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BIAS IN RADAR DATA RECORDING TECHNIQUES

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Abstract.—Three sets of data taken from the same radar screen using two time exposure and one time lapse photographic recording systems were found to have small but significant differences for direction and speed of detected migrant birds. These differences appear due to minor system biases with regard to types of radar echo detected.

PREJUICIO EN LA TÉCNICAS PARA RECOPILAR DATA UTILIZANDO RADAR

Resumen.—Se detectaron pequeñas diferencias, pero significativas, en la dirección y velocidad de aves migratorias, a base de tres grupos de datos tomados de una misma pantalla de radar utilizando exposición doble y un sistema fotográfico de tiempo controlado. Estas diferencias parecen haber sido causadas por pequeños vicios del sistema de radar en cuanto a el tipo de eco detectado.

Radar observations of migrant birds are usually recorded photographically from the Plan Position Indicator display (radar screen) of the radar (see Eastwood 1967). Either time exposures or time lapse movie films may be used to obtain direction and speed of movement. I recently had an opportunity to compare three sets of data taken from the same radar screen using two time exposure techniques and one time lapse technique, and found small but significant differences between the three data sets for some variables.

METHODS

From 25 Aug. to 26 Oct. 1983 I studied bird migration on the island of Guam with an FPS-93 surveillance radar (frequency 1300 MHz, peak power 2.46 MW, antenna rotation rate 5 RPM). Data were recorded from the screen of the radar with the following three camera systems:

System A: a 395 mm format Polaroid 340 camera made time exposures of 240 to 570 s on ASA 3000 black and white film as described in Williams et al. (1977): for the last 60 or 120 s the shutter was closed and then reopened again, allowing moving echoes to produce a streak with a dot at the end indicating the direction of movement. The length of the streak plus dot was measured from the Polaroid print using a 5× lens. Average range of the echo, distance moved (length of the streak and dot), direction of movement, and duration of the exposure were entered by hand into a computer program which calculated speed and other variables.

System B: a 35 mm format Pentax Spotmatic camera with a 28 mm lens made time exposures on ASA 120 black and white film. The time exposures were made as described by Osgood (1982): three time exposures were made in rapid succession; in each exposure a moving target produced a streak on the film. The three frames of film were then projected on

33 × 27 cm paper, aligned, and the streaks from each frame traced in a different color ink. True moving echoes were easily distinguished from non-moving line echoes as they produced three streaks aligned end to end in the proper time sequence. Only the middle streak (lasting 120 to 361 s) in the time sequence was measured for length and direction of movement. Analysis then proceeded as for the Polaroid system.

System C: a super 8 mm Kodak Analyst camera, modified to hold the shutter normally open, recorded one complete scan of the radar on each frame of film (see Kloeckner et al. 1982). The camera was automatically activated for periods of 3300 s at a time. These films were then projected on 43 × 32 cm sheets of paper and the echoes of all relatively small (compared to aircraft or rain clouds) targets moving at 20 to 200 km/h were traced at 10 frame intervals. The endpoints of the tracks formed by each series of traced echoes were digitized using a Hewlett Packard 9874A Digitizer and recorded with the duration of each track on an Apple IIe computer. These data were then transferred to the same program used for the analysis of the other two data sets.

For all three systems time was provided by a digital clock located within the photographic frame. Direction was measured relative to map coordinates displayed directly on the radar screen.

Only one camera system could be operated at a time; thus, although some observations were only a few minutes apart, simultaneous observations were not made with the three systems. The time lapse system (C) was activated automatically four to six times a day for 55 min, but for the analysis below I used only data gathered during the same 12 h period as systems A and B. The time exposure systems (A and B) were operated manually one or two times a day.

The Polaroid data (A) were scored by me in Guam. The 35 mm data (B) were traced in Guam by P. Grout, and scored by her at Swarthmore 6 mo later. The movie data (C) were traced and scored by P. Grout at Swarthmore. In all cases there was no selection of tracks; all observed tracks were traced and all tracks meeting the criterion for inclusion were scored.

RESULTS AND DISCUSSION

Table 1 shows significant differences in duration, direction, and speed, but not range, of bird echoes detected by the three methods. Upon finding these differences, I checked for errors in tracing, timing, measurement, scoring, and analysis. Table 1 excludes data from any questionable cases. The differences in duration reflect the different sampling windows of the three systems; systems A and B were limited to tracks of a few minutes while system C obtained tracks of almost an hour. Despite the disparity in track length there was no significant difference in range suggesting similar overall sensitivity of the three systems. The possible basis for differences in direction and speed are discussed below.

Occasionally observations were made sufficiently close together in time that tracks recorded by one system would be expected to show up on one

TABLE 1. Radar data taken at Guam, 1983. Analysis of variance of four variables in three data sets; number of tracks for each data set: A = 157, B = 200, C = 178.

Variable	Data type	Mean	SD	95% confidence interval	F ratio	P
Duration (s)					618.4	<0.0001
	A	430	91	415–444		
	B	243	36	238–248		
	C	1289	516	1212–1364		
Range (km)					2.44	<0.09
	A	43.7	17.7	41–47		
	B	43.1	17.2	41–46		
	C	40.2	12.6	38–42		
Direction (0 degrees = north)					7.13	<0.001
	A	177°	25.5°	173°–181°		
	B	183°	22.5°	180°–186°		
	C	187°	20.7°	184°–190°		
Speed (km/h)					27.8	<0.0001
	A	59.6	14.0	57–62		
	B	54.6	12.8	53–56		
	C	65.1	14.0	63–67		

of the other systems. On two dates we recorded enough tracks (23) to check for differences between systems B and C. Six tracks recorded on system B could be aligned with tracks recorded on system C and did not show consistent differences in speed or direction, but the remaining 17 tracks were recorded by only one of the systems. Thus, it appears that the systems differ in which tracks they record rather than in recording different results for the same tracks.

The differences reported here might result from measurement or calibration errors causing consistently high or low values to be recorded by some systems. Alternatively the systems might differ in their overall sensitivity to certain classes of migrant birds with different migratory directions or flight speeds. The analysis reported above and my extensive checking of the raw data leads me to reject systematic errors of one or more systems as the basis of the differences. An effort was made to control interobserver bias by having myself and P. Grout each score a small sample of each data set; there were no discernable differences. In addition, the tracks we scored were clearer and less numerous than I have encountered at any other radar site. Unlike migrations at continental radar sites, migrants over Guam consisted of small numbers of shorebirds (Williams and Grout 1985), which produced relatively large echoes and nonoverlapping tracks. Thus, I believe that our individual biases in scoring the data played a minor role, if any. I suggest instead that system C may have a tendency to favor echoes that are less persistent, such as extended flocks while systems A and B may preferentially record echoes that are detected for a short period of time, but are persistent within that time, such as lower flying, tightly clustered bird flocks. Such an analysis is consistent with the inability of time exposures (systems A and B) to record the diffuse migratory flights of passerines over continental areas while time lapse (system C) films when projected clearly convey the direction of passerine movement (Eastwood 1967).

Richardson (1972) cautions that comparison of bird migration data between different radar installations may be unreliable due to uncalibrated performance characteristics at each radar site. This *caveat* should be extended to include data recording and analysis. In particular, our results indicate that minor differences in direction or speed of migrants recorded by different camera systems should be interpreted with great caution.

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