

**by H. Blokpoel**

**Migration of  
Lesser Snow  
and Blue Geese  
Part I**



**Canadian  
Wildlife  
Service  
Report Series  
Number 28**



Environment Canada  
Wildlife Service

Environnement Canada  
Service de la Faune

**Migration of  
Lesser Snow and  
Blue Geese  
in spring  
across southern  
Manitoba**

**Part I:  
Distribution,  
chronology,  
directions,  
numbers,  
heights and  
speeds**

by H. Blokpoel

Canadian Wildlife Service  
Report Series Number 28

A series to consist of two parts:

Part 1:

Distribution, chronology, directions,  
numbers, heights and speeds

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Influence of the weather and  
prediction of major flights

by H. Blokpoel and M. C. Gauthier

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Price subject to change  
without notice  
Information Canada  
Catalogue No. CW65-8/28  
Ottawa, 1974

Design: Gottschalk + Ash Ltd.

Printing:  
Imprimerie Jacques-Cartier Inc.  
Contract No. 02KX-KL-131-3-9138

Cover photo by C.G.Hampson



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### **The author**

Hans Blokpoel received B.Sc. and M.Sc. degrees in biology from Leiden University, Holland. His work at the Fisheries Research Institute in Ymuiden, Holland on fish behaviour with respect to towed nets had only just begun when he was drafted into the Royal Netherlands Air Force. He spent two years at the Air Staff, The Hague, working on military bird strike problems.

In 1967 he came to Canada to work on contract with the Canadian Wildlife Service to develop a bird migration forecast system for Canadian Forces Base Cold Lake, Alberta. In 1968 Mr. Blokpoel became a member of the CWS staff in Saskatoon and in 1971 he was transferred to Ottawa. Radar studies of bird movements and developmental work on a bird radar for use in air traffic control operations are the main aspects of his work.

### **Acknowledgements**

The project was started at the suggestion of W. W. H. Gunn and carried out under the auspices of the Associate Committee on Bird Hazards to Aircraft of the National Research Council of Canada. I am thankful to V. Skinner, Chief, Air Traffic Control, Winnipeg, and his staff for their interested co-operation; to A. Lamont, Head, Winnipeg Meteorological Office, and his staff for providing weather data; to R. W. Gemmell for his field assistance and help with the analysis of the radar films; to F. Harbrink for operating the WF-3 radar; to T. Hammell and P. Willis for preparing and installing the film equipment; and to L. Wight for providing the band data.

Snow goose records were gratefully received from the following: G. D. Adams, J. Aitken, P. Aylward, H. Baker, W. Banting, B. Batt, J. A. Barrie, L. J. Bidlake, R. Blanchard, R. S. Brown, R. A. Bueller, T. Chudy, G. Collins, M. Comeau, J. Conway, H. W. R. Copland, G. E. Cotter, T. L. Couture, R. D. Dittmar, C. Dixon, M. Dixon, G. Edwards, J. Frisholz, E. Fritzell, K. Gardner, R. W. Gemmell, A. Gervais, M. Gillespie, D. Glays, G. Graham, G. de Groot, W. W. H. Gunn, D. R. M. Hatch, E. Harris, W. C. Harris, E.

Hill, J. Hines, R. C. Hutchinson, F. Jenkins, R. E. Jones, R. Kemp, L. King, W. G. Leitch, H. Libby, E. Marner, S. A. McIvor, J. McKay, M. R. McLandress, D. Molloy, A. Montgomery, H. Mossop, A. Nýssen, A. J. Pakulak, D. Purvis, D. G. Raveling, D. G. Rays, D. Reese, E. Sainsbury, R. Schweinsburg, N. R. Seymour, A. Shortt, G. J. Smith, K. Steward, R. W. Sutton, H. Tirschman, G. H. Townsend, W. Urbanski, L. Wallace, G. Wood, J. Woolison and V. E. Yakobi.

I am grateful to H. Boyd for his comments on an earlier draft of this paper.

### **Perspective**

Collisions between birds and aircraft (bird strikes) are a problem in both civil and military aviation and will continue to be so in the near future, as it appears very difficult to build bird-proof aircraft. Single-engine jet fighters on low-level high-speed missions are particularly vulnerable to bird strikes because a single bird ingested into the air intake can completely ruin the engine. Multi-engine jet liners are less likely to suffer serious bird strikes en route, but if birds do cause the crash of a big carrier (as they have done twice so far in North America), the results are catastrophic.

A near-disaster collision between a B-737 and migrating snow geese, near Winnipeg in the spring of 1969, provided the impetus for a research project at Winnipeg Airport to develop techniques for (1) detecting and warning of the spring snow goose migration and (2) predicting this annual flight.

The two standard surveillance radars used in Canada (the long-range AASR-1 and the short-range ASR-5) were found to detect flocks of geese very well. The recently introduced Bright Scan Display technique greatly facilitates bird detection. As surveillance radars do not provide height information on the bird flocks, work is now being carried out to develop an inexpensive height-finding radar for use in air traffic control operations (Hunt and Blokpoel, 1973).

The development of a technique to predict the spring snow goose migration requires a long-term study, which is likely to

result in a bird migration forecast system somewhat similar to the one now in use at Canadian Forces Base Cold Lake, Alberta (Blokpoel, 1973).

The work at Winnipeg is a pilot study, the results of which will have possibilities for application at other airports as well.

#### **Abstract**

In spring 1970 and 1971 the migration of Lesser Snow and Blue Geese (*Anser c. caerulescens*) in the vicinity of Winnipeg International Airport was monitored to prevent collisions between geese and aircraft.

Both the long-range and short-range surveillance radars at Winnipeg Airport detected the flocks of migrating geese very well. There was good agreement between radar data and visual observations made in and around Winnipeg.

Analysis of radar and visual observations provided information on the staging areas, routes, chronology, directions, numbers, ground speeds, heights and air speeds of the migrating geese.

#### **Résumé**

Au printemps de 1970 et de 1971, on a surveillé la migration des populations de Petites Oies blanches et d'Oies bleues (*Anser c. caerulescens*) dans les environs de l'aéroport international de Winnipeg, afin d'empêcher des collisions entre ces oiseaux et des avions.

Les radars à courte et à grande portée de l'aéroport de Winnipeg ont facilement détecté les oies, et les résultats de cette radio-détection ont concordé avec ceux des observations visuelles.

L'analyse de ces résultats a permis d'obtenir des précisions sur les phénomènes suivants: haltes; voies migratoires; dates, heures, direction et altitude des vols; nombre d'oiseaux; et vitesse au sol et en vol.

#### **РЕЗЮМЕ**

Весной 1970 г. и в 1971 году в окрестностях Виннипегского Международного аэропорта производилось наблюдение за полетом *Anser c. caerulescens* с целью предотвращения их столкновения с самолетами.

Наблюдение с помощью радара с малым, а также с большим радиусом действия в Виннипегском аэропорту позволило весьма хорошо обнаружить стаю перелетных гусей. Данные наблюдений радара совпали с результатами визуальных наблюдений, произведенных в самом Виннипеге и его окрестностях.

Анализ, проведенный с помощью радара, и визуальные наблюдения позволили получить следующие сведения о перелетных гусях: о маршрутах и времени, направлениях, путевых скоростях, высоте и скоростях полета.

# Introduction

The eastern populations of the Lesser Snow and Blue Goose, *Anser c. caerulescens* (snow geese), winter along the coast of the Gulf of Mexico. In spring they migrate in a north-northwesterly direction through the United States and into southern Canada. Their major staging areas are Squaw Creek, Missouri; Onawa, Iowa; Sand Lake, South Dakota; Devil's Lake, North Dakota; and southern Manitoba (Bellrose, 1968). When migrating from the plains in southern Manitoba to the coasts of James and Hudson bays the geese fly in northeasterly directions, often in large flocks. A large proportion of the migrating geese cross the Terminal Control Area of Winnipeg International Airport, an area with a radius of 30 n mi (56 km) with the centre at the airport.

In spring 1969 a flock of snow geese was struck by a civil airliner 12 n mi (22 km) northeast of Winnipeg. The aircraft was seriously damaged. The Associate Committee on Bird Hazards to Aircraft of the National Research Council of Canada was requested (1) to monitor this migration in spring 1970 and 1971, (2) to develop techniques to predict it and (3) to design and test techniques for determining the height of migrating flocks of birds for use in air traffic control. This work was begun by CWS under the auspices of the committee and is now a joint project of CWS and the National Research Council.

Work on the first objective provided the data for the present report as well as necessary background information for the second objective. Results of the continuing work on the third objective were given in a progress report (Hunt and Blokpoel, 1973).

The present paper deals with the staging grounds, migration routes, directions, numbers, heights, ground speeds and air speeds of snow geese in south-central Canada and is based on radar and visual observations made in 1970 and 1971. Most of the 1970 results were reported previously (Blokpoel, 1971) but are included here for easier reference.

# Methods and materials

CWS summer assistant, R. W. Gemmell, aims the WF-3 radar at a flock of snow geese prior to automatic tracking.



## Visual observations and band returns

Routine field observations of staging and migrating geese were made in the springs of 1970 and 1971 in the vicinity of Winnipeg. Non-routine sightings by volunteer observers in and around Winnipeg were reported in both 1970 and 1971. In the spring of 1971 members of the Winnipeg Bird Club and conservation officers in southern Manitoba were provided with reporting forms. Personnel at weather stations in northwestern Ontario also co-operated.

Detailed lists of sightings of migrating geese (66 records in 1970 and 99 in 1971) are deposited in the libraries of the Headquarters of the Eastern and Western Regions of CWS in Ottawa and Edmonton.

Spring band returns for the provinces of Ontario and Manitoba were obtained from CWS.

## Radar observations

1. Time-lapse films were taken of the screen of the AASR-1 23-cm long-range surveil-

lance radar of the Air Traffic Control (ATC) Centre at Winnipeg International Airport, May 2–19, 1970, and April 28 – May 22, 1971. The range was set at 60 n mi (111 km). The screen was fitted with a clock and data tab. The antenna made six revolutions per minute. Each second sweep was recorded on one film frame. Solman (1969) gives details of the camera setup and the manual of the Civil Aviation Branch (Canada Dept. of Transport, 1967) describes the AASR-1 radar.

Figure 1. Polaroid pictures taken of the Bright Scan display of the AASR-1 surveillance radar at Winnipeg International Airport. Range rings are 10 n mi (18.5 km) apart. Top of the scope is the Magnetic North (= True North  $-9^\circ$ ). The variable trail time (persistence of the echoes on the scope) was set at maximum and the display was then "erased" (i.e. all echoes were removed electronically). The

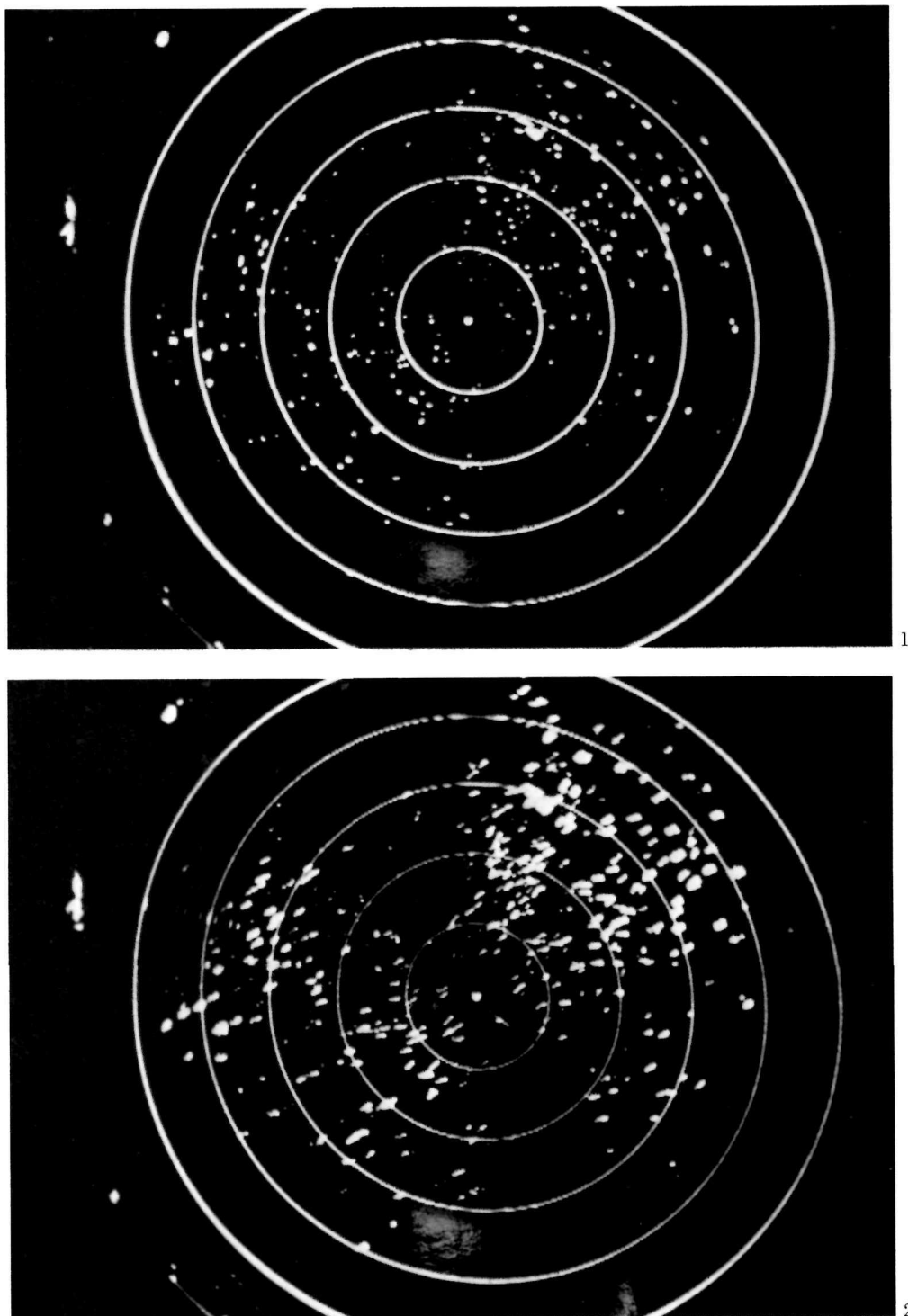
first picture was taken at 0014 CDT on May 16, 1970, and 50 sec after erasion. Pictures 2 and 3 were taken 2 min and 9 min after erasion. The display shows a heavy movement of "goose echoes". Note that few "goose echoes" are visible at close range. The dark sectors to the NNW and SSE are due to cancellation of "goose echoes" by the Moving Target Indicator

As the snow geese migrate in spring in northeasterly directions, in large flocks and at altitudes of up to more than 5,000 ft (1,520 m), one would expect the echoes of the goose flocks to be big, non-fluctuating, moving at a steady speed and on a straight course in directions between north and east and visible for long distances on the screen. All echoes with these characteristics were considered "goose echoes". Figure 1 shows a heavy movement of "goose echoes". See the appendix for further discussion of the "goose echoes" and arguments that the great majority (more than 90 per cent) of them are caused by snow geese.

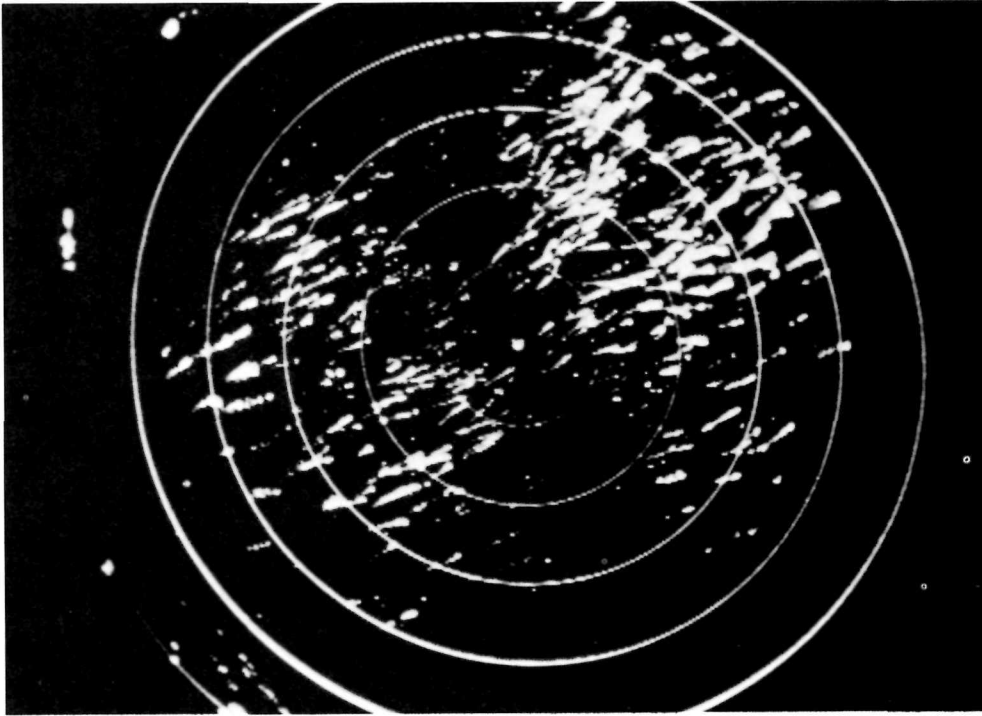
Directions of "goose echoes" on the 1970 radar film were determined from tracks obtained by projecting the film on a sheet of paper and manually tracking the path of the echoes with a pencil, and those on the 1971 films were determined using a Vanguard Motion Analyzer, with a sheet of mylar taped on its ground-glass projection screen. The latter method required one, the former two persons. All ground speeds of "goose echoes" were obtained using the Vanguard equipment. The mean air speeds of the geese were found by vector analysis of mean ground speed and mean direction of the geese, and the wind speed and direction at the height the geese were flying. Numbers of "goose echoes" on the 1970 radar films were obtained by counting the hourly numbers that crossed a line 50 n mi (93 km) in length and perpendicular to the mean flight direction. The centre of the line was 30 n mi (56 km) from the centre of the radar scope. No count was made of "goose echoes" on the 1971 radar films, because some of the films were of insufficient quality.

2. Observations were made with the 3-cm Precision Approach Radar (PAR) of ATC Winnipeg on two evenings in 1970. Details of the PAR are given in the manual of the Civil Aviation Branch (Canada Dept. of Transport, 1967). Height information obtained with the PAR was used for the air speed calculations.

3. In 1971 a balloon-tracking radar was used to track targets that caused "goose







3

echoes" (the positions of which were obtained from the AASR-1 scope), as well as visually observed goose flocks. Height, range and bearing readouts were updated every second and recorded every 30 sec. Details of this 3-cm, pencil-beam wind finding radar are given in the company's manual (Plessey Radar Ltd., 1970). This radar provided information on direction, height and ground speed of the flocks.

#### **Weather data**

Weather data for Winnipeg (including upper-air wind data obtained at 6-hr intervals) were provided by the Meteorological Office at Winnipeg Airport. In 1971 additional upper-air wind data were provided on my request.

#### **Terminology**

All times given in this report are Central Daylight Time (CST plus one) and all directions are in degrees azimuth, True North being 360° or 0°. The direction of the wind indicates from where the wind blows, the

direction of the birds to where the birds fly. Wind speeds were usually provided in knots: 1 knot (kn) = 1 nautical mile (n mi) per hour = 1.151 statute mile (mi) per hour = 1.852 km per hr = 0.514 m per sec. Heights were always given in feet: 1,000 ft = 0.189 mi = 304.8 m. These nonmetric units are used in the tables, but in the text the equivalent metric values are given as well.

# Results and discussions

## Staging areas

### Results 1970 and 1971

Observations of geese staging in southern Manitoba are given in Tables 1 (1970) and 2 (1971) and plotted in Figs. 2 and 3. A map of southern Manitoba is given in Fig. 4. In both years most geese staged along the international border between Cartwright and Windygates. Largest goose numbers were observed in the area of Pilot Mound – Crystal City – Snowflake – Windygates. Minor concentrations were observed near Whitewater Lake. In 1970 great numbers of geese were seen as far east as Dominion City (50 mi due south of Winnipeg) and a small number as far west as Coulter in the south-western corner of Manitoba.

### Discussion

Bellrose (1968) described the spring migration routes through the United States of the snow geese that winter on the Gulf Coast. Using seven sources of information, he developed the concept of “migration corridors”, which “differ from flyways in being smaller and more precisely defined as to species and population elements using them” (Fig. 5). At least 90 per cent of the geese wintering in Texas and Louisiana migrate to Devil’s Lake, North Dakota, in northerly or north-northwesterly directions. According to Bellrose the geese proceed from Devil’s Lake to “agricultural and water areas north-west of Winnipeg, Manitoba”. The first and most important stop-over in Canada used to be the Grant’s Lake area (Fig. 4), some 30 mi (48 km) northwest of Winnipeg (Soper, 1942), but since 1943 this area has not been used, possibly due to disturbance by low-flying aircraft (Soper, 1946). According to Lawrence (1953) the geese left the Grant’s Lake area in the late thirties and early forties and “they made Traverse Lake, a depression in the Red River valley in Minnesota, their main stop-over place.” D. R. M. Hatch (pers. comm.) reported that by the latter half of the 1950’s many geese staged near Snowflake and “Throughout the 1960’s, Snow Geese concentrated in excellent numbers in the Snowflake – Pilot Mound area and also

**Table 1**

Observations of Lesser Snow and Blue Geese staging in southern Manitoba during spring 1970

Date	Location (nearest town within 4 mi radius)	Estimated number	Observer
April 28	Whitewater Lake	5,000 – 8,000	J. P. Ryder
April 29	Boissevain	10,000	J. P. Ryder
April 29	Cartwright	5,000	J. P. Ryder
April 29	Mather	4,000	J. P. Ryder
April 29	Crystal City	21,000	J. P. Ryder
April 29	Pilot Mound	10,000	J. P. Ryder
May 6	Marquette	500	J. L. Bidlake
May 7	Pilot Mound	12,000 – 15,000	J. L. Bidlake
May 7	Crystal City	3,000 – 4,000	J. L. Bidlake
May 7	Purves	18,000 – 20,000	J. L. Bidlake
May 7	Snowflake	3,000 – 5,000	J. L. Bidlake
May 7	Windygates	3,000 – 4,000	J. L. Bidlake
May 8	Meadows	3,000 – 4,000	J. L. Bidlake
May 8–15	Sperling	3,000 – 5,000	J. Hines
May 13	Cartwright	2,800	R. C. Hutchinson
May 13	Morris to St. Jean (Red River Valley)	6,000	J. L. Bidlake and M. Comeau
May 14	Coulter	900	R. C. Hutchinson
May 16	Morris–Arnaud– Dominion City–Letellier	9,200	R. C. Hutchinson (from light aircraft)

around Boissevain. The Boissevain concentrations overflowed northwest into the Hartney – Souris area by 1965, and this area is now regularly used.”

The results shown in Figs. 2 and 3 fit well with the view of Hatch, who wrote (pers. comm.), “The largest and most regularly used concentration centre is the Snowflake – Pilot Mound area . . . . The second major concentration point is the Boissevain – Souris – Hartney area . . . . I doubt that there are more than 25% as many geese in this western concentration area as there are in the Snowflake – Pilot Mound area . . . . Small numbers of Snow Geese stop (1) in the Cartwright – Mather area connecting the east and west concentration points, (2) in the Red River valley, and (3) at Oak Lake. These are, however, minor stop-over areas.”

### Migration routes

#### Results 1970 and 1971

From the Manitoba plains the snow geese continue their migration to the breeding

grounds. The locations and size classes of the breeding colonies are given in Fig. 5, which shows that most birds are likely to fly in northeasterly directions to reach their breeding grounds.

Records of migrating snow geese in southern Manitoba totalled 66 in 1970 and 99 in 1971. Locations of the sightings during the main waves (55 records in 1970 and 87 in 1971) are plotted in Fig. 2 (1970) and Fig. 3 (1971). All migrating snow geese were seen to the east, northeast and north of the staging areas.

Observations of migrating snow geese in central and northern Manitoba and north-western Ontario are available only for 1971. Sightings reported by personnel of weather stations, the Royal Canadian Mounted Police and pilots are given in Table 3 and plotted in Fig. 6, along with inland spring band returns. Figure 6 shows that snow geese take northeasterly routes across the mainland to the coasts of James and Hudson bays.

## Discussion

Figures 2 and 3, as well as the radar data, indicate that the main migration in 1971 was more to the west of Winnipeg than in 1970.

The small numbers of snow goose observations and inland band returns in north-western Ontario may be explained by the very small and scattered human population in this large area and by the fact that many geese may pass unnoticed at night or when flying at great height. Furthermore, it is unlikely that the geese have major resting areas on the Precambrian Shield between the prairies and Hudson and James bays (A. J. Pakulak, pers. comm. and H. G. Lumsden, pers. comm.). Results for one period in 1971 do suggest a very rapid, probably non-stop flight to the coast: the first major movement in 1971 occurred on May 2 (with most hourly mean directions between 45° and 50°), and on May 3 the first snow geese were seen at Winisk, 600 mi (960 km) to the northeast (49°) of Winnipeg (Lumsden, pers. comm.). Assuming an average ground speed of at least 30 mph (48 km/hr) and a straight flight, these geese would easily make the Winnipeg–Winisk flight in less than 24 hr.

Thirty years ago, Soper (1942, p. 192) wrote of the Blue Geese, "The detailed character and exact route of the great flight of these geese from Manitoba to James Bay, remains one of the outstanding, unsolved questions of their life-history. Practically nothing is known about it. The immense flocks noisily leave Manitoba, disappear beyond the horizon in an apparent, general northeasterly direction and that is the last we know about them until they reappear about James Bay." He assumed that James Bay was the goal for the great majority of the blues "... since records of the Blue Goose are so rare on the west side of Hudson Bay, at least on the Manitoba and Keewatin coasts" (*op. cit.*, p. 193). Thus he had some difficulty explaining Blue Goose sightings at the southern end of Lake Winnipeg, Lake Dauphin and Lake St. Martin (Fig. 4) and Island Lake (Fig. 6). However, when Blue Geese were reported from the west coast of

**Table 2**

Observations of Lesser Snow and Blue Geese staging in southern Manitoba during spring 1971

Date	Location (nearest town within 4 mi radius)	Estimated number	Observer
April 15	Mowbray–Snowflake area	—	D. Reese
April 23	Pilot Mound	5,000	R. S. Brown
April 23	Purves area	57,500	R. S. Brown
April 23	Crystal City	15,000	R. S. Brown
April 23	Crystal City to Snowflake	10,000	R. S. Brown
April 24	Crystal City	20,000	R. S. Brown
April 24	Pilot Mound	5,000	R. S. Brown
April 24	Fallison	12,000	R. S. Brown
April 25	Darlingford	8,000	R. S. Brown
April 30	Mowbray–Snowflake area	200,000	D. Reese
May 2	Riverton	70	G. Clark
May 3	6.5 mi WSW of Emerson	500	R. C. Hutchinson (air survey 1040–1730 hr)
May 3	Emerson to Gretna	30	R. C. Hutchinson
May 3	5–6 mi E of Windygates	1,150	R. C. Hutchinson
May 3	Windygates to Mowbray	500	R. C. Hutchinson
May 3	Mowbray	1,000	R. C. Hutchinson
May 3	Snowflake	4,800	R. C. Hutchinson
May 3	Crystal City to Snowflake	600	R. C. Hutchinson
May 3	Mather	2,700	R. C. Hutchinson
May 3	Cartwright area	2,550	R. C. Hutchinson
May 3	Whitewater Lake	1,000	R. C. Hutchinson
May 3	Fairfax	1,800	R. C. Hutchinson
May 3	Cypress River	400	R. C. Hutchinson
May 3	Fannystelle	2,300	R. C. Hutchinson
May 3	Starbuck	300	R. C. Hutchinson
May 3	Winnipeg	400	R. C. Hutchinson
May 4	Langruth	5,000–10,000	C. Davis and P. Stone
May 5	6 mi N of Riverton	85	G. Clark
May 5	Lockport	800	R. C. Hutchinson (air survey 1410–1720 hr)
May 5	Red River Delta	830	R. C. Hutchinson
May 5	Shoal Lakes	3,525	R. C. Hutchinson
May 5	Lake Francis	650	R. C. Hutchinson
May 5	Delta area	900	R. C. Hutchinson
May 5	Southwestern tip of Lake Manitoba	4,150	R. C. Hutchinson
May 5	Grant's Lake	950	R. C. Hutchinson

Hudson Bay (possibly due to a change in their colour phase distribution), and when he heard that there was an annual spring flight of thousands of birds in the vicinity of Hargrave Lake (Fig. 6), Soper (1946, p. 110)

concluded "... that these flights were aimed at the west coast of Hudson Bay in either Manitoba, or Keewatin, or both".

Since then, Bremner (1949) and Baillie (1955) have reported visual observations of

Figure 2. Observations of staging and migrating Lesser Snow and Blue Geese in southern Manitoba during spring 1970. Twenty-seven other records for Winnipeg (16 reports of 1–500 birds and 11 of 501–5,000 birds) are not plotted

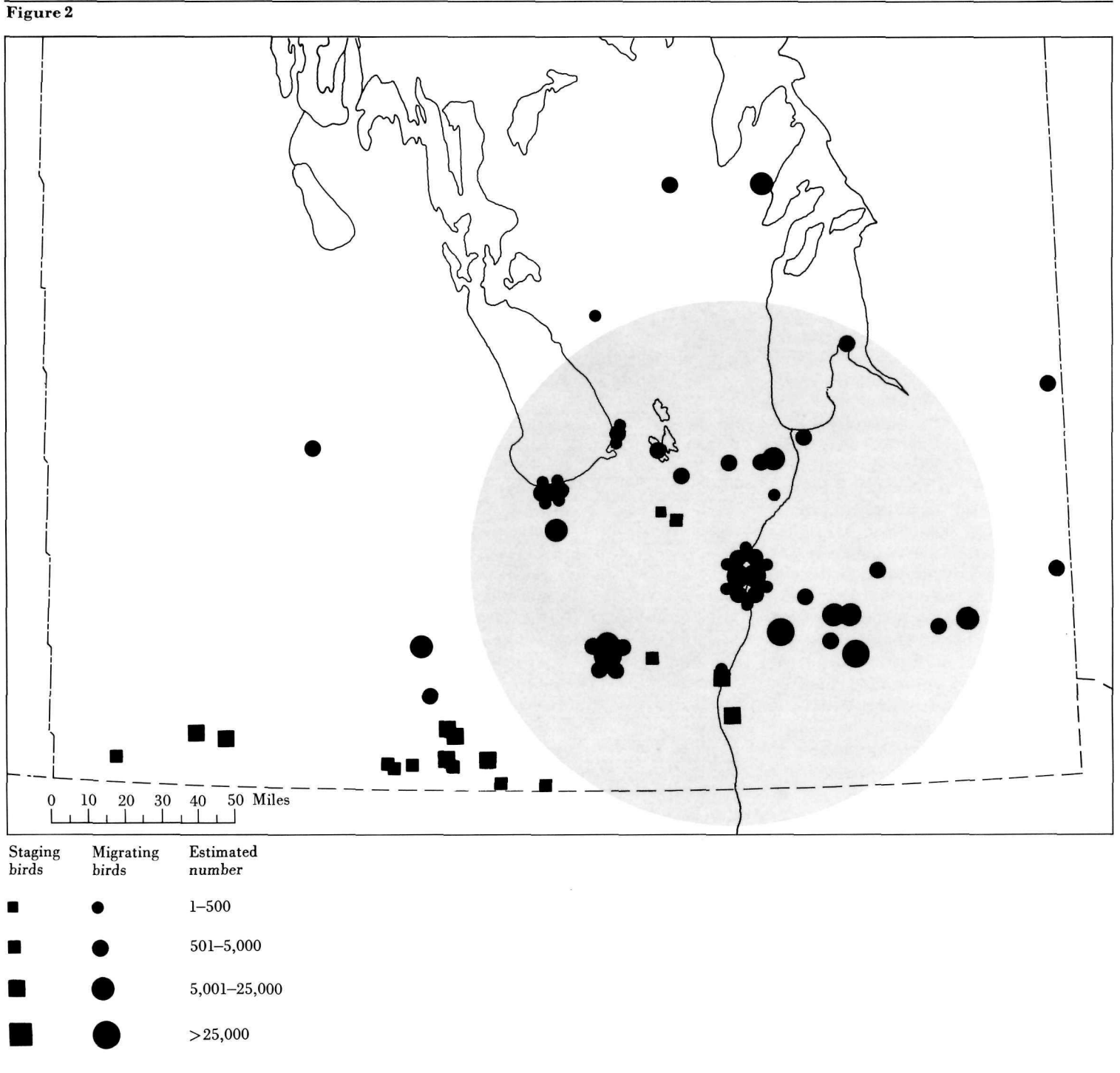
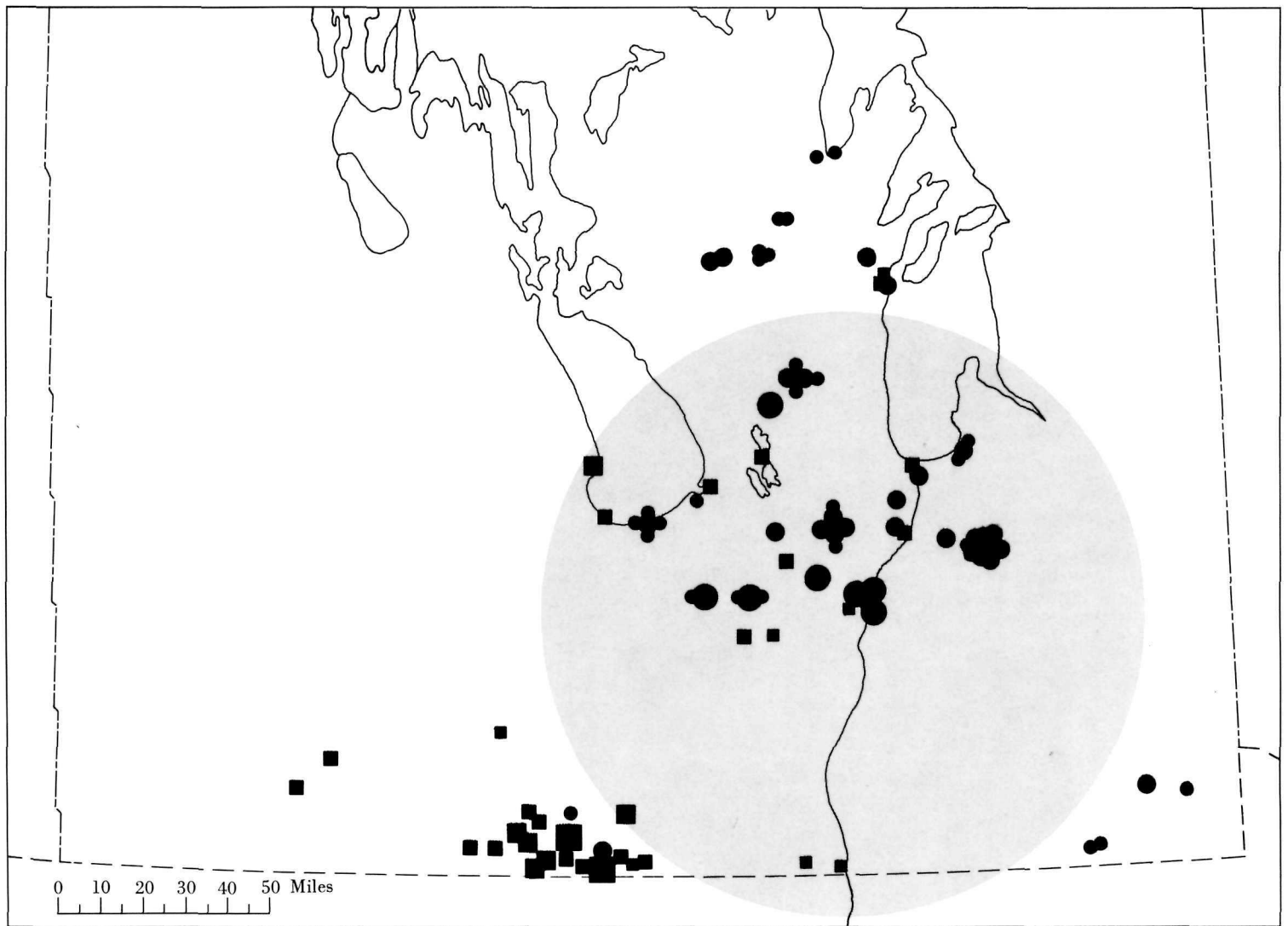


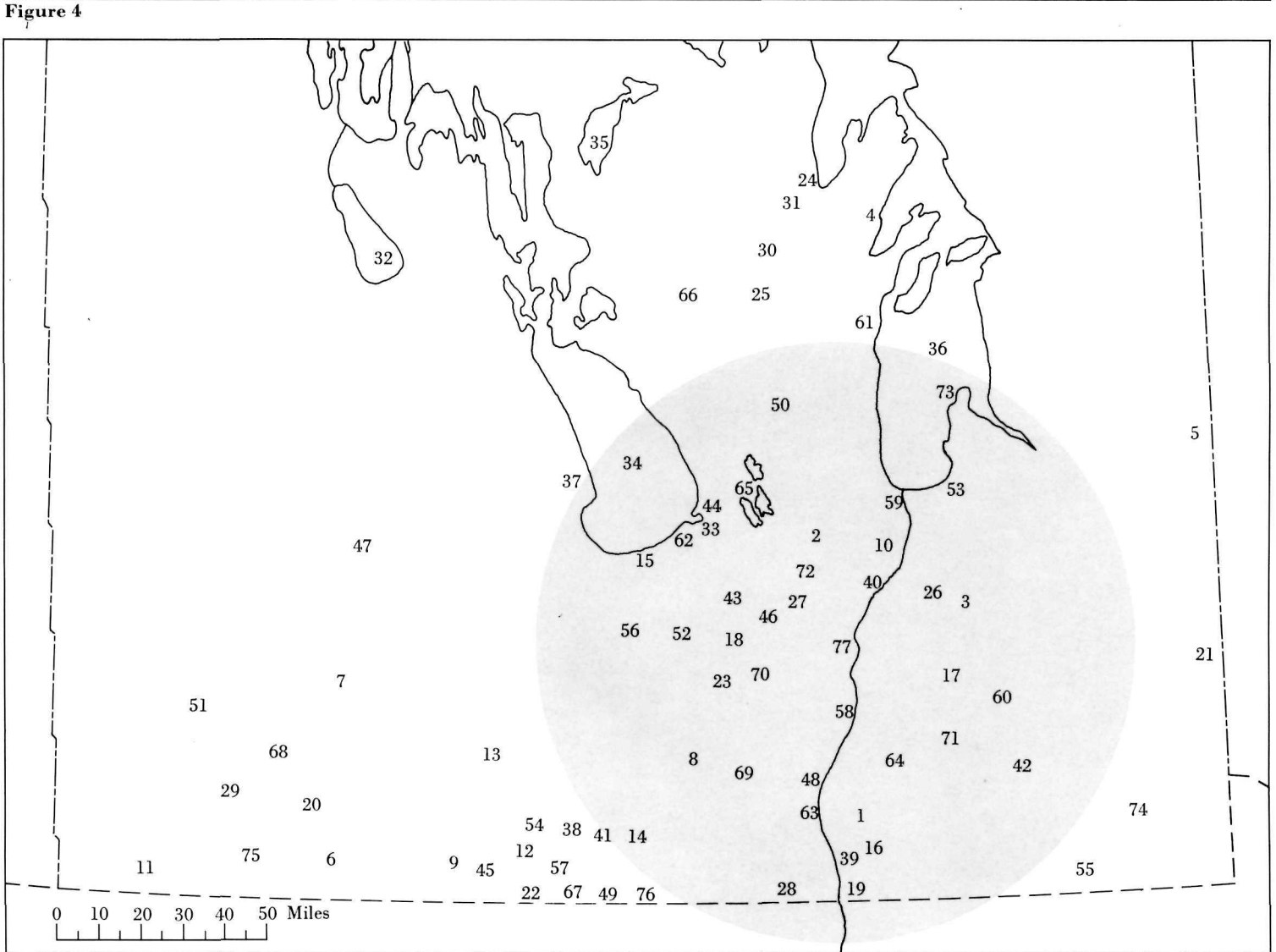
Figure 3. Observations of staging and migrating Lesser Snow and Blue Geese in southern Manitoba during spring 1971

Figure 3



Staging birds	Migrating birds	Estimated number
■	●	1-500
■	●	501-5,000
■	●	5,001-25,000
■	●	>25,000

Figure 4. Map of southern Manitoba showing locations mentioned in the text and tables. The circle shows the area covered by the ASSR-1 radar at Winnipeg International Airport as adjusted for this study



- |                   |                    |                     |                  |                        |                     |
|-------------------|--------------------|---------------------|------------------|------------------------|---------------------|
| 1. Arnaud         | 14. Darlingford    | 27. Grant's Lake    | 40. Lockport     | 53. Patricia Beach     | 66. Sleeve Lake     |
| 2. Balmoral       | 15. Delta          | 28. Gretna          | 41. Manitou      | 54. Pilot Mound        | 67. Snowflake       |
| 3. Beauséjour     | 16. Dominion City  | 29. Hartney         | 42. Marchand     | 55. Piney              | 68. Souris          |
| 4. Beaver Creek   | 17. Dufresne       | 30. Hodgson         | 43. Marquette    | 56. Portage la Prairie | 69. Sperling        |
| 5. Bird Lake      | 18. Elie           | 31. Koostatak       | 44. Marshy Point | 57. Purves             | 70. Starbuck        |
| 6. Boissevain     | 19. Emerson        | 32. Lake Dauphin    | 45. Mather       | 58. Red River          | 71. Steinbach       |
| 7. Brandon        | 20. Fairfax        | 33. Lake Francis    | 46. Meadows      | 59. Red River Delta    | 72. Stonewall       |
| 8. Carman         | 21. Falcon River   | 34. Lake Manitoba   | 47. Minnedosa    | 60. Richer             | 73. Victoria Beach  |
| 9. Cartwright     | 22. Fallon         | 35. Lake St. Martin | 48. Morris       | 61. Riverton           | 74. Whitemouth Lake |
| 10. Clandeboye    | 23. Fannystelle    | 36. Lake Winnipeg   | 49. Mowbray      | 62. St. Ambrose        | 75. Whitewater Lake |
| 11. Coulter       | 24. Fischer Bay    | 37. Langruth        | 50. Narcisse     | 63. St. Jean           | 76. Windygates      |
| 12. Crystal City  | 25. Fischer Branch | 38. La Rivière      | 51. Oak Lake     | 64. St. Pierre         | 77. Winnipeg        |
| 13. Cypress River | 26. Garson         | 39. Letellier       | 52. Oakville     | 65. Shoal Lakes        |                     |



Figure 5. The spring migration corridors of the Lesser Snow and Blue Geese from the Gulf Coast to Canada (after Bellrose, 1968), and their breeding colonies in the central and eastern Arctic

Figure 5

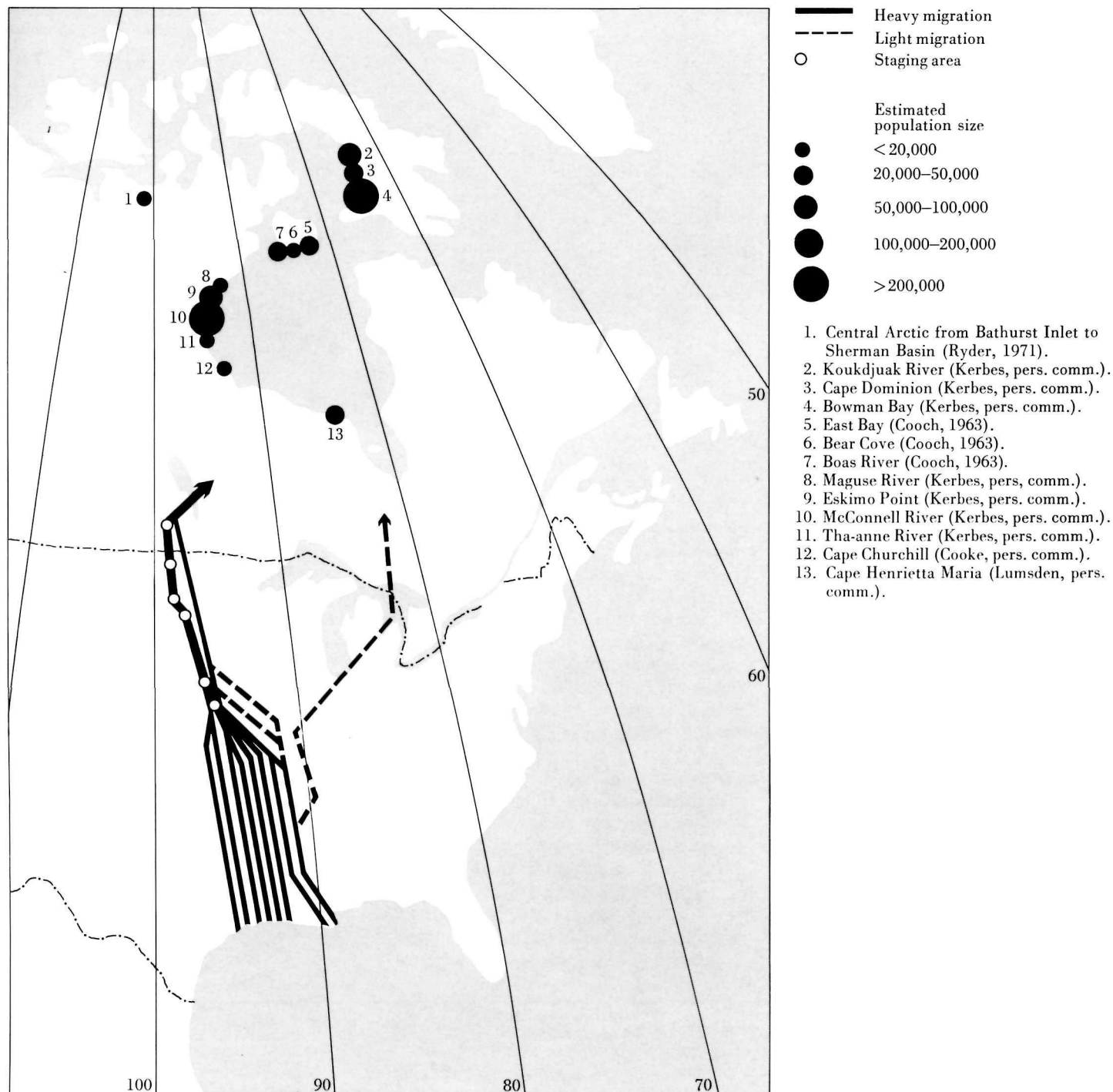
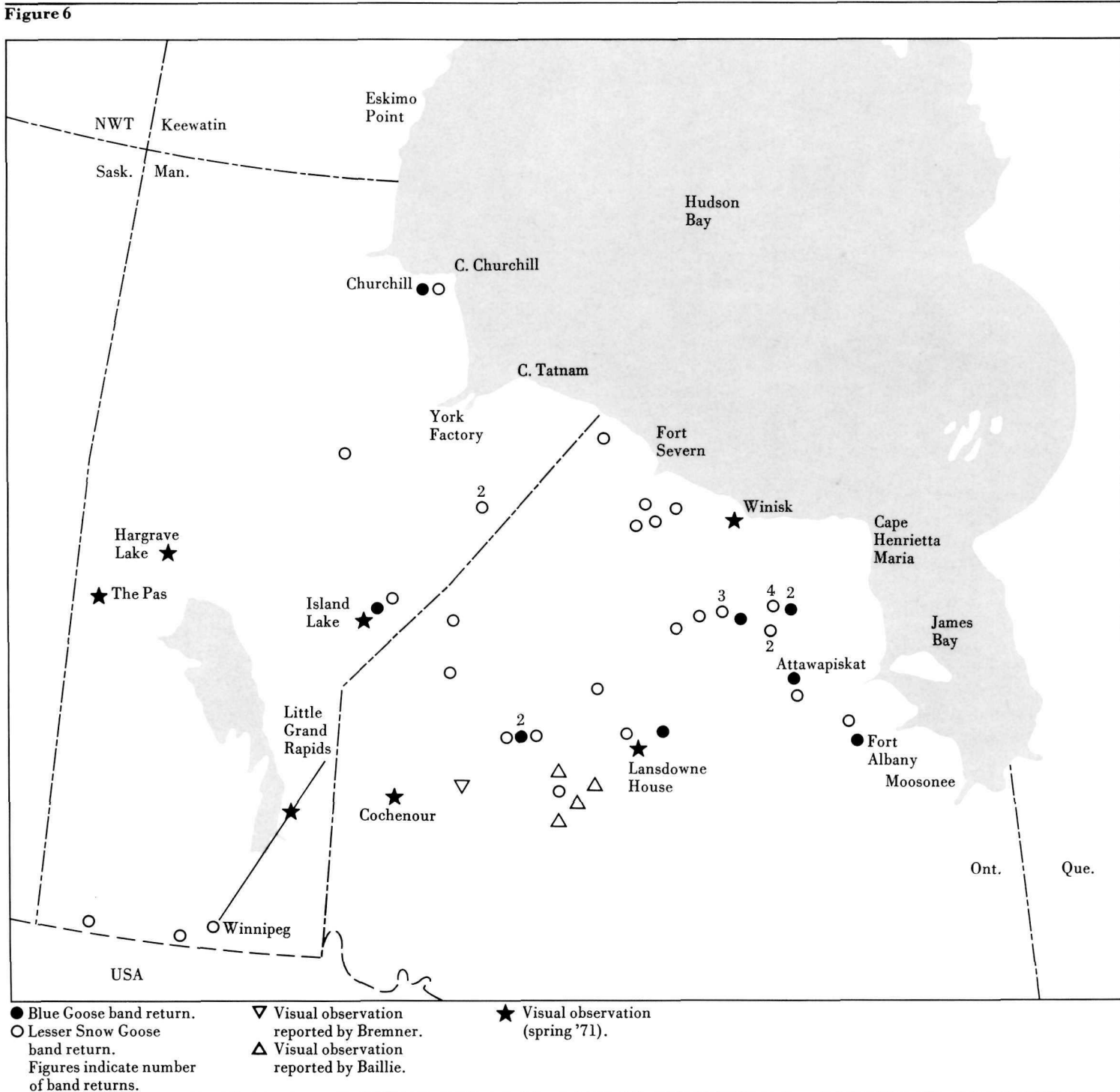


Figure 6. Inland band returns (spring 1953-71), migration observations during spring 1971 (Table 3), and spring migration observations reported by Bremner (1949) and Baillie (1955) for Lesser Snow and Blue Geese in Manitoba and northwestern Ontario



Lesser Snow and Blue Geese in northwestern Ontario (see Fig. 6). The question of the migration routes will be further discussed in the section on directions.

### Chronology Results 1970

The visual observations of migrating snow geese indicated that, apart from a few minor movements, most of the migration occurred in one big wave on May 15–17. The main wave started on the afternoon of Friday, May 15, when many migrating flocks were seen near Delta and Marshy Point (Fig. 4). In the early evening one flock was reported just north of Winnipeg and Bidlake (pers. comm.) reported “main migration after clearing of skies from south and west in the late evening”. Migration must have gone on into the night because flocks were heard between 2200 and 2300 hr. On the morning of Saturday, May 16, migrating geese were seen by many observers in and around Winnipeg. In the early afternoon few birds were reported migrating. During an air survey from 1400 to 1600 hr (Winnipeg–Carman–Snowflake–Manitou–Winnipeg, see Fig. 4) I estimated 18,000 snow geese on the ground. Migration apparently picked up again in the evening because migrating geese were observed by many observers. Migration continued during this night as well because geese were heard in the dark. On Sunday, May 17, many migrating flocks were seen at Victoria Beach (Fig. 4) in the early morning. The last observation for Winnipeg was a flock heard at 0620 hr. No birds were seen on the ground or in the air during a survey by car near Carman on May 17, from 0700 to 0900 hr. No reports of migrating or resting geese were received after the morning of May 17. This main wave of snow goose migration over the Winnipeg area apparently started on the afternoon of May 15 and ended by mid morning of May 17, a total of less than 48 hr.

The radar films, which started on May 2, showed very small numbers of scattered “goose echoes” on the mornings of May 3, 4 and 7, and the evenings of May 5, 11 and

**Table 3**  
Observations of Lesser Snow and Blue Geese migrating through central Manitoba and northwestern Ontario during spring 1971

Date	Location*	Est. direction	Est. no. flocks	Est. no. birds	Observer	Remarks
April 26 to May 6	Cochenuour, Ont.	NE	20	1,300	N. W. Ferly	“Most of these [20 flocks] were Snow Geese”
“The first two or three days of May”	Landsdowne House, Ont.				B. W. Parker	“Large flocks”
May 3	Winisk, Ont.				B. Norris	“No reports of any for Fort Albany or Attawapiskat”
May 6	Island Lake, Man.				DC-3 Pilot	Reported by A. Ball
May 6	Little Grand Rapids to Winnipeg, Man.	NNE	25	“Very many”	A. Ball	Flying a Cessna-185
May 8	The Pas, Man.	N	2	110	H. Reimer	“On May 12, 4 unidentified flocks”
May 9	Island Lake, Man.	NNW	—	50	K. Koros	“Both white and blue phase”
May 10	Island Lake, Man.	NW	—	150	K. Koros	“Both white and blue phase”

\*See Fig. 6 for locations.

13. Throughout May 6 heavy movements of bird echoes occurred in a general direction just west of north, together with smaller movements of “goose echoes” in northeasterly directions between 0400 and 2200 hr. The main wave of “goose echoes” started around 1400 hr on May 15 and ended on May 17 at about 1100 hr. Very few widely scattered “goose echoes” were seen after the morning of May 17. Radar filming ended on May 19.

There was good agreement between the visual and radar observations during the main wave, but there were no records of visual observations confirming the minor movement on May 6, which occurred 15–30 n mi (28–56 km) west of Winnipeg. During observations from the ATC tower from 0530 to 0730 hr and from 2030 to 2115 hr no migrating geese were seen.

### Results 1971

The visual observations showed that, apart from a few flocks, the snow geese migrated heavily through the Winnipeg area on the afternoon, evening and probably the night

of May 2, the morning of May 3, all day and evening of May 6, all day, evening and probably night of May 8 and morning of May 9, and the morning of May 12. No migrating flocks were reported after May 13.

The radar films, taken from April 28 through May 22 showed movements of “goose echoes” from 0900 hr on May 2 to 1400 hr on May 3, from 0900 to 1600 hr on May 4, from 0600 to 2400 hr on May 6, from 0400 hr on May 8 to 2200 hr on May 9, and from 0200 to 1500 hr on May 12.

Thus there was a very good agreement between radar and visual observations. In 1971 almost all snow geese migrated in five waves spread out over a 10-day period whereas in 1970 almost all birds passed through in one big wave lasting less than 48 hours, and occurring three days later than the last wave in 1971.

### Discussion

Soper (1942, p. 191–192) wrote “The spring departure of Blue and Lesser Snow Goose from Manitoba varies from year to year to a maximum extent of about 12 days.

The average in a ten-year period from 1927 to 1937 is May 6; May 10 is the latest date for the main evacuation, which occurred two seasons in succession in the years 1932 and 1933. The earliest date of mass movement is April 28 for the year 1935. It should be kept in mind that the dates given are for the principal migration of the flocks from southern Manitoba and not the last birds seen."

Hochbaum (1971) noted (p. 41) that the usual spring arrival date of snow geese at Delta lies between April 17 and May 1, with mass migration to the arctic breeding grounds taking place from May 7 to 15 (p. 50).

Jehl and Smith (1970) reported that the peak of the snow goose migration in the Churchill area (Fig. 6) occurs in mid or late May. The largest Blue Goose migrations near the mouth of the McConnell River (Fig. 5) usually take place between May 20 and June 7 (MacInnes, pers. comm.). If one assumes a non-stop flight from the plains to the sea coasts, a good proportion of the snow geese would have to make a 1- or 2-week stop-over at the coast. A suitable staging area lies between York Factory and Cape Tatnam (Pakulak, pers. comm.).

### Directions

Visual estimates showed that the great majority of the snow geese migrated in directions that varied between north and east, most commonly northeast. Unless the birds are flying overhead it is usually very hard to determine accurately the flight direction. Detailed analysis of flight directions can be more profitably carried out from radar observations.

### Results 1970

(the main movement on May 15 to 17 only)  
The mean hourly directions of "goose echoes" (Table 4) remained about 70°-75° from the afternoon of May 15 till the morning of May 16, when a sudden shift occurred towards more northerly directions (generally about 40°-50°). From then on there was a gradual but consistent shift towards still more northerly directions and by 0900 hr on May 17 the mean direction was about 25°.

**Table 4**  
Directions of "goose echoes" on radar film taken May 15-17, 1970, at Winnipeg International Airport

Date (1970)	Period (CDT)	Directions of movement of "goose echoes"			
		Mean (° True N)	Range (° True N)	S.D.	N
May 15	1400-1500	73.6	69-77	3.8	4
May 15	1500-1600	72.6	55-85	9.7	12
May 15	1600-1700	73.1	57-88	8.9	14
May 15	1700-1800	72.6	48-83	13.5	14
May 15	1800-1900	79.8	56-90	12.6	13
May 15	1900-2000	73.3	50-88	12.2	9
May 15	2000-2045	61.4	38-86	13.1	10
May 15	2100-2200	64.3	47-74	7.9	14
May 15	2200-2300	72.4	63-88	7.5	18
May 15	2300-2400	71.7	59-87	7.1	34
May 16	0000-0100	74.3	52-90	7.6	38
May 16	0100-0130	76.2	61-90	8.2	48
May 16	0230-0300	77.0	51-90	8.9	42
May 16	0300-0400	80.8	60-90	6.3	53
May 16	0400-0500	75.2	54-90	9.5	44
May 16	0500-0600	71.7	41-88	9.8	50
May 16	0600-0700	71.0	58-90	9.4	29
May 16	0700-0800	70.2	46-88	9.1	51
May 16	0800-0930	—	—	—	—
May 16	0930-1000	49.3	4-64	12.6	36
May 16	1000-1100	45.2	12-78	13.0	36
May 16	1100-1200	40.3	2-59	14.7	43
May 16	1200-1300	45.6	10-70	16.9	41
May 16	1300-1400	52.9	1-78	16.0	29
May 16	1400-1500	48.7	4-83	21.4	35
May 16	1500-1600	43.0	3-71	21.8	27
May 16	1600-1700	50.3	6-76	16.4	35
May 16	1700-1800	59.1	38-75	9.0	21
May 16	1800-1900	46.0	0-83	16.7	26
May 16	1900-2000	46.7	16-80	13.0	43
May 16	2000-2100	40.8	18-72	13.0	63
May 16	2100-2200	40.3	17-81	13.0	60
May 16	2200-2300	35.6	14-64	8.2	61
May 16	2300-2330	38.5	18-52	7.8	26

*cont'd on p. 19*

The almost constant mean direction of 70°-75° from 1400 hr on May 15 to 0800 hr on May 16 suggests that the migrating geese belonged to populations with southern breeding ranges or migration routes. Moosonee (Fig. 6) is at a bearing of about 76° from Winnipeg. Assuming a straight flight

and complete correction for wind drift, many geese flying on the night of May 15 and early morning of May 16 were apparently going to the southern part of James Bay.

The abrupt change in flight direction from about 70°-75° to about 40°-50° on May 16, at about 1000 hr, suggests that, after the

Table 4 cont'd

Date (1970)	Period (CDT)	Directions of movement of "goose echoes"			
		Mean (° True N)	Range (° True N)	S.D.	N
May 17	0000-0100	34.5	6-59	11.8	77
May 17	0100-0200	36.7	17-58	9.7	61
May 17	0200-0300	36.1	18-56	9.4	52
May 17	0300-0400	36.0	22-59	7.8	35
May 17	0400-0500	34.7	12-59	11.5	32
May 17	0500-0530	30.3	12-40	5.1	46
May 17	0600-0700	30.7	16-42	6.3	45
May 17	0700-0800	35.0	20-43	6.7	18
May 17	0800-0900	24.9	12-39	7.6	22
May 17	0900-1000	27.7	0-59	13.1	29
May 17	1000-1100	15.7	5-31	8.7	9

Table 5

Directions of "goose echoes" on radar film taken during spring 1971 at Winnipeg International Airport

Date (1971)	Period (CDT)	Directions of movement of "goose echoes"			
		Mean (° True N)	Range (° True N)	S.D.	N
May 2	0900-1000	38.2	15-56	13.1	10
May 2	1000-1100	34.5	16-84	13.5	25
May 2	1100-1200	39.4	13-57	10.2	25
May 2	1200-1300	41.1	12-65	10.4	26
May 2	1300-1400	45.2	12-60	10.9	26
May 2	1400-1500	46.3	20-69	12.4	28
May 2	1500-1515	50.3	33-60	10.8	6
May 2	1600-1700	45.7	27-73	10.7	21
May 2	1700-1800	46.0	29-75	9.1	38
May 2	1800-1900	54.0	30-78	8.9	55
May 2	1900-2000	51.9	21-75	10.8	59
May 2	2000-2035	43.8	15-66	11.8	53
May 2	2100-2200	—	—	—	—
May 2	2210-2300	47.6	31-58	5.9	45
May 2	2300-2400	50.9	37-65	6.8	30
May 3	0000-0100	50.1	36-64	6.2	29
May 3	0100-0200	47.8	30-59	7.4	33
May 3	0200-0300	48.0	36-63	7.0	26
May 3	0300-0400	48.4	37-64	7.8	20
May 3	0400-0500	39.7	6-58	13.3	26
May 3	0500-0600	34.1	9-53	14.1	20
May 3	0600-0700	39.0	12-53	8.4	49
May 3	0700-0800	39.9	26-54	5.8	46
May 3	0800-0900	42.1	8-62	8.2	73
May 3	0900-1000	40.9	9-57	8.3	70
May 3	1000-1100	41.5	23-57	8.5	36

cont'd on p. 20

nocturnal movement had passed (see Table 6), the morning flight consisted of geese of populations with more northerly migration routes. Birds flying on a course of 40°-50° would reach the coast somewhere between Fort Severn and Winisk (Fig. 6). During the night of May 16/17 (with fairly constant directions from 2200 through 0500 hr) and the morning of May 17 (with fairly northerly directions), still different populations of snow geese may have been migrating. The snow geese flying at 0900 hr on May 17, heading in a direction of about 25°, would have reached Hudson Bay in the vicinity of Cape Tatnam, the area that Pakulak (pers. comm.) considers to be a major staging area.

### Results 1971

The directions of "goose echoes" during the major movements in spring 1971 are given in Table 5. From 0900 hr on May 2 to 1400 hr on May 3, the mean direction fluctuated between 34.5° and 54.0°, without showing any clear trend other than that around midnight the mean direction was 47°-50° while in the morning of May 3 it was about 40°. On May 4 the mean directions from 0900 to 1600 hr varied between 54.9° and 78.5° (with an average of about 70°). On May 6 the mean hourly directions from 0600 to 2400 hr varied between 28.7° and 51.9° with a clear change from more northerly directions in the morning to more easterly directions in the evening. From 0400 hr May 8 to 2200 hr May 9, the hourly mean directions slowly fluctuated (with 21.7° and 49.6° as extremes), but without any clear trends and showing a remarkably steady flow in a direction of about 30° to 40°. The last major movement occurred on May 12 from about 0200 to 1500 hr. The mean directions fluctuated around an average of about 45° (extremes 36.2° and 53.2°) without showing any noticeable trend with time.

### Discussion

The sometimes rather sudden changes in mean directions from hour to hour (Tables 4 and 5) were often caused by the appearance or disappearance of a certain "batch" of



echoes, moving as a small group in a direction that clearly differed from the main course, and probably representing a different population element of the snow geese or, perhaps, another species.

Comparing the 1970 and 1971 data for southern Manitoba, it appears that in 1970 some geese staged further east, the migration was much later, and the directions were more easterly.

The 1970 and, to a lesser extent, 1971 data showed that different snow goose populations migrated along different migration routes from their common staging areas in southern Manitoba and northern North Dakota to their breeding areas. This agrees largely with the view of H. G. Lumsden, who wrote (pers. comm.): "My impression is that Blue/Snows fan out from the prairie staging area over about a 90° arc and hit the sea coast all the way from Moosonee to Churchill."

In 1971 we asked both routine observers and volunteers also to record the snow/blue colour ratio. The few data obtained showed that although there was much variation on each day, there was a general tendency for more snows during the later waves (snows predominated on May 8–9 and May 12, whereas on May 2–3 blues were in the majority). It was not possible to correlate the colour ratio with mean direction.

Although visual and radar observations in the vicinity of Winnipeg show that the snow geese migrate in directions between north and east, this does not seem to be the case in the Oak Lake area. Hatch (pers. comm.) reported: "Between 7:00 and 9:00 a.m. on May 4, 1967, a total of 1,200 migrated over Oak Lake at a low altitude as though they had just left a concentration area such as Souris. Exactly one year later, May 4, 1968, a total of 8,400 snows left Oak Lake between 6:45 and 7:35 p.m. These birds were in many small flocks, gained a high altitude and then headed northwest." I do not know to what extent these observations are representative of the normal migration route of snow geese staging in the Boissevain–Hartney–Souris area. I back-

Table 5 cont'd

Date (1971)	Period (CDT)	Directions of movement of "goose echoes"			
		Mean (° True N)	Range (° True N)	S.D.	N
May 3	1100–1200	34.5	11–51	8.6	36
May 3	1200–1300	36.4	8–59	10.7	27
May 3	1300–1400	39.4	31–48	5.9	10
May 4	0900–1000	64.1	50–82	8.3	40
May 4	1000–1100	66.5	52–84	7.8	22
May 4	1100–1200	54.9	29–77	12.1	27
May 4	1200–1300	63.5	48–83	9.8	28
May 4	1300–1400	70.7	59–90	10.3	12
May 4	1400–1500	78.5	68–87	6.1	10
May 4	1500–1600	65.3	63–83	8.6	3
May 6	0600–0700	31.5	19–43	7.0	31
May 6	0700–0800	36.0	25–48	6.0	42
May 6	0800–0900	40.4	25–55	7.6	39
May 6	0900–1000	37.1	25–52	6.9	43
May 6	1000–1100	36.0	24–49	7.7	41
May 6	1100–1143	28.7	20–45	6.4	40
May 6	1236–1300	34.6	19–53	8.0	51
May 6	1300–1400	37.3	22–57	8.1	40
May 6	1400–1451	39.0	24–57	7.7	45
May 6	1452–1600	—	—	—	—
May 6	1600–1700	41.6	24–58	7.3	40
May 6	1700–1800	47.2	37–61	5.5	41
May 6	1800–1900	47.0	40–54	4.0	19
May 6	1900–2000	48.8	25–62	6.8	48
May 6	2000–2100	51.8	43–53	5.3	16
May 6	2100–2200	47.9	24–62	8.5	50
May 6	2200–2300	51.8	37–63	6.7	40
May 6	2300–2400	51.9	36–73	7.7	30
May 8	0400–0500	35.2	17–60	13.5	15
May 8	0500–0600	38.6	20–57	11.7	20
May 8	0600–0700	35.0	16–69	11.5	40
May 8	0700–0800	43.9	31–59	8.0	43
May 8	0800–0900	39.4	16–68	9.3	83
May 8	0900–1000	33.3	23–44	6.3	39
May 8	1000–1025	31.6	23–45	5.3	40
May 8	1100–1200	21.7	2–38	7.8	40
May 8	1200–1300	24.6	13–44	8.0	35
May 8	1300–1400	26.0	10–38	6.3	25
May 8	1400–1500	—	—	—	—
May 8	1500–1600	32.8	18–53	7.7	41
May 8	1600–1700	32.8	19–50	6.6	44
May 8	1700–1800	37.0	25–57	7.4	42
May 8	1800–1900	35.5	20–65	8.7	43
May 8	1900–2000	34.4	19–56	8.5	39
May 8	2000–2100	33.6	21–51	7.6	42

cont'd on p. 21



Table 5 cont'd

Date (1971)	Period (CDT)	Directions of movement of "goose echoes"			N
		Mean (° True N)	Range (° True N)	S.D.	
May 8	2100-2200	33.5	19-63	8.4	42
May 8	2200-2300	28.5	15-41	7.1	40
May 8	2300-2400	30.8	15-59	9.6	42
May 9	0000-0100	33.7	23-61	8.6	24
May 9	0100-0200	34.6	23-54	8.8	40
May 9	0200-0300	38.9	16-64	8.2	44
May 9	0300-0400	38.6	11-54	10.3	42
May 9	0400-0500	39.3	10-56	10.8	42
May 9	0500-0600	35.0	17-56	8.4	31
May 9	0600-0700	37.2	16-55	8.1	40
May 9	0700-0800	39.7	29-49	4.8	40
May 9	0800-0900	36.4	22-52	7.7	43
May 9	0900-1000	31.9	19-45	6.0	41
May 9	1000-1100	26.3	15-37	5.9	40
May 9	1100-1200	24.9	13-40	7.2	41
May 9	1200-1300	26.0	14-40	6.5	42
May 9	1300-1400	33.0	11-47	8.9	32
May 9	1400-1500	34.2	10-59	12.8	15
May 9	1500-1600	34.0	17-51	8.2	15
May 9	1600-1700	36.3	19-51	8.3	25
May 9	1700-1800	39.3	25-56	8.7	25
May 9	1800-1900	43.9	34-54	5.4	18
May 9	1900-2000	36.7	12-55	10.5	25
May 9	2000-2100	45.5	27-58	7.5	19
May 9	2100-2200	49.6	37-67	9.3	10
May 12	0200-0300	47.8	36-71	11.6	12
May 12	0300-0400	48.4	30-69	12.2	15
May 12	0400-0500	53.2	37-82	10.8	26
May 12	0500-0600	46.9	22-77	12.7	40
May 12	0600-0700	50.1	26-78	11.4	42
May 12	0700-0750	45.6	32-59	6.9	40
May 12	0750-0900	—	—	—	—
May 12	0900-1000	—	—	—	—
May 12	1000-1100	41.3	16-70	9.9	41
May 12	1100-1200	37.4	24-57	8.0	41
May 12	1200-1300	36.2	10-50	8.2	39
May 12	1300-1400	44.8	23-63	8.2	40
May 12	1400-1500	50.2	36-66	8.2	32

tracked the "goose echoes" that crossed the radar screen on the night of May 15-16, 1970, when their average direction was 70° to 75°. Assuming straight flight and complete correction for wind drift, about 44 per cent came from the Boissevain-Hartney-Souris area.

### Numbers

#### Results 1970 and discussion

Counts of "goose echoes" were made only for the May 15-17, 1970, period. The results are given in Table 6. There clearly was a peak on both nights (May 15/16, and 16/17). Although the migration increased

Table 6

Hourly numbers of "goose echoes" crossing a 50 n mi line (see Methods section) on radar film taken May 15-17, 1970, at Winnipeg International Airport

Period (CDT)	Number of "goose echoes" per hour		
	May 15	May 16	May 17
0000-0100		118	210*
0100-0200		168	179
0200-0300		132†	150
0300-0400		58	172
0400-0500		60	63
0500-0600		24	32†
0600-0700		11	85
0700-0800		8	58
0800-0900		No data	29
0900-1000		40‡	21
1000-1100		42	6
1100-1200		65	
1200-1300		41	
1300-1400		27	
1400-1500		16	
1500-1600		15	
1600-1700	2	37	
1700-1800	2	9	
1800-1900	2	12	
1900-2000	0	8	
2000-2100	0‡	77	
2100-2200	1	154	
2200-2300	11	186	
2300-2400	35	346†	

\*Estimate based on 50 min of radar film.

†Estimate based on 30 min of radar film.

‡Estimate based on 45 min of radar film.

during both evenings and the geese were flying at night, I have only circumstantial evidence that the large numbers of nighttime "goose echoes" were caused by snow geese (for discussion see the appendix).

More than 2,500 "goose echoes" were counted crossing the 50 n mi (93 km) front. Usually few "goose echoes" were seen outside the 50 n mi front (see Methods and Fig. 1), which may be due to the effect of the Moving Target Indicator (see Richardson, 1972) or to the actual paucity of goose flocks. Assuming an average flock size of 200 birds, about 500,000 geese crossed the 50 n mi front on May 15-17.

**Table 7**  
Ground speeds of Lesser Snow and Blue Geese,  
migrating near Winnipeg, May 15–17, 1970

Date (1970)	Period (CDT)	Ground speed of "goose echoes"				N
		Mean (kn)	Extremes (kn)		S.D.	
May 15	1400–1500	25.3	24	28	1.9	4
May 15	1500–1600	24.3	20	28	2.3	12
May 15	1600–1700	26.5	19	34	4.8	13
May 15	1700–1800	27.2	17	42	7.6	13
May 15	1800–1900	31.3	17	42	7.1	12
May 16	0000–0100	31.9	17	39	4.2	40
May 16	0600–0700	29.5	24	37	4.2	11
May 16	1200–1300	27.2	22	32	2.5	43
May 16	1800–1900	31.5	27	40	4.0	17
May 16	2300–2400	39.7	31	49	3.8	32
May 17	0000–0100	40.6	32	50	4.0	42
May 17	0600–0700	57.2	53	70	4.3	21
May 17	0700–0800	53.5	45	65	4.6	27
May 17	0800–0900	59.9	52	73	5.1	14
May 17	0900–1000	61.4	54	71	6.3	5
May 17	1000–1100	62.3	59	67	4.2	3

**Table 8**  
Ground speeds, heights and air speeds of eight  
goose flocks tracked with a balloon-tracking radar  
on May 6, 1971, between 2015 and 2155 hr CDT  
at Winnipeg International Airport

Number of track	Duration of track (min)	Direction of track (° True N)	Ground speed of flock (kn)	Height of flock (ft agl)		Air speed of flock (kn)
				Mean	Extremes	
1*	2.5	54	44	3,900	3,780–4,020	30–31
2†	2.5	59	41	2,100	1,970–2,290	32
3†	2.5	52	50	5,730	5,380–6,080	38–43
4†	3.5	54	45	3,530	3,430–3,600	32–33
5†	6.5	54	46	3,440	3,200–3,590	33–34
6*	1.5	46	43	2,710	2,550–2,800	29–34
7*	1.5	27	43	1,840	1,800–1,880	37–39
8‡	15.0	64	45	4,100	3,320–4,670	33

\*Visually identified as Lesser Snow and Blue Geese.

†Visually identified as probably Lesser Snow and Blue Geese.

‡Picked up by searching with WF-3 radar.

It was hard to estimate the average flock size because the geese sometimes flew in large "superflocks" consisting of up to eight flocks, loosely strung together. Individual flocks would often separate from and rejoin the "superflock". The radar films showed this phenomenon as well: big echoes would

sometimes split up in two or three smaller ones, which sometimes fused again. H. A. Hochbaum (pers. comm. to A. L. Pakulak) estimated the average flock size as 200–250 birds. My own estimate is about 200. This of course pertains to day-time flocks only. At night the flocks may be smaller because

night-time "goose echoes" were often somewhat smaller than daytime ones.

My estimate of 500,000 snow geese crossing the 50 n mi front is very high compared with Pakulak's estimate (pers. comm.) of 300,000 staging snow geese for spring 1968 but agrees somewhat better with the estimates of the 1969/70 winter populations in the southern United States (361,000 for the Mississippi and 359,000 for the Central Flyway, total 720,000; U.S. Bureau of Sport Fisheries and Wildlife, 1971). Discussions held with the Blue/Snow Subcommittee of the Central Flyway Technical Section indicate that wintering numbers may have been underestimated in recent years (Dzubin, pers. comm.). According to Bellrose (1968), 90 per cent of the snow geese migrated through southern Manitoba and their numbers at Sand Lake National Wildlife Refuge, South Dakota, varied from 200,000 to 500,000.

## Ground speeds

### Results 1970

(the main movement of May 15–17 only)

Because of the highly interesting situation on the afternoon of May 15 (almost a head wind) and the morning of May 17 (a tail wind), more speeds were calculated for these periods than for the rest. Table 7 shows that on the average the "goose echoes" were moving more than twice as fast during the late morning of May 17 as during the early afternoon of May 15. The smallest and greatest individual ground speeds recorded were 17 and 73 kn (31 and 135 km/hr), while the average hourly ground speeds varied from 24.3 to 62.3 kn (45.0 to 115.4 km/hr).

### Results 1971

Useful data were obtained for only eight flocks because of technical problems. (When tracking targets at low elevation the radar beam was often "pulled down" by large ground targets causing unreliable height information and when tracking flocks that flew close together the radar beam jumped from one flock to the other, causing unre-

**Table 9**  
Heights and directions of echoes from large bird flocks (very likely Lesser Snow and Blue Geese) on the scope of the Precision Approach Radar at Winnipeg International Airport May 15–17, 1970

Date (1970)	Period (CDT)	Height (ft agl)				
		Most common height (band)		Extremes	N	Direction
		Range	% of total no. of echoes			
May 15	2000–2330*	1,200–1,400	—	—	10+	Easterly
May 15	2331–2350	1,100–1,200	75	1,100–4,200	4	Easterly
May 15/16	2351–0045	1,200	67	700–2,700	9	Easterly
May 16	1600–2029*	“about 1,200”	—	–4,200	“many”	—
May 16	2030–2048	1,100–1,200	88	400–1,200	14	Northeasterly
May 16	2049–2140†	1,000–1,400	71	400–1,900	24‡	Northeasterly
May 16	2141–2210	1,100–1,400	74	500–3,200	19	Northeasterly
May 16	2211–2240	1,200–1,800	68	600–3,000	31	Northeasterly
May 16	2241–2310	1,200–1,800	63	1,200–>3,700	8	Northeasterly
May 16	2311–2348	1,000–1,600	55	1,000–>3,300	18	Northeasterly

\*Observations by PAR operator. †Of the 16 echoes at ranges less than 5 n mi, 11 were caused by visually observed goose flocks.  
‡Period with co-ordinated visual observations from the ATC tower.

liable azimuth and range information as well.) Of the eight tracked flocks, seven were visually observed (three flocks were definitely identified as snow geese and four tentatively).

The individual ground speeds obtained with the WF-3 radar (Table 8) varied from 41 kn (76 km/hr) to 50 kn (93 km/hr) with a mean of 44.6 kn (82.6 km/hr). Ground speeds were also calculated from the AASR-1 radar film for the period 2025 to 2125 hr. Ground speeds of 17 “goose echoes” varied from 39 kn (72 km/hr) to 51 kn (94 km/hr) with a mean of 44.7 kn (82.9 km/hr), showing a very good agreement between the WF-3 and AASR-1 radar information.

#### Discussion

The spread in individual ground speeds of the “goose echoes” in the hourly samples (Table 7) may be the result of pooling echoes from goose flocks with differences in altitude, direction and rate of climb. The spread may also be increased by the inclusion of echoes from other species as “goose echoes”. The gradual change in hourly mean ground speed is almost completely due to changes in wind direction and mean

track directions of the echoes, as will be shown below.

Speirs *et al.* (1971) used radar to study goose migration (species not certain but very likely a mixture of Lesser Snow, Blue and Canada Geese) at Fort William (now Thunder Bay) in western Ontario. They reported individual ground speeds varying from 29 to 80 kn (54 to 148 km/hr), with average hourly ground speeds from 41.4 to 57 kn (76.6 to 106 km/hr). Meinertzhagen (1955, p. 98) reported a ground speed of 50 mph (80 km/hr) for Lesser Snow Geese in California (obtained from aircraft with doubtful accuracy).

#### Heights

##### Results 1970

Heights of migrating birds are hard to estimate visually and such estimates are usually of limited reliability. Yet visual estimates of the altitude of the snow geese showed good general agreement with the height data obtained with the Precision Approach Radar (Table 9). Because of its low elevation angle the height finder of the PAR could not detect all echoes visible on its azimuth screen. Thus for high-flying targets

at close range I have only a minimum altitude above which the birds must have been flying, making it impossible to calculate the mean flight altitude. The size, speed and direction of the bird echoes on the PAR, the time they occurred, and the few simultaneous visual observations make it very likely that the echoes were caused by migrating snow geese. Table 9 shows that on the evening and night of May 15 most geese were flying at about 1,200 ft (370 m) above ground level (agl). The birds were also flying at that height on the late afternoon and early evening of May 16, but later that night the birds were spread out over altitudes from about 1,000 ft (300 m) to more than 3,700 ft (1,130 m) agl, with more than 50 per cent between 1,000 and 1,600 ft (300 and 490 m) agl.

##### Results 1971

The eight individual flock heights given in Table 8 showed considerable fluctuation per track (mainly caused by the WF-3 radar equipment), as well as large height differences between the tracks (from about 1,840 to 5,730 ft; 560 to 1,750 m). The variation in individual heights suggests that the birds

were climbing at different angles, or coming from different staging areas, or both. Climb rates for two goose flocks were calculated. The longest track (lasting 15 min) showed a rate of about 4,100 ft/hr (1,250 m/hr). This corresponds to an angle of climb of 1° using the ground speed, or 1.3° using the air speed. The second longest track (lasting 6.5 min) showed a climb rate of 2,150 ft/hr (660 m/hr), corresponding with an angle of climb of 0.5° using the ground speed, or 0.7° using the air speed. Other tracks were considered too short for calculating climb rates.

A. Ball, flying a Cessna-185 from Little Grand Rapids to Winnipeg on the morning of May 6 (Table 3), noted that most snow geese were at 2,200 ft (670 m) agl over Little Grand Rapids (Fig. 6) and at 1,200 ft (370 m) over the southern tip of Lake Winnipeg, indicating an angle of climb of less than 0.1°.

### Discussion

Unidentified geese have been reported by Meinertzhagen (1955) at heights from 2,800 to about 8,500 ft (850 to 2,590 m) agl. Cooch (1955) reported geese (probably Blue Geese) at 6,000 to 8,000 ft (1,830 to 2,440 m) and Speirs *et al.* (1971) estimated an altitude of 4,000 ft (1,220 m) agl for a mixture of Lesser Snow, Blue and Canada Geese.

Rates of climb for migrating waterfowl and cranes are given by the Canada Department of Transport (1970) as "usually not more than 125 feet per minute or 100 feet per mile" (or an angle of climb of 1.1°), in good agreement with my results.

### Air speeds

#### Results 1970

Air speeds for individual "goose echoes" could not be calculated as no individual height data were available. I calculated the mean air speeds (given in Table 10) from the mean ground speeds (Table 7), the mean track directions (Table 10), the most frequent heights and the wind speeds and directions at those heights (Table 10) for

**Table 10**

Mean ground speeds, directions and air speeds of Lesser Snow and Blue Geese migrating near Winnipeg, May 16–17, 1970

Date (1970)	Period (CDT)	Mean ground speed (kn)	Mean direction* (° True N)	Upper wind†			Mean air speed (kn)
				Height (ft agl)	Direction (° True N)	Speed (kn)	
May 16	0000–0100‡	31.9	76.1	1,200	315	13	27.5
May 16	1200–1300§	27.2	48.7	0	310	16	29.4
				1,200	310	10	27.4
				2,200	310	09	27.3
				3,200	320	15	31.4
May 16	1800–1900‡	31.5	53.5	1,200	315	16	33.2
May 17	0000–0100‡	40.6	41.7	1,200	205	15	26.6
				2,200	225	09	31.6
May 17	0600–0700	57.2	32.8	1,200	220	28	29.6

\*As determined with the Vanguard Motion Analyser.

†Winnipeg upper winds were available only for the 1,200, 2,200, 3,200 etc. ft agl levels.

‡Height information from Table 9.

§Height data for this period are based on visual estimates only (seven independent observers reported many flocks between 500 and 3,000 ft agl).

||Height information for only one flock of Lesser Snow and Blue Geese observed at 1,200 ft by a pilot-biologist from a light aircraft.

the five 1-hr periods for which this information was available.

Because for two of the periods the most frequent height of the birds was not fully known, I also calculated the mean air speeds for the other heights at which the birds were reported flying. Table 10 shows that the mean air speeds were in the range 26.6 to 33.2 kn (49.3 to 61.5 km/hr), with an average of about 30 kn (56 km/hr).

#### Results 1971

Of the eight individual air speeds (Table 8), six were in the range 29 to 34 kn (54 to 63 km/hr) while two were rather higher (about 38 and 40 kn; 70 and 74 km/hr). I have no explanation for the two abnormal values other than the speculation that the flocks were startled by passing aircraft.

### Discussion

My 1970 data were subject to the following sources of error: measurements of length, direction and duration of tracks of "goose echoes"; measurement of upper air winds by pilot balloon for 1,000-ft intervals; lack of upper wind data for the exact height at which the birds were flying; poor informa-

tion on the height of the birds; and lack of proof that all migrants were snow geese (see the appendix).

Excluding the two abnormal 1971 air speeds, there is a good agreement between the 1970 and 1971 results. There is also agreement with the results obtained by Speirs *et al.* (1971) for fall migrating geese (probably Canadas and snow geese). They found mean air speeds varying from 24 to 36 kn (44 to 66 km/hr) with an average of 31.1 kn (57.6 km/hr). Pennycuick (1969) calculated two theoretical air speeds for flying animals: the "minimum-power speed" and the "maximum-range speed", which is bigger than the first and is the more likely to be used on migration. Snow geese weigh from 4 to 6 lb (1,816 to 2,724 g) according to Gabrielson and Lincoln (1959). Assuming that the geese had the higher weight when departing for the sea coast, they would have a "maximum-range speed" (estimated from Pennycuick's Fig. 8, p. 534, using the information on *Anser anser* as a guideline) of about 20 m/sec or 72 km/hr, quite a bit higher than the mean air speed I found for the 1970 data (56 km/hr).

In 1970 the mean air speeds showed very little variation (at most from 26.6 to 33.2 kn; 49.3 to 61.5 km/hr) compared to the variation in mean ground speeds (27.2 to 57.2 kn; 50.4 to 105.9 km/hr). It is not likely that the variation in air speeds was due to greatly differing rates of climb as most birds were probably either flying level or climbing at a very small angle (about 1° at most).

For the first two periods in Table 10, I estimated the angles of climb as less than 0.1° from the AASR-1 film, assuming gradual continuous climbing and using the vertical coverage diagram method (i.e. estimating the height of an incoming or outgoing target from the range at which it appears or disappears as an echo on the screen; see Eastwood, 1967, p. 233-4). This method could not be used for the last three periods of Table 10 because the outgoing "goose echoes" did not disappear from the screen (i.e. they were still visible at the very edge of the scope, the maximum range of which was set at 60 n mi). However, considering the 1971 results and the rule of thumb given by Canada Department of Transport (1970), it is very likely that climbing angles were very small for the last three periods of Table 10 as well.

I think that the apparent variations in air speed are largely due to errors of measurement and I conclude that the air speed of migrating snow geese varies very little, if at all, with different wind speeds or directions.

My results do not agree with those of Bellrose (1967, p. 308), who reported "Migrating birds appear to reduce their flight speed somewhat proportionately to the increase in wind speed. Hence, the ground speed of migrants tends to remain fairly constant even when wind speeds vary greatly." Nor do they support the results of Bruderer (1971, p. 157), who found that "Ground speeds are not influenced in an additive way by the wind component along the birds' tracks. Only about 2/3 of the corresponding wind vector are added to the ground speed."

Tucker and Schmidt-Koenig (1971), working on a number of birds of different species mostly flying at altitudes less than 50 m and "cruising" cross-country, found that air speeds varied significantly with wind direction. They concluded that "Although the large variation of air speeds in nature does not support the hypothesis of a closely regulated air speed, neither does it deny it. ... Further testing of the hypothesis will depend on accurate measurements of air speed when the wind velocity is constant, preferably zero." Their results and mine are not fully comparable because the snow geese were making a long-distance flight whereas the "cruising" birds studied by Tucker and Schmidt-Koenig were probably engaged in daily activities such as looking for food or a place to rest.

As pointed out by Bruderer (1971, p. 119), a bird's airspeed will increase with flight altitude because of the thinner air at greater heights. This increase has been calculated as 5.5 per cent per km (3,281 ft). In our case, most of the recorded heights in 1970 (Table 9) showed a spread of only a few hundred feet (100-200 m), but the differences between the extreme height values were at least 3,100 ft (950 m). The eight flocks tracked in 1971 (Table 8) showed great variation in height, the difference between the highest and lowest being about 3,800 ft (1,160 m). Thus, the effect of these height differences of the birds on their airspeed would be a matter of only a few per cent at the very most, and would not seriously modify the results obtained.



# Summary

1. Radar observations on the spring migration of Lesser Snow and Blue Geese, *Anser c. caerulescens* (snow geese), were made in 1970 and 1971 at Winnipeg International Airport, Manitoba. Routine field observations near Winnipeg and non-routine sightings in Manitoba and northwestern Ontario supplemented the radar data. Observations of staging snow geese in southern Manitoba were reported as well.
2. On days with snow goose migration the time-lapse film taken of the screen of the long-range surveillance radar showed many "goose echoes" (i.e. big bird echoes visible over great distances and moving at steady speed on a straight course in directions between north and east).
3. There is considerable circumstantial evidence that the great majority of "goose echoes" were caused by flocks of migrating snow geese. Analysis of the radar films provided information on the numbers, direction and ground speeds of the "goose echoes".
4. From information on the birds' height (obtained with the Precision Approach Radar in 1970 and a balloon-tracking radar in 1971) and the wind speed and direction at that height, air speeds were calculated using vector analysis.
5. Both in 1970 and 1971 staging snow geese were found along the international border with the biggest concentration in the Pilot Mound-Crystal City-Snowflake-Windygates area (Figs. 2 and 3).
6. In 1970 almost all snow goose migration occurred in two waves: a small one on May 6 (radar data only) and a much bigger one between the afternoon of May 15 and mid morning of May 17. In 1971 the geese migrated in five waves on May 2-3, May 4, May 6, May 8-9 and May 12.
7. Hourly mean directions of the 1970 "goose echoes" were east-northeasterly on the night May 15/16, northeasterly on May 16 and north-northeasterly on May 16/17, suggesting that different populations flew at different times in different directions. In 1971 the mean hourly directions were east-northeasterly on May 4 and northeasterly during the four other waves.
8. The radar data as well as the sightings and spring band returns in central Manitoba and northwestern Ontario (Fig. 6) indicated that the snow geese fan out from their staging grounds in Manitoba and reach the coasts of James and Hudson bays all the way from Moosonee to Churchill by overland flight.
9. Strong evidence for a rapid (and probably non-stop) flight from the plains to the coast was obtained in 1971 when the first wave over Winnipeg was observed going northeast on May 2 and the first arrival at Winisk, 600 miles (960 km) northeast of Winnipeg, was noted on May 3.
10. The May 15-17, 1970, radar films showed a total of more than 2,500 "goose echoes" crossing a front 50 n mi (93 km) wide. From this figure it was "guesstimated" that 650,000 to 1,000,000 geese were migrating across southeastern Manitoba during that period.
11. In 1970 the mean hourly ground speeds varied from 24.3 to 62.3 kn (45.0 to 115.4 km/hr), while the smallest and greatest individual ground speeds were 17 and 73 kn (31 and 135 km/hr). In 1971 the ground speeds of eight goose flocks varied from 41 to 50 kn (76 to 93 km/hr) with a mean of 44.6 kn (82.6 km/hr).
12. On the evening and night of May 15, 1970, and the afternoon and early evening of May 16, most geese were flying at about 1,200 ft (370 m) agl. During the night May 16-17, 1970, the birds were spread out from 1,000 ft (300 m) to more than 3,700 ft (1,130 m) agl. Heights of the eight tracks obtained in 1971 varied from about 1,840 ft (560 m) to 5,730 ft (1,750 m) with a mean of 3,460 ft (1,050 m) agl.
13. In 1970 mean air speeds, calculated from mean ground speeds for five 1-hr periods, varied from 26.6 to 33.2 kn (49.3 to 61.5 km/hr) with a mean of about 30 kn (56 km/hr). Of the air speeds obtained for eight flocks in 1971, six were in the range 29 to 34 kn (54 to 63 km/hr) while two were much higher: about 38 and 40 kn (70 and 74 km/hr). The 1970 data indicated that the air speed of migrating snow geese varied very little, if at all, with different wind speeds or directions.



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# Appendix: Identity of the “goose echoes”

## Introduction and technical considerations

All echoes that were big, persisted over great distances (at least 10 but usually 35 km or more), and moved at steady speed and on a straight course in directions between north and east were considered as “goose echoes”.

As the size of an echo is an important criterion for it being a “goose echo” or not, it is important to realize that whether or not a bird or a flock of birds will show up on a radar depends on the number of birds per flock, the range, height and aspect of the flock, the echoing area of one bird, the overall performance of that radar, the radar aids used (such as Moving Target Indicator, Circular Polarization, Fast Time Constant, Sensitivity Time Control) and the weather at the time. Whether or not two flocks flying closely together will be shown as two separate echoes depends on the radar resolution in range and azimuth and on the sizes and ranges of the flocks. Furthermore, the radar beams of both the AASR-1 and ASR-5 do not cover the area directly above the antenna, causing a blind spot in and around the centre of their screens (see Fig. 1). The ASR-5 is the 10-cm short range surveillance radar used at Winnipeg Airport (for specifications see Canada Dept. of Transport, 1967).

Both the number and the size of bird echoes were dependent on factors beyond my control, because the radar was frequently adjusted so as to provide optimum performance for air traffic controllers (for discussion on the effects of different radar settings on the number and size of bird echoes on the screens of AASR-1 and ASR-5 radars see Richardson, 1972). This meant that the “bigness” of a bird echo had to be judged while taking the radar settings into account. This often was possible by comparison with aircraft echoes, the size of which is also dependent on radar settings in much the same way as the size of bird echoes. Most “goose echoes” were at least about one third the size of an echo from a large aircraft, while some were as big as or even bigger than aircraft echoes. It is usually possible to group bird echoes on the screens of surveillance radars into a few broad categories. Drury and Keith (1962), for example, were able to differentiate “gulls”, “waders” and “passerines” (based on size, intensity, speed and range of the echoes), but mentioned that there remained “a number of other types of angels which we cannot yet identify satisfactorily”. In general it is impossible to tell the species from the bird echo without visual information, an exception being the morning dispersal flight from starling roosts (see Eastwood, 1967, for review).

## Proof and circumstantial evidence that the “goose echoes” were caused by snow geese

The only way to prove that “goose echoes” were caused by snow geese would be to have identified representative samples. This could have been done

by vectoring a light aircraft close enough to “goose echoes” to identify the birds involved, but this might have caused serious flight safety problems, particularly at night when “goose echoes” were most numerous. For this and other organizational reasons no aircraft were used. The following arguments that the majority of the “goose echoes” represent only one species are based on (1) simultaneous observations made at the ATC tower of “goose echoes” and the bird flocks that caused them, (2) the close agreement between the occurrence of “goose echoes” and sightings of migrating snow geese and (3) the almost total absence of other bird species that could have produced the “goose echoes”.

## 1970

### Argument 1

Two identical screens of the ASR-5 short-range surveillance radar are used by the controllers in the ATC tower at Winnipeg. On May 16, I watched these screens from 0900 to 1230 hr and Gemmell made observations from 2030 to 2135 hr. During both periods many “goose echoes” crossed the screen and many flocks of migrating waterfowl were observed from the tower. In the morning period 44 flocks were seen and in the evening period, 45 flocks. All 89 flocks were flying in directions between north and east and all looked like migrating snow geese with the exception of one flock of five Double-crested Cormorants. Kortright (1967) briefly described the irregular, non-V flock formations of migrating snow geese. About a quarter of the flocks were close enough to be definitely identified as snow geese.

I did not examine quantitatively how many “goose echoes” were caused by flocks of what species, of what size, and at what range and height, because (1) the screens were not available for our use, (2) the nearer the flocks (i.e. the better they could be observed visually), the smaller became their echoes and the less they appeared as “goose echoes”, see Fig. 1, (3) echoes of flocks flying at tangential azimuth (i.e. having no radial speed) are suppressed or cancelled by the radar’s Moving Target Indicator, see Fig. 1, and (4) the snow geese tended to come in waves often with loose associations of flocks, which sometimes separated and regrouped.

But despite this lack of quantitative data, it was evident that all “goose echoes” near the radar’s centre were caused by flocks of migrating waterfowl and, as mentioned above, of the flocks that could be identified all but one were snow geese. The radar films showed that all “goose echoes” on the ASR-5 radar screen also showed up as “goose echoes” on the AASR-1 screen and there to much greater ranges. Study of the AASR-1 films showed that most of the “goose echoes” were of similar size and moving in similar directions, at similar speeds and appeared on and disappeared from the screen at similar ranges, suggesting that most of the “goose echoes” probably represented only one type of bird

### **Argument 2**

A total of 66 reports of migrating snow geese were received for the period April 25 to May 17, 1970; 55 reports were for the period May 15–17. Before May 15 mainly single flocks were reported but during May 15–17 large numbers of flocks were observed. The visual observations indicated that the great majority of the snow geese migrated between the afternoon of May 15 and the early morning of May 17. Most flocks were reported to fly northeast, but some flew north or east.

Comparison of the visual observations and the presence of “goose echoes” (Table 4) showed good general agreement, although there were no visual observations of migrating geese for the morning and evening of May 6 when relatively small but distinct movements of “goose echoes” occurred west of Winnipeg (during observations from the ATC tower from 0530 to 0730 hr and 2030 to 2115 hr no migrating birds were seen). The correlation between “goose echoes” and snow goose sightings was not carried out quantitatively because of the technical difficulties mentioned above.

### **Argument 3**

During routine field observations near Carman on May 15 and 16 more than 38,000 migrating snow geese were reported but no migrants of other species. No records of staging or migrating snow geese were received after the major movement of May 15–17. The volunteer observers never reported migration of other species migrating simultaneously with and in the same direction as the snow geese.

I know no other species that migrates over the Winnipeg area, both during day-time and night-time, in large numbers of large flocks, in northeasterly directions, in the middle of May, with air speeds of about 30 kn (56 km/hr) and that, therefore, could be responsible for the bulk of the “goose echoes” on the radar films. I think it is justified to conclude that the great majority of the “goose echoes” actually represented flocks of migrating snow geese.

1971

### **Argument 1**

On May 2, I watched the scope of the ASR-5 from 1930 to 2115 hr and observed many “goose echoes”. A total of 41 flocks were observed from the ATC tower. Six flocks were close enough for definitive identification as snow geese. All others looked like snow geese as well. A total of 28 “goose echoes” at close range were caused by goose flocks. On May 6, W. Gemmell watched the ASR-5 screen from 1830 to 1840 hr. “Goose echoes” were present on the scope, 10 of which could be attributed to flocks of migrating geese (considered snow geese from their size and flock pattern) observed from the ATC tower. On May 8, I watched the ASR-5 screen from 0905 to 1020 hr. “Goose echoes” were present on the scope and those passing at close range were caused

by flocks of migrating waterfowl. Of the 13 such flocks, 9 came close enough to be identified as snow geese.

During spring 1971, many pilots reported their visual observations of migrating birds. In a few cases pilots were asked by interested ATC personnel to identify certain bird echoes along their flight route. Most pilots reported large flocks of “geese” or “birds” but those who identified the species always said snow geese.

### **Argument 2**

A total of 99 reports of migrating snow geese were received for the period April 22– May 13, 1971. Visual observations indicated that the snow geese moved in great numbers on May 2–3, 6, and 8–9 and in smaller numbers on May 4 and May 12, showing good agreement with the presence of “goose echoes” on the AASR-1 display (Table 5).

### **Argument 3**

Regular observations in the vicinity of Winnipeg were made routinely from May 2 through 8 by two experienced bird watchers. They reported a total of at least 101 flocks of snow geese, 25 flocks of unidentified geese and 2 flocks of White-fronted Geese all migrating in directions between north and east and no flocks of other species. In spring 1971 the Manitoba game officers recorded their sightings of snow geese as well as other geese, swans, cranes and pelicans on special forms. In the period May 2 to 12, they reported a minimum of 170 flocks of snow geese, as well as 13 flocks of Canada Geese, 1 flock of Whistling Swans and 1 flock of White Pelicans, all migrating in directions between north and east. During the period May 2–9, several observations were made by Blokpoel, Gemmell and Yakobi at Winnipeg Airport. They observed a total of 212 flocks of waterfowl migrating in directions between north and east: 57 flocks of snow geese, 1 flock of 75 Canada Geese, and 154 flocks of unidentified geese (usually large and flying in typical snow goose flock patterns). Mr. Ball, flying a Cessna-185 from Little Grand Rapids (see Fig. 6) to Winnipeg on May 6 from 1145 to 1300 hr, observed at least 25 flocks of migrating snow geese but no other species.

Canada Geese do migrate in rather large numbers through the Winnipeg area in northerly, northeasterly and northwesterly directions, but usually most birds have passed through by the end of April, well before the major snow goose movements (Raveling, pers. comm.). In 1971, the last major Canada Goose movements were on April 24, 28 and 29 (Clark, Cross, Couture and other game officers, pers. comm.). The 40–50,000 Canada Geese that staged in the Grant’s Lake area had all left by April 30 (Reese, pers. comm.). Nevertheless small numbers of Canada Geese, especially the small race that breeds in the Arctic, were still present in southern Manitoba in the first part of May as they were ob-

served migrating on the same days as the snow geese.

Although some migrating Canada Geese probably produced “goose echoes” on the radar screen, I think that it is safe to assume that the great majority (more than 90 per cent) of the “goose echoes” were produced by snow geese. The fact that not all “goose echoes” were caused by snow geese is of course a shortcoming of this study, which had to be taken into account when discussing the results.

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