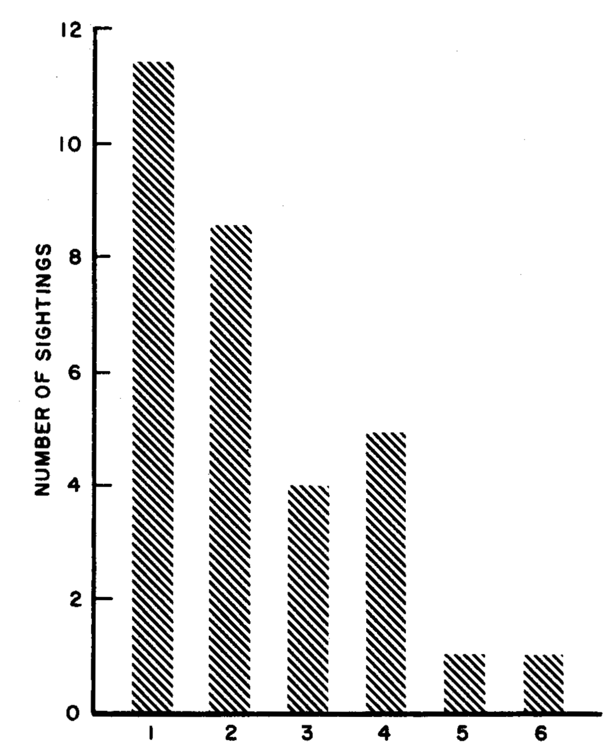

FIG. 6. Sizes of groups (herds) of Dall's porpoises seen during transects ("on effort"), blocks 1, 2 and 3 combined.

numerically, constituting 30% of the total take (1510 of 5027 whales identified to species in 23 years) but being 66.7% of the total take at nearby Port Hobron (1573 of 2357 taken identified to species in 11 years) (Reeves *et al.*, 1985). From their apparent dispersal during recovery in various portions of the North Atlantic (IWC, 1984:135-6), one would predict that as their population grows, humpbacks would recolonize former grounds in the North Pacific.

The status of the North Pacific fin whales has not been adequately assessed. Stocks there have remained classified by the International Whaling Commission (IWC) as Protection Stocks for a decade (Gambell, 1985) and populations were most recently estimated to contain some 20 000 individuals, about 38% of the pre-exploitation stock size of 53 000 (Allen, 1980). This was the species most important to shore whalers at Akutan, constituting 49.7% (2498 of 5027 whales identified to species) of takes there in 23 years and the second most important at Port Hobron, nearly 20% (464 of 2357 whales identified to species) of takes there in 11 years (Reeves *et al.*, 1985). Further, fin whales were the balaenopterids seen second most often (after minke whales) in recent surveys (Leatherwood *et al.*, 1983). We expected to see them, especially on the continental shelf, during the present surveys.

The status of sperm whales in the North Pacific is problematical and highly disputed. For the present, the species there is managed in two divisions, eastern and western (Gosho *et al.*, 1984), which are at reduced levels. There apparently are 61 000 males over 10 years of age in the western North Pacific and 111 400 over 12 years of age in the eastern North Pacific, 47% and 79% of the original (in 1910) stock sizes respectively (Gosho *et al.*, 1984:Table 4). Whatever the correct delineations of stocks and actual numbers, adult males from the eastern and western Pacific intermingle(d) in higher latitudes, and we would not have been surprised to have encountered a few male sperm whales in the deeper water portions of the survey areas.

The other three northern North Pacific great whales are not commonly reported in or near any of the three study blocks and so were not expected on these surveys. Bowheads may assemble near St. Matthew Island in spring (Braham *et al.*, 1980; Brueggeman *et al.*, 1984) but are rarely reported farther south (Leatherwood *et al.*, 1983); right whales are seriously endangered and rarely seen anywhere in the eastern North Pacific (Rice, 1974; Brownell *et al.*, 1986; Scarff, 1986; Reeves and Leatherwood, 1985); and sei whales are generally uncommon north of the Aleutians, being found in pelagic regions farther south (Rice, 1974:181; Leatherwood *et al.*, 1983).

With the above in mind, there were surprisingly few sightings of great whales in or near the roughly 14 400 nm^2 area of study blocks 1 and 2 or in the 4000 nm^2 area of block 3 during the 29 field days. By comparison, in surveys by aircraft of portions of an approximately 50 000 nm^2 area within about 100 nm of shore off eastern Newfoundland-Labrador in August 1980, Hay (1982) observed 31 groups of humpback whales and 18 groups of fin whales, supporting his estimates of populations of 738 (SD = 221) and 478 (SD = 250) for the two species respectively. Hay's surveys were designed to cover essentially the whaling grounds used by Canadian whalers from South Dildo and Williamsport, Newfoundland, between 1964 through 1971 (Mitchell, 1974:Fig. 5-1). From cumulative catches, it has been estimated there were populations of at least 1500 fin, 1000 humpback, 500 blue and 300 sperm whales available within a 100 nm radius of the Akutan whaling station at some point in the history of the fishery (Leatherwood *et al.*, 1985). If populations of these four species had been present on the Akutan grounds in comparable numbers in July and August 1985, it is reasonable to suppose, from Hay's (1982) experience, that some whales would have been seen. The appreciable number of smaller animals detected suggests large numbers of whales were not missed simply by lack of vigilance. The results from sightings of Dall's porpoises are a useful case in point. Leatherwood *et al.* (1983) estimated that there were 97.20 (SD = 49.50; CV = 0.51) Dall's porpoises per 1000 nm^2 in study blocks between the north side of the Aleutians and about the southern latitude of the Pribilofs, from longitude 166°W to 170°W. From the present surveys we estimated that there were 16.6 (CV = 0.0) individuals per 1000 nm^2 in block 3 and 115.0 (CV = 0.263) individuals per 1000 nm^2 in blocks 1 and 2 during the period of the surveys (Table 4). The results of the present surveys bracket those from the previous work.

Results of the present surveys appear to support the hypothesis that the relatively low numbers of baleen whales, other than gray and minke whales, seen in the eastern Bering Sea and northern North Pacific near Akutan actually do indicate low density of these animals and are not merely artifacts of sparse coverage and poor survey conditions. However, one must be cautious when interpreting a scarcity of sightings of cetaceans from aerial surveys as evidence of their low density in the area(s) under study, unless survey methods have been carefully controlled to maximize the probability of sightings. Such was the case. First, present surveys used an aircraft with downward visibility, permitting observers to see the transect center line and thereby more nearly satisfying the second assumption of line-transect methodology (i.e., that all animals on or near the track line are seen). Such increased visibility would result in larger numbers of sightings near the center line. The absence of data in that strip could significantly affect credibility of estimates. There were few sightings of cetaceans during our surveys, but when all sightings (including pinnipeds and sea otters, not analyzed) were combined, about 25% of them (51 of 206) were within 0.04 nm of the transect center line.

Second, present surveys were conducted only in acceptable conditions of sea state and visibility (91% of the survey effort was in Beaufort 3 or below, 61% in the two best visibility classes), when the probability of detecting animals is highest. This was made possible by the proximity of lines in blocks 1 and 2 to the operational base and the relatively short time required to complete a replicate set of transects in each. Therefore, observers were afforded the luxury of waiting at the operational base for acceptable weather conditions before departing for survey and of surveying on whichever side of the Aleutians offered the best weather conditions. The absence of any lee effect at block 3, the greater distance to that block and the often significant differences in weather near the chain and weather offshore (making difficult any decisions of when conditions would be acceptable for surveying block 3) resulted in completion of only one of four planned replicates in block 3 in 29 possible survey days. Previous surveys of the Bering Sea (Leatherwood *et al.*, 1983) had covered large areas, including many for which accurate weather reporting is not available. The result was a high percentage of time in conditions of unacceptable visibility.

Third, the eight sets of replicates in blocks 1 and 2 were completed within a month, at a time of year when peak catches of fin, humpback, blue and sperm whales were made (Leatherwood *et al.*, 1985). Further, transects were spaced at narrow distance intervals, affording higher coverage (per survey and overall, during the month) with concomitant higher probability of detecting animals present than on previous surveys of the area.

Fourth, special attention was paid to precision in distance estimation (helped by the increase in proportion of sightings close to the aircraft where an error of a few degrees amounts to an error <0.004 nm in the estimated perpendicular sighting distance) and to remaining with groups long enough to confirm species and number of individuals present. The added time required for these last activities is not available on longer surveys, in which the aircraft is stretched to safety limits just to complete transects.

One problem that will always exist in aerial surveys of cetaceans is that of estimating numbers of animals missed because they were submerged, and therefore not visible, during the period of the overflight (Leatherwood *et al.*, 1982). This problem can only be corrected meaningfully with data, preferably collected at the time of the surveys, on diving frequencies and times for each species seen and their resultant effects on visibility. Submergence is likely a more significant problem in attempts to estimate density of great whales (which usually travel singly or in small groups and remain submerged for long periods), particularly when they occur in low densities, than it is with animals such as Dall's porpoises, which travel in larger groups and remain submerged for shorter periods.

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