ANGLE OF CANADA GOOSE V FLIGHT FORMATION MEASURED BY RADAR

Timothy C. Williams, Thomas J. Klonowski, and Philip Berkeley

A recent paper by Gould and Heppner (1974, Auk 91: 494) reports the measurement of several parameters of formation flight by Canada Geese (*Branta canadensis*) revealing considerable variation in formation flight of these birds and suggesting that factors other than aerodynamic advantage in flight may lead to the V flight formation (see also Heppner 1974, Bird-Banding 45: 160). Gould and Heppner used a photographic technique to record the appearance of avian flight formations, and the angle of the V was obtained by an ingenious geometrical transformation. The requirements of the technique were such that of 34 formations filmed only 5 yielded measurable angles. In an effort to extend these data we have used a high resolution radar to measure the angles of V formations of geese.

The radar used was a mobile, high resolution, low power radar (termed an Ornithar) designed for studies of avian behavior by T. C. Williams, and is described in Williams et al. (1972, Amer. Birds 26: 555). Further details on the use of the Ornithar will be found in Williams et al. (1974, Flight patterns of birds studied with an "Ornithar." Proc. Conf. Biol. Aspects Bird/Aircraft Collision Problem, Arlington, Virginia, USAF Off. Sci. Res.). The Ornithar is a 3-cm wavelength, 3-kw peak power radar with a 30° vertical beamwidth (3 db points) and a 2.5° horizontal beamwidth (3 db points). High resolution is obtained by operating at a pulsewidth of 0.08 microseconds and a maximum range of 1 km. The radar antenna rotates at 32 rpm. Simultaneous visual and radar observations on ducks and geese revealed that the Ornithar reliably distinguished two targets at 400–500 m range if they were separated by at least 50 m. Thus, the resolution is sufficient to display the angle of a V of geese as shown in Fig. 1, but not to separate individual members of the flocks.

The Iroquois National Wildlife Refuge in western New York State is a temporary stopover for thousands of Canada Geese (primarily subsp. *interior*) during the spring and fall migratory seasons. In the spring of 1973 the first of these birds had arrived 13 February and most of the remaining by 15 March. During March and April 1973 we positioned the Ornithar approximately 2 km to the southwest of the largest pond in the Iroquois Refuge. From this position we were able to watch flocks

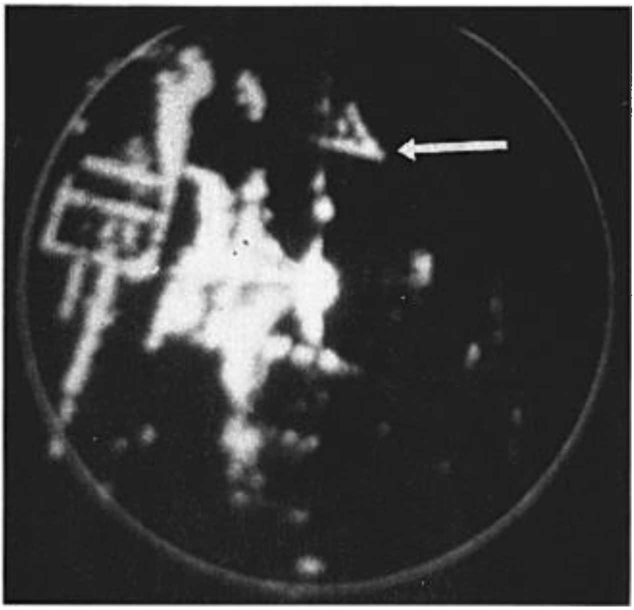

Fig. 1. A single frame of the 8-mm film used to record radar data. Arrow points to a group of geese flying in a V. Diameter of the area shown in radar display = 1.85 km. Other radar echoes are from objects on the ground (primarily trees and farm fences).

of geese moving to and from the pond on daily feeding flights, at altitudes estimated to be between 40 and 80 m above the ground. Observations were made during 6 days and 6 nights, between 1600 and 2300 local time. The sky was clear on all days, with southwest winds at less than 10 kph. The temperature was between 5° and 16° C. Data reported here were obtained on 27 and 29 March; on the other 4 days, geese chose flight routes that did not pass near enough to the radar to obtain good quality data. V formations were never seen during the six nights we watched, but possibly at night geese were not moving or they were using routes too far from the radar. The radar data were recorded on Super-8 mm film from the PPI display of the radar as described in Williams et al. (1972 ibid.). Each frame of film recorded data from a single revolution of the radar and showed the position of one or more V's of geese as in Fig. 1. Single frames of the films were projected on large sheets of white paper and a straight line was drawn on the paper down the leading edge of each arm of the V formation. The intersection of these two lines was measured as the angle of the V formation. If the films showed isolated radar echoes corresponding to a few geese that left

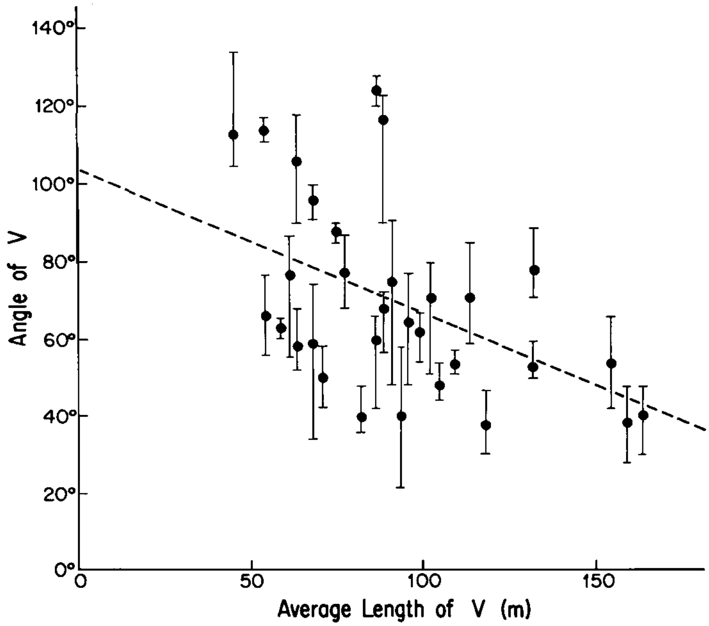

Fig. 2. Angle of V formation of Canada Geese observed with radar vs. total length of both arms of the V. Bars indicate total range of observed angles for each formation observed.

the V formation, these were ignored. If a line could not be clearly fitted to a flight formation, the data were not used.

We recorded 54 V formations for 2 to 10 rotations of the radar beam. The closest V measured was 230 m from the radar and the most distant was 920 m. V's seen for a single rotation or formations that did not show a clear V were not measured. The V's were rarely regular and more often should be described as a "J" (see Heppner ibid.). In many formations, although the arms of the V were relatively straight, the apex of the V was rounded. The angle of a single V formation did not remain constant with successive sweeps of the radar beam but varied by 5° to 43°. The mean values for each of the measured V's varied between 38° and 124°. The range and the mean of measured angles of V formations are plotted in Fig. 2. The variance between V's was significantly greater than the variance within V's ($P < 0.001$), indicating significant differences between the angles of different V's.

Errors may be introduced in our measurements in three ways: distortion of the angle of the V by the radar display, errors in measurements of the recorded radar data, and departures from level flight or V flight

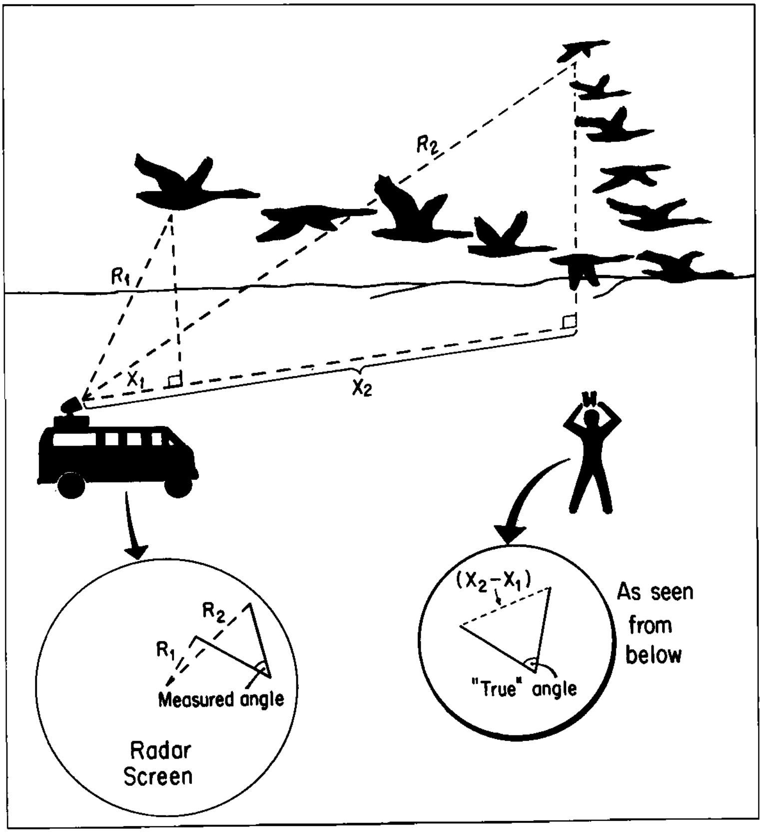

Fig. 3. Diagram illustrating distortion of the angle of a V of geese by the PPI screen of a radar. V seen on screen of mobile radar is compared with angle of the same V as seen by an observer directly below the geese. Altitude scale and magnitude of the distortion is greatly exaggerated. Actual distortions were probably less than 3°.

formation by the geese. A radar PPI display such as shown in Fig. 1 shows the position of objects giving radar echoes as a function of slant range (straight line distance between the target and the radar) and azimuth of the target from the radar. The difference between the slant range and the distance from the radar to a point on the earth's surface under the target will result in the measured angle being smaller than the angle of the V projected on the earth's surface. This relationship is illustrated in Fig. 3. The magnitude of this distortion increases with altitude of the target and decreases greatly with range. (The distortion is greatly exaggerated in Fig. 3.) The distortion in a V with an angle of 80° at an altitude of 60 m at a range of 230 m would be 2.5°; at a range of 1000 m the distortion would be 0.26°. If we had incorrectly estimated the altitude of the geese by a factor of 2 and the true altitude were 120 m, the error at 400 m range would be a maximum of 3° for an 80° V. Measurements of the angle of a V from the radar films were repeatable to within 5° (2° in most cases). Although most of the formations of geese appeared to be in level flight, this is difficult to ascertain from the ground. If the geese happened to be flying so that the far arm of the V were higher than the near arm as seen from the radar, then the PPI display of the radar would give a more accurate picture of the angle of the V than would a photograph taken by someone directly below the geese. For an 80° V with arms of 100 m each at a range of 400 m from the radar at an altitude of 60 m, the two geese at the ends of the V would differ in altitude by only 19 m to cancel the distorting effect of the radar's PPI display.

As all our measurements were made on the same species during 2 days with almost identical weather conditions, it does not appear that the angles of the V formations of geese we measured were affected by cloud cover, temperature, wind speed or direction. A plot of angle of the V vs. airspeed of the birds revealed no significant correlation ($r = 0.005$, $P > 0.05$) between these variables. As shown in Fig. 2 the only factor that we found to be correlated with the angle of the V was the size of the flight formation as measured by the total length of the arms of the V ($r = -0.482$, $P < 0.01$).

Our data lead us to concur with Gould and Heppner (1974 ibid.) that "V" formation flight by Canada Geese is probably not the result of a simple aerodynamic relationship but may have behavioral components as well. We would further add that one may expect the factors affecting this type of flight to be complex as the basic formation is so variable.

Note added in proof.—On 23 March 1975 Frank Heppner and the authors made simultaneous observations on several small V formations at the Iroquois National Wildlife Refuge. Of these, two gave data that were measurable both with Heppner's optical technique and the radar technique described above. The angles measured with the two techniques showed no significant differences. However it was apparent that some V formations measurable with Heppner's optical technique were too small to be resolved by the radar and some large formations measurable on the radar were too poorly organized at the apex of the V to be measurable with Heppner's optical technique. Thus, the large variance in the angle of V flight formation we observed (compared to that reported by Gould and Heppner) may be due to a different scale of observation.

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Department of Biology, State University of New York at Buffalo, Health Sciences Building, Buffalo, New York 14214. Present address of first author: Woods Hole Oceanographic Institute, Woods Hole, MA 02543.
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