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Comparison of on-ice counts of harp seal pups with counts from 35-mm ultraviolet aerial photography

by

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ABSTRACT

In March 1977 an attempt was made to design and test a new ground-truth procedure to accompany an ultraviolet aerial census of whelping harp seals off eastern Canada. Despite several problems, reasonably good agreement between on-ice counts of harp seal pups and counts on ultraviolet aerial photographs were obtained on good quality imagery. However, behavioural responses of seals to activity associated with the on-ice count, treacherous ice on the Front, and the precise requirements for conducting the entire procedure, seriously limited the success of this experiment. It is unlikely that such an approach to ground-truthing will ever produce suitable correction factors to apply to the results of an ultraviolet aerial census. A more economical and practical method for obtaining somewhat comparable data necessitated on the Front in 1977, although not ideal, may provide more useful information for future surveys.

INTRODUCTION

The use of remote sensing techniques to obtain scientific data requires confirmation that the subject under study is reliably detected by the sensor. This necessitates first hand observation of the subject and the exercise is usually termed "ground-truthing" or ground-verification

Aerial photographic surveys of adult harp seals using conventional black and white photography have been conducted for over 50 years (Sergeant, 1975). In these surveys it has been generally accepted that all adult seals on the surface of the ice in direct line with the camera are detected on film from low altitudes of 300 to 1200 m.

Recently, ultraviolet photography has been introduced as a technique for detecting white-coated seal pups on ice (Lavigne and Øritsland, 1974). White-coated harp seal pups absorb much of the ultraviolet component in solar radiation, and thus appear as black images on an ultraviolet-reflecting grey-white background of ice and snow (Lavigne and Øritsland, 1974). Because of their behaviour and smaller size, all pups may not always be equally visible from the air. This is especially true when the ice is rafted, creating overhanging ledges where the pups can find shelter at night and during inclement weather. Adult seals are detected equally well by ultraviolet photography and normal black and white photography (Lavigne et al., 1974; Lavigne, 1976) since the adult pelt also tends to absorb ultraviolet radiation (Lavigne and Øritsland, 1974).

Ground-truthing in conjunction with an ultraviolet aerial census is thus primarily concerned with comparing counts of seal pups made at ice level, with counts of the same area made with ultraviolet aerial photography. Some ground-truthing experiments have been attempted in the past (Lavigne et al., 1975). In 1976, a new approach to ground-truthing was introduced after discussion with W.G. Doubleday, Fisheries and Marine Service, Environment Canada, in an attempt to increase sample sizes for statistical analysis. Designated ground-truth areas were subdivided into three or four smaller areas, each to be counted separately after being photographed from the same remote sensing aircraft used for the actual census. Testing in the field during March 1976 showed that this approach was not suitable. The amount

of human activity involved in marking out the sub-areas resulted in undue disturbance of the animals, and produced variable counts over a brief period of time because of movements of animals, both adults and pups, out of the designated area.

In 1977, further changes were made in the experimental design in an attempt to devise a satisfactory ground-truth procedure. Ground-truthing was separated from the main survey operation and conducted from a Gazelle helicopter equipped with a 35 mm ultraviolet camera. Human activity associated with the delineation of the ground-truth areas on the ice, and helicopter movements, were organized to reduce the disturbance of seals and thus, hopefully, to reduce seal movements during the time the area was photographed from the air and counted on the ground.

METHODS

1. Development

Since most helicopter canopies filter out much of the ambient ultraviolet radiation, it was necessary to locate a helicopter such as a Gazelle, with a camera port which could be fitted with an ultraviolet transmitting plexiglass window. A simple aluminum camera mount was then designed to hold a Pentax KX-motor driven camera with an 85 mm f/4.5 Ultra-Achromatic-Takumar lens (Asahi Optical Co., Japan) equipped with an ultraviolet transmitting, visibly opaque filter (Wratten 18A, Eastman Kodak Co., Rochester). When installed in the helicopter, the camera lens was positioned 7.7 cm above the plexiglass window.

Lenses used in ultraviolet photography, e.g. Hasselblad 105 mm UV-Sonnar lens (C. Zeiss, W. Germany)(Lavigne and Øritsland, 1974) seem to be affected by cold temperatures which cause differential contraction of lens elements resulting in loss of focus (Lavigne et al., 1974). Cold tests were thus conducted on the Takumar lens prior to its use in the

field. When the camera was taken from room temperature (18 C) to outside temperatures of about -8 C, loss of focus was initially observed after only 10 min and reached a maximum after about 30 min.

In order to counteract this temperature effect, it was necessary to keep the camera in a warm environment, and reduce temperature fluctuations to a minimum. A hatch cover was made to receive an air line from the helicopter heating system and at the same time to keep snow and water out of the camera hatch. Fiberglass insulation pads were placed between the plexiglass window and the camera when the helicopter was not in use, to reduce heat loss from the camera port. A 12 volt heating pad powered by a 6 volt tractor battery was also used to keep the camera warm. The combination of these three methods appeared to maintain the temperature around the camera at a satisfactory level and no evidence of differential contraction was observed during the final flight tests conducted during February.

2. On-ice techniques

Once a whelping patch was located the helicopter was flown at low altitude (150-200 m) until a reasonably dense concentration of pups was located. Different types of ice for ground-truthing were then selected in approximate proportion to the occurrence of these ice types throughout the entire whelping patch. In the Gulf of St. Lawrence, seals were found on large pans of ice, often containing one or more pressure ridges. Two areas (5, 9) contained pressure ridges reaching heights of 2.4 to 3.0 m. Maximum distance from the flat pan level to the tallest protruding ice was estimated in 6 of the 16 ground-truth areas (2, 4, 12, 13, 15, 16) to reach between 0.9 and 1.8 m. In four areas (1, 7, 8, 10) the ice was essentially flat and no estimates of ice protrusion were made in the remaining four areas (3, 6, 11, 14).

Nursing female seals and their pups appeared to be concentrated along the pressure ridges running across the pans, or along major leads

between the pans. Thirteen out of 16 ground-truth areas were aligned with these ridges and an open water lead was used as a boundary to the long axis in another ground-truth area.

Having selected a suitable area, the helicopter was landed and the ground-truth crew marked out a "numeral square" (Fig. 1a; ABCD). The corners of this square were identified with 2 m crosses using blue ultraviolet-absorbing dye, and a flag pole was placed at the centre of each cross (Fig. 1). In wind, flag poles required an anchor in the form of an ice piton or lumps of ice. Distances AB and CD were 46 m, AC and BD, 30 m, while the length of the strip (CE and DF) was variable. It was important to get lines AC and BD approximately parallel, otherwise the other end of the strip (EF) was either too large for three men to count, or too small to contain a suitable number of seal pups. A 30 m length of cord with a knot at 15 m was used as a measuring device. Finally, a large number was placed in the centre of each square to later identify each ground-truth area on film.

After the numeral square was delineated the ground-truth crew flew a wide arc around the ground-truth area, with the pilot "crabbing" the helicopter across the strip until flags AC and BD were approximately in line. The lengths of CE and DF were limited by the concentration of seal pups in the area, the edge of the ice pan, and/or the visibility of flags ACBD. Attempts were made to include approximately 100 pups in each ground-truth area.

The helicopter then landed at Y (Fig. 1a), crosses E and F were made in line with flags AC and BD respectively to designate the entire ground-truth area (CDEF) and the crew lined up on the centre line of the strip (Fig. 1b). The helicopter then flew upwards to an altitude of about 274 m, facing towards the numeral square; the camera operator observed the position of the crew on the ice and the pilot, the numeral square. On several occasions, sight of the numeral square was lost, and the three crew members provided sufficient orientation for the pilot until

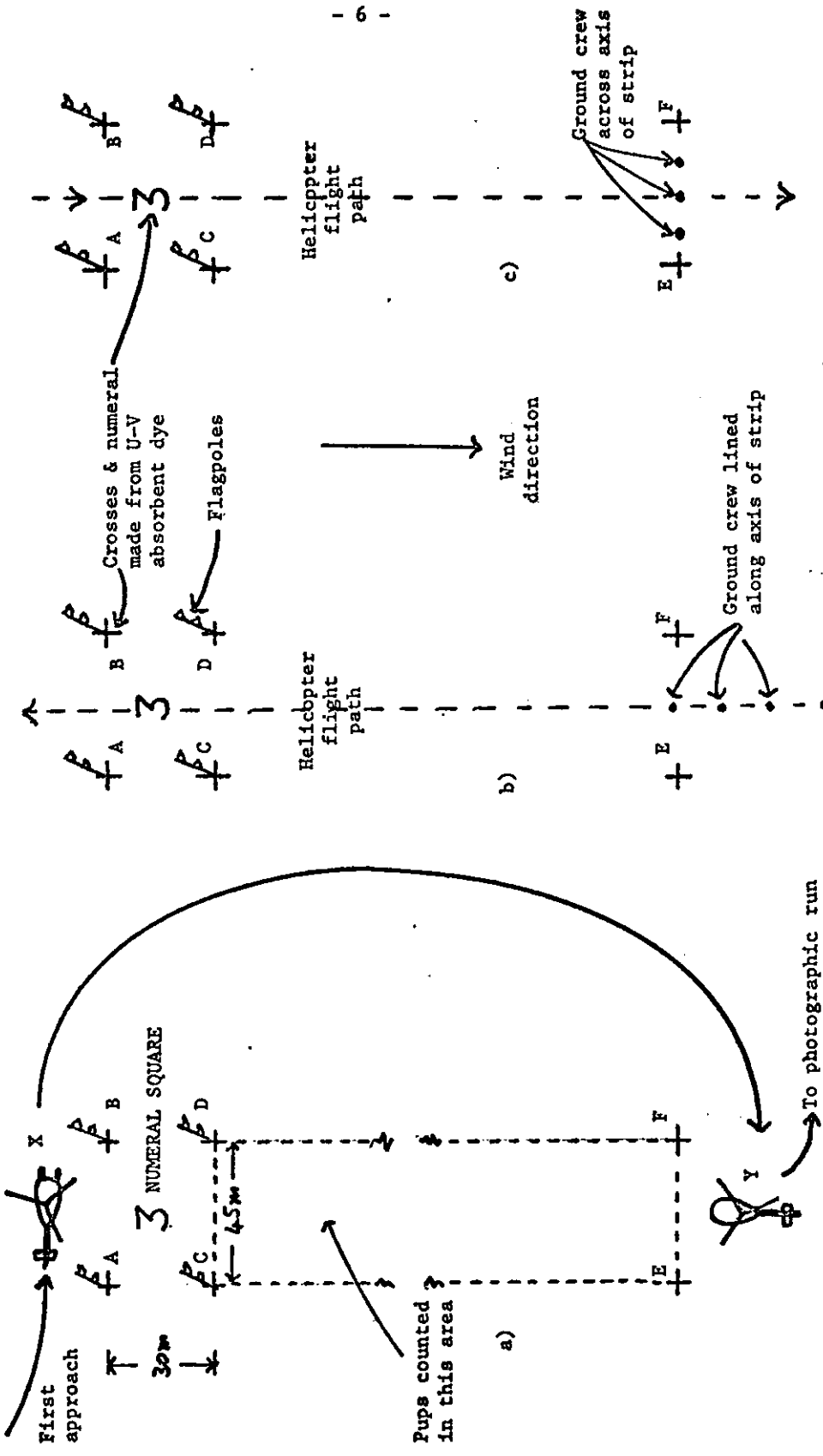

FIGURE 1. Marking-out and photographing a ground truth area.
a) Marking-out. b)First photographic run. c)Second photographic run.

sight of the numeral square was regained. A head wind on the nose of the helicopter was useful at this stage to help the pilot move the machine away from EF, so that some reasonable speed could be attained before EF was crossed with the camera running. The camera was stopped after the numeral square was passed, and a wide 180° turn was made while maintaining altitude. The numeral square was usually visible at the completion of the turn, and the ground crew members, now evenly spread out between the markers E and F, were clearly visible at the other end of the strip (Fig. 1c). The second photographic run was then made at the same altitude, 2 or 3 min after the completion of the first run. Helicopter speeds during photographic runswere not critical; slower speeds resulted in better alignment at the negligible cost of using more film.

The quality of the imagery appeared to be particularly insensitive to a variety of possible camera settings. On clear, sunny days a shutter speed of 1/500 s and f/8 were used; on cloudy days either 1/500 s and f/4.5 or 1/250 s and f/4.5 were used depending on the amount of radiation which appeared to reflect from the ice.

When both photographic runs were completed, the ground crew was notified by radio to commence counting, and the helicopter made a wide circle around the strip to land at X (Fig. 1a). Camera checks and film changing were carried out while counting was completed.

In order to count the pups on the ice, two men walked the flanks of the area, keeping flags AC and BD in line. All pups on, or inside the designated area were counted and marked by the flank men, who also looked ahead and attempted to note any pups entering or leaving the area immediately ahead. Those leaving the designated area were counted; those entering were ignored since they would not have been photographed within the area several minutes earlier. All observed movements across the boundary were entered in the master field note book on completion of the count. The third man counted all unmarked pups in the centre of the area,

between, and slightly behind, the flank men. Hand counters were used to record the numbers and each pup, when counted, was immediately marked on the head with a spot of dye to avoid duplicate counts.

The original plan involved counting each area twice, but ice conditions in the Gulf were such that the ground crew were confident that all pups were counted in one sweep, so a second count was not made.

Once the counts were recorded, the flag poles and bases were dismantled, loaded into the helicopter which then departed with the crew to the next area. With experience, one complete ground-truth area could be marked out, photographed and counted in one hour.

3. Film processing

The film was developed in the field to allow preliminary assessment of the film coverage in each of the ground-truth areas. This also permitted the ground-truth crew to evaluate the experimental design on site and to make minor adjustments in their procedure as deemed necessary.

4. Analysis of ground-truth imagery

Three persons were employed to assist with the analysis of all the aerial imagery obtained during March 1977 (Lavigne et al., 1977). An experienced photointerpreter from the 1975 experimental census (Lavigne et al., 1975; Lavigne, 1976) spent much of the first week training these inexperienced individuals using imagery from the 1975 work, and the ground-truth imagery from 1977.

Because of the high degree of overlap on adjacent frames (∿90%) alternate 35 mm negatives obtained during the ground-truth operation in the Gulf of St. Lawrence were enlarged and printed as transparencies (11.8 x 17.7 cm). A mosaic of the area photographed was then constructed by matching overlapping transparencies. An estimate of the area counted by the ground-truth crew was then drawn on the mosaic by joining

the numeral square markers with the end markers (Fig. 1). Areas of overlap were also marked on the frames to ensure that each area would be included only once. The frames were then separated and counted individually. Frames which completely overlapped with others were kept for reference in cases where the imagery was difficult to interpret.

The counting procedure consisted of independent tabulations by three photointerpreters. Sometimes, poor focus, lack of contrast and/or ice conditions, necessitated counting individual frames or even whole areas directly from the negatives. In such cases, the transparencies were used as guidelines indicating the area to be counted. Counts were made on a light table with the aid of an 8x magnifying hand-lens.

The basic criteria for the identification of seals were as follows: 1) discernible flippers; 2) fusiform shape; 3) density of the image in comparison to background feature; and 4) change in position over a series of overlapping frames indicative of movement. A minimum of two of these criteria was considered sufficient for a positive identification of a seal. Pups were separated from adults on the basis of smaller size and greater variability in shape when compared to adults. These criteria were developed independently by the three photointerpreters during the week of preliminary training, in consultation with an experienced photointerpreter.

5. Ground-truthing on the Front

Since ice conditions on the Front precluded the above ground-truth procedures, a back-up procedure was employed. Two observers on the Arctic Explorer, B. McCullogh and R. Greendale, were asked to classify pups on the ice into three groups: pups in the open which would be in direct line with a camera overhead; pups which would obviously be hidden from view; and pups which might or might not be photographed. This exercise was conducted on March 14 between 1230 and 1430 h and the results were reported to C.K. Capstick.

RESULTS

Sixteen ground-truth areas were marked out on the ice and photographed, usually in duplicate, in the Gulf of St. Lawrence between February and March 1977.

Preliminary evaluation of each roll of film involved determining whether all the dye markers for a given area were visible on film. Areas where all dye markers were visible were assumed to be completely photographed and areas with one or more dye markers missing were rejected (Table 1). During this evaluation it was noted that film roll 7 was of inferior quality; the negatives lacked contrast and light and dark bars were observed across the length of the film.

At Guelph, transparencies were produced for areas where all dye markers were present, and mosaics were constructed. Some of these areas were subsequently found to be incompletely photographed, despite the fact that all the dye markers were present, and these were also rejected from further analysis (Table 1).

For each of the remaining areas, counts of adults and pups were made independently by each of the three photointerpreters (Table 2). For areas 1A, 1B, 4, 6, 8, and 16, similar counts were obtained by the three individuals (Table 2a). No such agreement was present on the number of seals in areas 13B, 14A, 14B, 15A, 15B, and all three photointerpreters listed several "doubtful" seals in their counts (Table 2b). All but one of these areas (13B) was from roll 7 whose quality had been questioned during preliminary assessment. The latter half of roll 6 which included area 13B was however of similar poor quality, although this had not been noted earlier.

While analysing the imagery, the photointerpreters made the following observations. The enlargement of 35 mm Tri-X negatives resulted in considerable graininess in the transparencies. This reduced the clarity of the transparencies and in some cases the first generation imagery (the 35 mm negatives) was used to obtain a count of seals. The

TABLE 1

Qualitative evaluation of ground-truth imagery

ROLL #	AREA	FIELD EVALUATION[1]	PRELIMINARY LAB EVALUATION
1	1A	+	+
1	1B	+	+
1	2	-	-
2	3	-	-
2	3	-	-
2	4	+	+
3	5	-	-
3	6	+	+
3	7	-	-
4	8	+	+
4	9	-	-
4	10	+	-
5	11	+	-
6	12A	+	-
6	12B	-	-
6	13A	+	-
6	13B	+	+
7	14A	+?	+
7	14B	+?	+
7	15A	+?	+
7	15B	+?	+
8	16A	-	-
8	16B	+	+

[1] + all dye markers visible.
- one or more dye markers missing, or area was incompletely photographed.
? roll 7 was characterized by a lack of contrast and had over and under developed bars across the length of the film.

TABLE 2

Counts of harp seals, Pagophilus groenlandicus, obtained from ground-truthing the direct counts of animals on the ice

a.

ROLL #	AREA	IMAGERY #ADULTS	IMAGERY #PUPS	GROUND-TRUTH #PUPS
1	1A	7 ± 0	7 ± 0	8
1	1B	8 ± 0	7 ± 0	
2	4	27 ± 0	65.5 ± 0.7	66
3	6	51 ± 0	51 ± 0	53
4	8	14 ± 0	19 ± 0	25 + 1 dead
8	16B	27 ± 0	34 ± 0	35

b.

ROLL#	AREA	IMAGERY[1] #ADULTS 1	#ADULTS 2	#ADULTS 3	#PUPS 1	#PUPS 2	#PUPS 3	GROUND-TRUTH #PUPS
6	13B	52(1)	51(1)	51	50(6)	55(1)	52(4)	86 + 1 in water
7	14A	20	20(1)	19	27(4)	31(8)	27(1)	43
	14B	18(3)	20	18	22(2)	26(5)	19(2)	
7	15A	28(1)	25(1)	25	43(1)	46(5)	46(5)	56 + 1 in water
	15B	17(2)	21	21	34(1)	34(4)	33(6)	+ 2 dead

[1]Counts made on this imagery were characterized by increased variability between counters and numerous "doubtful" seals which could not be positively identified. For this reason the counts are given by counter (1, 2 and 3) with "doubtful" seals given in brackets aft each individual count.

use of negatives did not resolve "doubtful" seals in roll 7 and one area of roll 6 (13B) because the imagery was out of focus.

After the above analyses were completed and rechecked, comparisons were made with counts recorded by the ground-truth crew in the field (Table 2). To this time, these results were known to C.K. Capstick who was in charge of the on-ice counts. None of the 5 individuals involved in photointerpretation had any prior knowledge of these counts.

Counts of pups in areas 1A, 1B, 4, and 16, were very similar to the actual ground counts (Table 2). The results from area 8 were somewhat different (19 vs 26). Aerial counts from 13B, 14A, 14B, 15A and 15B underestimated the number of seals counted by the ground-truth crew (Table 2b).

On the Front, the two observers examined 232 pups on small (less than 30 m maximum dimension) loose pans of ice near the Arctic Explorer on March 14. Of these, 6 per cent were hidden from overhead view and another 7 per cent were classified as doubtful i.e. there was some question as to whether these seals would be detected by aerial photography (Table 3a).

Somewhat comparable observations from the Gulf of St. Lawrence ground-truth areas indicated that more than 98 per cent of the pups were in the open and that the number of pups classified as doubtful, dead or in the water totalled about 1 per cent (Table 3b).

DISCUSSION

The objectives of this year's ground-truth operation were to locate and delineate at least 10 representative areas on the ice, each about 30 x 300 m in both the Gulf of St. Lawrence and on the Front off Labrador. These areas were then to be photographed from the air and counted on the ground to provide, ideally, an indication of the propor-

tion of seal pups not detected by ultraviolet photography during the 1977 aerial census of whelping harp seals (Lavigne et al., 1977).

Several problems were encountered which limited the success, and thus, the utility of this ground-truth experiment. Some of the imagery obtained was of poor quality and as a result could not be used to obtain reasonable counts of seals on the ice. Detailed consideration of possible causes related to the lack of focus and poor contrast on the last half of film roll 6 and all of roll 7, failed to identify any satisfactory explanations. Such results might be attributed to improper focusing of the lens, the use of exhausted developer and/or fixative or the presence of haze near the surface of the ice (Lavigne et al., 1975). It seems unlikely, however, that these factors were involved. The procedures employed produced acceptable results on other film rolls, and no significant amount of ground haze was noted when these films were exposed.

Helicopter crabbing, changes in altitude during photography, and problems associated with aligning a helicopter over the centre of a ground-truth area resulted in the rejection of imagery from several additional areas (Table 1). In these instances the whole ground-truth area was not completely photographed and any count of seals obtained on the film are thus essentially meaningless relative to the counts made in the whole area at ice level.

During the analysis of the imagery it was also noted that some seals were obviously moving during the aerial photography. As a result, some seals may have been counted in the aerial photographs but not by the ground-truth crew several minutes later. Similarly, some seals may have moved into the area after the photography but before the ground count was completed.

In order to outline the ground-truth area on film, the dye markers on the transparencies were joined with straight lines. The numeral square and the end markers did not, however, always line up

exactly. Thus, the ground-truth crew's on-ice perception of the area, and the photointerpreters' projection of this area could easily differ, and the position of the boundaries of an area obviously influences the total count of seals obtained for that area. For example, many seals were found near the border of area 8 and the somewhat arbitrary position of the boundaries would determine whether or not they were actually included in the counts by the photointerpreters. This problem alone may well explain the discrepancy between the number of seal pups counted on the ice in this area (26) and the number counted on film (19).

Despite these problems and potential biases in the ground-truth procedure, it would appear that reasonably good agreement between on-ice counts and counts from photographs was obtained using good quality imagery. In areas 1, 4, 6, 8, and 16B, ultraviolet aerial photography accounted for 94 per cent of the pups counted by the ground-truth crew (Table 2a). If area 8 (see above) is not included, the percentage detected by ultraviolet aerial photography becomes 97 per cent. Counts made on poor quality imagery, however, consistently underestimated the number of pups counted on the ice. In addition, counts of both adults and pups were characterized by increased between-counter variability, and the photointerpreters often recorded several "doubtful" seals (Table 2b).

In conclusion, the problem of seal disturbance by human activity was not completely overcome using this ground-truth procedure. There is still relatively more disturbance, and thus more variability associated with ground-truthing than is associated with the actual aerial census. Results of the ground-truth operation are biased by factors which do not influence the results of an aerial census. In addition, the ground-truth procedure employed this year requires a reasonably stable ice platform. This was not obtained at the Front, and the ground-truth operation had to be aborted, even though conditions were

suitable for an aerial census (Lavigne et al., 1977). Thus, data from this ground-truth experiment do not provide suitable correction factors to apply to the results of the aerial census (Lavigne et al., 1977).

Unless problems associated with satisfactory delineation of ground-truth areas without disturbing seals can be overcome, alternative methods of assessing the detectability of seals should be employed. The use of human observers to classify seals as visible or hidden, as was necessitated on the Front this year, would appear to provide satisfactory data at a fraction of the cost of a sophisticated, but fragile, ground-truth procedure. More animals can be observed per unit time and sufficient observations can be obtained concurrently with an on-going aerial census. Use of this method only requires the assumption that seal pups and adults absorb ultraviolet radiation (Lavigne and Øritsland, 1974) and will thus appear on film if they are in direct line with a properly functioning camera.

The results obtained for the Front on March 14, 1977, (Table 3a) indicate that 6 per cent of the pups were hidden from view and an additional 6.9 per cent were classified as doubtful. On the basis of these results it has been suggested that a factor of about 10 per cent might be used to correct the results of the aerial census for harp seal pups not detected by ultraviolet photography. Somewhat similar data obtained by the ground-truth crew in the Gulf (Table 3b) would suggest a comparable correction factor of about 1 per cent, reflecting the vastly different ice conditions in this area in 1977.

Ice and weather conditions, and timing of harp seal reproductive behaviour vary from year to year. Use of correction factors derived in one year to modify the results of surveys conducted in other years is not warranted.

TABLE 3

Qualitative assessment of the detectability of harp seal pups by aerial photography by on-ice observers

	CLASSIFICATION	#PUPS OBSERVED	% OF TOTAL
) FRONT	In the open	202	87.1
	Hidden from above	14	6.0
	Doubtful	16	6.9
	TOTAL	232	100.0
) GULF	In the open	869	98.86
	Hidden from above	0	0
	Doubtful	2	0.23
	In water	3	0.34
	Dead	5	0.57
	TOTAL	879	100.0

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