METHODOLOGY FOR MAINTAINING OBSERVER INDEPENDENCE IN AERIAL STRIP TRANSECT SURVEYS

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Abstract: We describe the internal communication systems and data recording protocol used for aerial strip transect surveys of polar bears (*Ursus maritimus*) conducted in the Beaufort Sea in June 1994. The communication system permitted 4 observers and a pilot to independently communicate bear sightings to a data recorder. This method allowed us to estimate the proportion of animals missed on the inside edge of the survey strip and within the survey strip. We discuss the effectiveness of our methods and their applicability to other aerial surveys.

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When sampling a population using line transects, animals along the centerline are always assumed to be detected. However, in many instances where these sampling methods are employed, this assumption is violated. Buckland et al. (1993) reviewed procedures for estimating the proportion of animals missed along the centerline ($g[0]$) from simultaneous counts made by independent observers. Typically, aerial surveys conducted with independent observers involve observer pairs seated fore and aft on the same side of the aircraft; to be independent, each observer must not influence the detection of animals by the other observers in the survey aircraft. The proportion of animals missed in the survey strip can also be estimated from these independent counts (double count methodology: Cook and Jacobson 1979, Bayliss and Yeomans 1989, Graham and Bell 1989, Marsh and Sinclair 1989, Crête et al. 1991).

These estimation procedures require data to be recorded in such a way that different observations of the same animal or group can be identified during analysis. We designed a communication and data recording system that allowed each of 4 observers and a forward observer (pilot) to independently communicate sightings to a data recorder, and we used this system during aerial surveys of polar bears. We describe the internal communication and data recording equipment and protocols that we used during the surveys and discuss the effectiveness of our methods for maintaining observer independence and efficiently recording survey data.

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MATERIALS AND METHODS

During June 1994, we conducted aerial surveys for polar bears over the sea ice north of Deadhorse, Alaska. We simultaneously tested several proposed methods for estimating polar bear population size, including aerial strip-transect surveys, single-season mark–resight methodology, and multi-year mark–recapture methodology (Garner et al. 1993). Four independent observers were used during the surveys so that estimates of $g(0)$ and the proportion of animals missed within the strip could be derived for the strip transects.

Transect lines were flown using a Bell 212 helicopter and a deHavilland Twin Otter fixed-wing aircraft at a speed of 185 km/hour and an altitude of approximately 90 m. Parallel transect lines were primarily used; however, during 1 phase of the survey, lines were flown in a saw-toothed pattern (see Garner et al. 1993). Surveys were conducted with observers seated both fore and aft on each side of the aircraft

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(Fig. 1); the pilot served as a forward observer. A sixth crew member recorded sighting reports and other survey data on a laptop computer. The fore and aft observers on each side of the aircraft switched seats at the end of every second transect line.

All crew members wore headphones connected to the aircraft's intercom system. Observers were visually separated by curtains placed between the front and rear positions. In the helicopter (Fig. 1b), curtains were also placed between the front observer and pilot positions (cabin partitions made this installation unnecessary in the fixed-wing aircraft; Fig. 1a). The curtains prevented any visible response by an observer when sighting a bear from influencing the detection of that bear by another observer.

Internal Communications

Independent Signaling Device.—For each aircraft, we constructed and installed a signaling device that allowed each of the 4 observers and the pilot to independently notify the data recorder of polar bear observations (Fig. 1c). A visual signal was sent to the data recorder via 5 panel lights mounted on the cover of a small box. Each of these 5 lights was independently connected to a momentary toggle switch mounted on a hollow wooden dowel. All 5 lights were also connected to a small piezoelectric buzzer mounted in the right earpiece of the data recorder's headset, with a control that allowed the data recorder to adjust the volume. A toggle switch was placed at each observer position and the light box was mounted on a laptop computer at the data recording position; each panel light on the light box was labeled with its corresponding aircraft position. A 12-volt rechargeable battery powered the system.

Protocol for Internal Communications.—Upon sighting a bear (or bear group), an observer pressed the toggle switch for 5 seconds, which lit up the corresponding light on the light box and triggered the headset-mounted buzzer. These signals notified the recorder to enter a computer sighting record for the observer position indicated. After a 15-second delay (about 0.8 km further travel) to allow the second observer time to see the bears, the data recorder an-

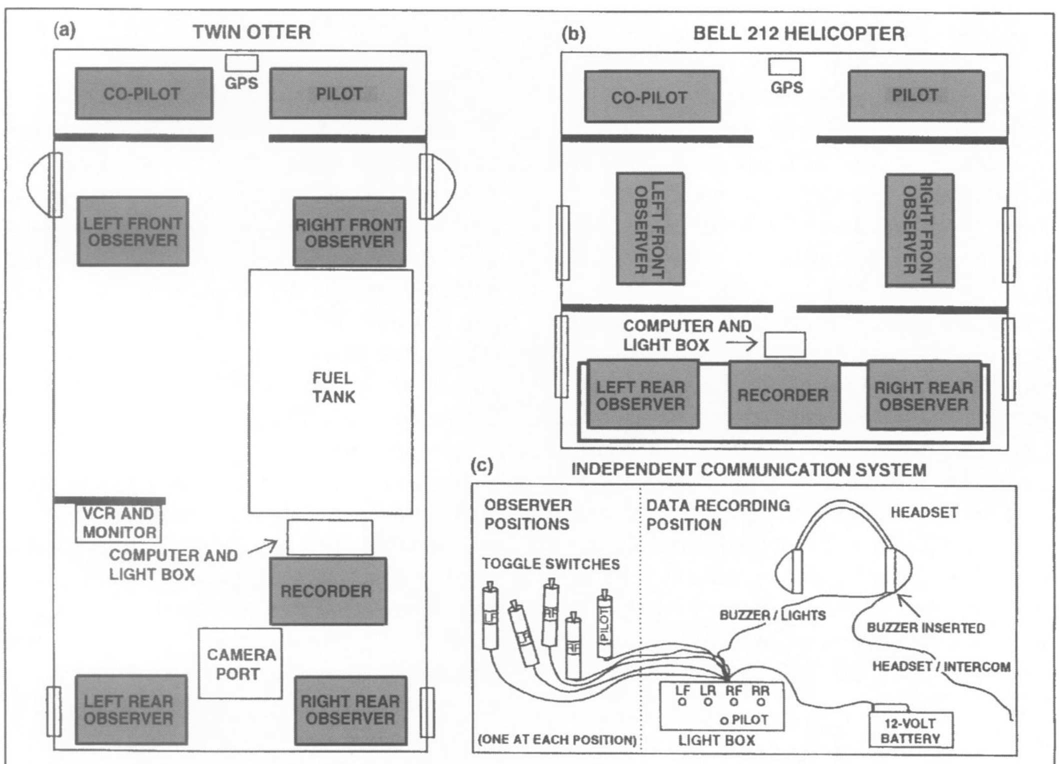

Fig. 1. Schematic diagram of the survey crew layout (a and b) and equipment (c) for aircraft used during aerial strip transect surveys of polar bears in the Beaufort Sea, June 1994. Curtains and cabin partitions used to visually isolate observers are indicated by heavy black lines.

nounced the sighting via intercom. The aircraft then left the transect line to relocate and inspect the bear or bears sighted; the break in the transect line was recorded in the data file. Observers used the intercom to direct the pilot back to the bear or bear group and to communicate sighting details to the data recorder. The intercom also was used throughout the surveys to report sightings of other species, polar bear tracks, and kill sites. After examining the bears, the aircraft returned to the transect line and continued the survey.

Data Recording

We recorded data on data sheets and on a laptop computer running MS-DOS (Microsoft Corp., Bothell, Wash.). The serial port of the computer was connected with the on-board Trimble Navigator global positioning system (GPS) receiver (Trimble Navigation, Sunnyvale, Calif.). The aircraft's location was automatically recorded at 1-minute intervals, and observation record details were entered manually using a data-logging program customized for our survey by the program author (J. Cubbage, Cascadia Research, Olympia, Wash.). In addition to latitude and longitude, for each record the program automatically included date, time, entry type, and transect number. The data recorder entered other variables for some record types (Table 1). Data records were automatically entered by the program into an ASCII text file on the hard disk and could be sent to a diskette or printer.

The following information was recorded in the computer file: (1) beginning and end points of transect lines and stop–start points within transects, (2) animal observations by observer seat position, (3) ice and weather changes, and (4) comments. Each observation type was assigned to a specific function key on the computer keyboard (Fig. 2; Table 2). For some observation types, the assigned key simply entered a record into the data file. For other types, a data entry template (Fig. 2) prompted the recorder to enter values for additional variables. Other function keys could be pressed while a data entry template was open; these additional entries were stored in a temporary buffer. Upon completion of the active template, records in the buffer were sequentially entered into the data file and associated templates were displayed for editing. A function key allowed the recorder to assign observer initials to each observer position. These initials were automatically entered by the program for sighting records. The delay between the report of an observation and the recorder pressing a sighting key was usually less than a few seconds (<200 m traveled).

Data entered by the recorder for a sighting report were limited to species, group count, observer initials, and codes to indicate whether the sighting was also reported by the paired observer. Additional information regarding polar bear sightings was recorded by the observers and the data recorder on data forms, with each sighting identified by its event number.

The function keys used to enter the locations of changes in ice and weather did not open data entry templates; rather, detailed records of ice and weather conditions were written by 1 observer on separate data sheets. For each ice or weather change entered into the computer data file, the

Table 1. The computer data record format used during aerial strip transect surveys of polar bears in the Beaufort Sea, June 1994. The first 9 variables were automatically entered by the program for all data records.

Variable	Column	Determined by
Observation type	1	Function key
Record number	3–6	Automatically incremented
Date	8–15	Computer
Time	17–24	Computer
Latitude	26–34	GPS
Longitude	36–45	GPS
On/off effort	47–49	Automatically entered, toggled by F8/F9 keys
Transect number	51–53	Manually entered, carried forward unless changed
Block number	55–56	Manually entered, carried forward unless changed
Observer ID	58–59	Defined by function key
Species	61–62	Manually entered, carried forward
Group size	64–67	Manually entered, not carried forward
Sighting number	69–71	Automatically entered consecutively if Y entered for new sighting
Also seen by alternate	73	Manually entered (Y or N)
Comments	75–132	Manually entered

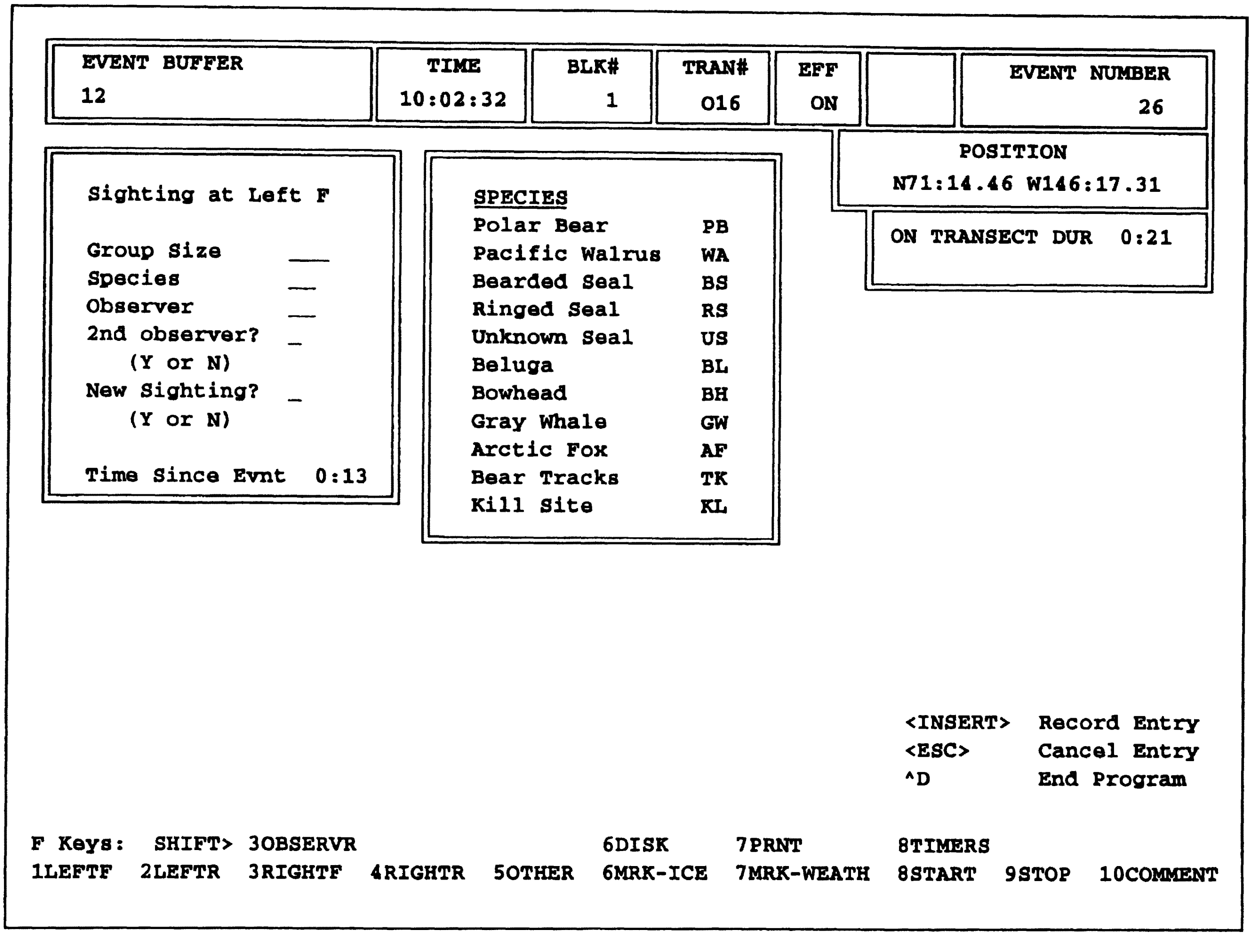

Fig. 2. Data entry screen displayed by the computer program used during aerial strip transect surveys of polar bears in the Beaufort Sea, June 1994. The left-front and left-rear sighting keys have been pressed in this example (event buffer code 1 represents left-front observer; 2, left-rear); the "event buffer" box displays the event codes for these records until they are entered into the data file.

respective event number was recorded as a part of associated written records.

RESULTS AND DISCUSSION

Internal Communications

The communication system was used to report 28 different bear groups (37 total bear group reports). The system worked well in most instances; however, in 2 cases the observer announced the sighting over the intercom before silently signaling the recorder. In 1 instance the audio communication was unclear and did not affect the alternate observer. Spacing between observers was minimal in the helicopter, thus curtains between observers were particularly important to maintaining observer independence aboard this aircraft. The response of an observer to spotting a bear could easily have influenced the detection of that bear by another observer had the curtains not been in place.

Data Recording

The data logging program was used for >11,945 km of strip transect sampling, during which 2,121 sighting reports (including reports of polar bears, other species, polar bear tracks, and kill sites) were recorded. The program proved efficient for recording survey data. However, each sighting required several seconds to record; consequently, the frequency of ringed seal (*Phoca hispida*) and bearded seal (*Erignathus barbatus*) sightings, ice, tracks, and weather changes occasionally was too great for the recorder to enter all reported information. Polar bear sighting records were given priority by the data recorder, and because

Table 2. Functions of programmed computer keys used during aerial strip transect surveys of polar bears in the Beaufort Sea, June 1994.

Key	Variable/function
F1–F5	Observer sightings
F6	Mark change in ice
F7	Mark change in weather
F8	Start transect and enter transect and block numbers; sets effort to "ON"
F9	Stop transect (does not stop logging); sets effort to "OFF"
F10	Comment line
SF3[a]	Observer identification for each seat position; did not enter data line
SF6[a]	Toggle disk drive on/off; did not enter data line
SF7[a]	Toggle printer on/off; did not enter data line
SF8[a]	Set interval for automatic logging of GPS location; did not enter data line

[a] S = shift.

of the low frequency of bear sightings, these records were not difficult to maintain.

We encountered 1 notable problem analyzing the data files from the surveys. Beginning and end points of transects were marked with the same event codes that marked stop–start points within a transect. We examined the files and edited the survey data to fix the problem, but minor modifications to the survey software would eliminate the need for editing. Two additional function keys could be programmed to mark stop–start points within transects with distinct event codes; these keys could toggle the effort entry (off and on), but retain the transect number and block number (an additional line identification variable) designations for each record entered while off the line.

Recommendations

Our independent signaling system was relatively easy to construct and required minimal time to install. We believe the system could be used for other surveys where the expected sighting rate is low to moderate and where the coordinates of sightings along the transect line or relocation of objects following a sighting report are of interest. System limitations would likely render it less effective when sightings are frequent. To ensure that the recorder received sighting signals long enough to record them, we instructed observers to press the toggle switches for 5 seconds; if >1 sighting was made by an observer in that 5 second period, our system would not permit immediate separate reports of each observation. Also, given the 15-second delay from the initial report of a sighting (to the data recorder) to announcement of that observation, it would likely be difficult to record sighting details, such as group counts, without confusion; verification of which sightings were made by both observers could prove difficult as well.

The data logging program and data recording protocol were efficient; use of a central data recorder allowed observers to more freely concentrate on detecting bears. Because we left the transect line to relocate bears sighted, most written records of bear sightings kept by observers were made while off the transect line. To ensure completeness and accuracy, our experience suggests that data entered into the computer record should be kept to a minimum. Data not critical to a given record can be written on prepared data forms; the event number of a computer entry can be noted with the written record to permit later merging with the computer file.

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