

Similar to *ceylonensis*, but with the throat and upper breast albescent.

Range: Sumba.

5. *Culicicapa ceylonensis sejuncta* Hartert

Culicicapa ceylonensis sejuncta Hartert, Nov. Zool., 4: 526, Dec. 3, 1897 (southern Flores Island, Indonesia).

Similar to *connectens*, but with the throat and upper breast more or less strongly overlaid with golden yellow.

Range: Flores.

U. S. National Museum
Washington, D. C.

CYCLIC INVASIONS OF THE SNOWY OWL AND THE MIGRATION OF 1945-1946¹

BY ALFRED O. GROSS

THE cyclic nature of Snowy Owl invasions is now recognized and the appearances of the owls in large numbers has been correlated with the periodic maximum of Arctic foxes and the lemming cycle in the north (Gross, 1931, 1946). It is therefore desirable to review the records of the past before considering the migration of Snowy Owls into New England in 1945-1946. As might be expected, the records of the earlier migrations are very fragmentary since field observers were fewer in number and there was no coöperative effort to obtain records over the entire invasion area as there is today. A certain number of the owls appear each year, at least in the northern sections of the invasion area, and the individual reports of local concentrations during ordinary years tend to obscure the more pronounced cyclic invasions. It is also obvious that at a time when the cyclic nature of the migrations was not recognized some, especially the less pronounced invasions, were not adequately reported. However, in various journals and publications there are recorded twenty-four dates between 1833 and 1945 during which major invasions occurred. These are by no means of uniform intensity and they vary as to the region and amount of territory covered.

It is confidently hoped that even earlier records will be discovered and that the evident gaps in the series of dates presented in the following table may be filled.

¹ Contribution Number 18, Bowdoin Scientific Station, Kent Island, Bay of Fundy, New Brunswick, Canada.

TABLE 1
SNOWY OWL INVASION DATES

<i>Date</i>	<i>Interval</i>	<i>Date</i>	<i>Interval</i>	<i>Date</i>	<i>Interval</i>
1833-34		1886-87	4	1917-18	5
1837-38	4	1889-90	3	1921-22	4
1839-40	2	1892-93	3	1926-27	5
1853-54	14	1896-97	4	1930-31	4
1862-63	9	1901-02	5	1934-35	4
1866-67	4	1905-06	4	1937-38	3
1876-77	10	1909-10	4	1941-42	4
1882-83	6	1912-13	3	1945-46	4

1833-1863

We are indebted to the Canadian Journal (7: 522-523, 1862) for the early records of this period. There was a very marked invasion of Snowy Owls especially on the shores of Lake Ontario during the winter of 1862-1863. "W. H." writes: "The extraordinary numbers this year excite great attention, and arouse our curiosity respecting the cause." Another observer who signs his article "Strix" states: "In their migratory course, they seem to keep by the line of the Great Lakes, attracted, doubtless, by quantities of dead fish and waterfowl which at this season are strewn along the shore. In this vicinity a few are generally seen every season; but never in the recollection of the oldest inhabitant, have they appeared in such numbers as during the present month" [November, 1862]. S. Passmore, a Toronto taxidermist, reported that he had received 40 to 50 specimens in a period of two or three weeks. Mr. Passmore also stated that the Snowy Owls were very abundant in the Ontario region in 1833-1834, 1837-1838, 1839-1840 and 1853-1854. These records are for the Ontario region, but the migrations during these years probably also extended southward into northern United States as they do today. For example, Cyrus Eaton in the Annals of Warren, Maine, writes of the great numbers of Snowy Owls in Maine during the winter of 1837-1838, one of the dates mentioned above. No doubt an exhaustive search of the obscure annals and records published in the nineteenth century would serve to corroborate the other dates mentioned in the Canadian Journal as well as to fill in certain intermediate dates such as those between 1839 and 1853, an interval of 14 years.

1866-1867

There are several reports including statements by Ruthven Deane (1877, 1902) that there was a marked migration of Snowy Owls into the British provinces and New England during the winter of 1866-1867.

Since the invasions follow approximately a four-year cycle we would expect that one occurred about 1870, but available published records do not indicate that unusual numbers of Snowy Owls appeared at that time.

1876-1877

The winter of 1876-1877 was marked by an invasion of unusual magnitude throughout southern Canada, the middle-western states, New England, and southward. This migration was reported in considerable detail by Ruthven Deane (1877). Mr. Deane was of the opinion at that time that the invasions occurred every ten years, and cited the invasion of 1866-1867. Statements by Barrows (1912), Eaton (1914), and W. E. D. Scott (1879) and reports by various observers which appeared in current issues of *Field and Stream* all agree that the winter of 1876-1877 was one of the great invasion periods.

1882-1883

Another similar migration occurred during the winter of 1882-1883 as reported by H. K. Job (1883), D. H. Talbot (1883), William Dutcher (1885), Philip A. DuMont (1933, 1934), E. H. Eaton (1914), and others.

1886-1887

P. A. DuMont (1933, 1934), basing his information primarily on dated museum specimens, and Butler (1897) are authorities for a marked invasion of Snowy Owls to the middle-western states in 1886-1887. Fleming (1907) reports an unusual number in Ontario in 1884-1885 and also in 1888-1889. Frank Webster (1885) reported that seven of the owls were received from Massachusetts localities by November 12, 1885. The appearance of the owls in this period seemed to have been erratic and, as far as eastern United States is concerned, 1886-1887 does not rank as a major invasion period.

1889-1890

E. S. Cameron (1907) states: "During the winter of 1889-90 there was a regular invasion of Snowy Owls. J. D. Allen, taxidermist, Mandon, N. D. had 500 of them sent to him for preservation which I examined in May, 1890." Various notes in *Forest and Stream* (1889-1890) indicate a very general invasion of these birds throughout New England, New York, New Jersey and Pennsylvania. A. W. Butler (1897), E. H. Eaton (1914) and others also cite 1889-1890 as an important invasion period.

1892-1893

Ruthven Deane (1902) states that in 1892-1893 there was a very heavy migration throughout northeastern United States. According

to Otto Widmann (1907) and W. B. Barrows (1912) there was also a marked invasion into the north-central states that winter.

1896-1897

This invasion, while not pronounced in eastern United States, was very marked in the far west, especially in British Columbia and the State of Washington according to Allan Brooks (1917), J. Fannin (1897), and J. H. Bowles (1906).

1901-1902

The invasion of 1901-1902 was one of great magnitude throughout the region of southern Canada and central and northeastern United States. We are indebted to Ruthven Deane (1902) for a very complete report of this invasion based on solicited information from a great many observers distributed over a large area. In addition to Deane's report, O. Knight (1908), J. H. Fleming (1902, 1907), W. Barrows (1912) Sage, Bishop and Bliss (1913), Eaton (1914), Hoyes Lloyd (1923), and others have confirmed 1901-1902 as an important invasion period.

1905-1906

The invasion of 1905-1906, like that of 1901-1902, was also of great magnitude and over a large area according to R. Deane (1906), Amos W. Butler (1906), Ora Knight (1908), J. Swain (1905), H. Spinney (1906), P. A. DuMont (1934), W. H. Brownson (1905), and others.

1909-1910

The invasion of 1909-1910, judging from available records, was not as marked in New England as it was in the north-central states as noted by T. C. Stevens (1933), L. E. Hicks (1932) and DuMont (1933, 1934). There are also many individual reports of one or more Snowy Owls throughout the middle-west indicating the presence of many more birds than usual for that region. According to L. E. Hicks (1932) the owls also appeared in considerable numbers in Ohio in 1910-1911.

1912-1913

L. E. Hicks (1932) states there were many Snowy Owls taken in Ohio during the winter of 1912-1913, and this is confirmed by individual records, but this year was not marked by an unusual invasion of Snowy Owls into New England.

In 1916-1917 there was, according to S. F. Rathbun (1917), J. Hooper Bowles (1917) and Alexander Walker (1924), an unusually large invasion in Washington and the northwest, but it was not until the following year that the owls appeared in numbers in the east.

1917-1918

This migration was especially well represented by reports in the middle west as well as statements by Philip DuMont (1933, 1934) and W. Youngsworth (1933). More than the usual number of reports were made of the presence of these owls in New England but the invasion is not to be classed with the larger invasions in this section of the country.

1921-1922

The invasion of 1921-1922 was marked in the middle-west as well as in the east by many individual records, but like that of 1917-1918 was not of great magnitude.

1926-1927 AND RECENT INVASIONS

The Snowy Owl invasion of 1926-1927 was very general and one of the largest up to that time when judged by the number of owls reported killed and observed. More than 1000 records were received from New England alone. Detailed reports were made by A. O. Gross (1927), Sutton (1927), E. S. Thomas (1928), J. H. Fleming (1930), and others. From this invasion and for those that occurred subsequently I have had the opportunity to assemble the records of New England, particularly those of Maine which is near the center of the eastern invasion area. Since the cyclic nature of the invasions and their relation to life, especially to the lemming in the north, have been better understood, much greater interest has been taken in the invasions by an ever increasing number of field observers.

There are a few Snowy Owls reported each winter in northern New England, but about every three to five years (usually four years) there has been a large invasion of these birds (*see* Table 1). The magnitude of these migrations is variable. By basing estimates on the numbers reported by the same number of observers distributed in all parts of the state, it has been possible to assign an approximate comparative numerical value to the invasions of this period. Giving the 1926-1927 invasion an arbitrary value of 10, then the subsequent invasions would be approximately as follows: 1930-1931, 6; 1934-1935, 4; 1937-1938, 2; 1941-1942, 5; and 1945-1946, 12 as far as Maine is concerned. I do not wish to imply that "How Maine goes, so goes the rest of the invasion area," but the relative values expressed above will apply in a general way, at least to the New England area.

Because of the importance of the periodic invasions, a Snowy Owl Committee has been formed to collect the records over the entire invasion area. Such a task, by its nature, requires the coöperative effort of a very large number of field observers, the records of which

are assembled by the 14 members of the committee representing every section of the invasion area. A condensed summary and a map of the 1940-1941 invasion was published by the committee (L. L. Snyder, (1943). A report dealing primarily with the records obtained in New York State was published by Dayton Stoner (1943). The Snowy Owl Committee is at present preparing a similar report of the 1945-1946 invasion which will be published at an early date. The student of Snowy Owl invasions of the future is destined to have more complete reports than have been available for the past century.

The Snowy Owl invasion of 1945-1946 is, as was stated earlier, the largest on record as far as the number of birds reported is concerned. The members of the Snowy Owl Committee received reports of 13,502 Snowy Owls of which 4,443 were reported as killed. However, if these numbers are to be used for comparative purposes it should be emphasized that in the case of the two recent invasions, especially the one of 1945-1946, there has been more thorough reporting by a larger number of coöperators over a greater area than ever before.

The invasion of 1945-1946 extended into a vast area including the entire width of the continent from the State of Washington and British Columbia to the Atlantic seaboard. The lower limits of the invasion extended roughly along a line from Oregon, Montana, southern Nebraska, Iowa, central Illinois, Indiana, Ohio, and Pennsylvania to Maryland and south along the Atlantic coast. The most southern records that have come to my attention were one reported by A. D. Shaftesbury (1946) as captured alive on December 14, 1945, in Core Sound off Davis, Carteret County, North Carolina, and one taken at Charleston, South Carolina, on January 24, 1946. The heaviest concentration extended in a broad band from Alberta through southern Saskatchewan and Manitoba.

Since the other members of the Snowy Owl Committee are expected to report on the various areas represented by them, the present account of the 1945-1946 invasion is restricted primarily to conditions in New England. It will serve to supply many details which cannot be incorporated in the general report of the Committee.

I am greatly indebted to the state departments of conservation for their coöperation and to the many persons who assisted in obtaining and assembling the many records throughout New England. I am especially grateful to Mr. D. C. Alexander for compiling all of the reports received by the Massachusetts Audubon Society.

During the 1945-1946 invasion a record number of 2043 Snowy Owls were reported from New England which were distributed by states as shown in the following Table 2.

TABLE 2
NEW ENGLAND RECORDS OF SNOWY OWLS

State	Snowy Owls received by taxidermists	Field observations		Total
		Reported killed	Observed alive	
Maine	247	325	358	930
Massachusetts	81	74	318	473
Connecticut	112	25	173	310
Rhode Island	101	12	43	156
Vermont	94	3	14	111
New Hampshire	41	5	17	63
Totals	676	444	923	2043

Great care was exercised to avoid duplication of reports, but this was not always possible in cases where more than one observer may have reported on the same owl at different times. The above records are merely a representative sample since many owls were seen or killed that never were reported to us. Five thousand would be a conservative estimate of the number of Snowy Owls which visited New England during the period of the invasion. We were able to examine the specimens and records received by eight Maine taxidermists. Taxidermists in states such as Massachusetts and Connecticut where these birds are protected, reported totals but were unwilling to furnish data for obvious reasons. Some of them stated that they refused to accept any Snowy Owls because they considered it illegal to do so. Some of the owls received were probably from other states in many cases and hence the numbers received by taxidermists do not serve as an index to the relative abundance of the owls in the various states. They are important in measuring the magnitude of the invasion into New England as a whole.

In Maine, letters and questionnaires were sent to 105 state supervisors and wardens, to the keepers of 56 lighthouse stations, and to field observers in all parts of the state. From these a total of 683 reports of owls were received—325 as killed or found dead and 358 as alive. In addition there were 247 Snowy Owls received by eight Maine taxidermists, making a grand total of 930.

As in previous invasions, few of the owls were seen in the densely wooded sections of the state, but there were marked concentrations along the chief river courses and lakes and especially in the open areas along the sea coast and the islands lying well off the shore. According to the reports it was not unusual to see ten or a dozen of the owls on a single small island at one time. The keepers at Duck Island, Metinicus Rock, and Petit Manan lights made estimates of 50 Snowy Owls each

at their stations. Even allowing liberally for duplication, this indicates that an unusual concentration occurred on our outer coastal islands. One coast guardsman proudly boasted of killing nine of the owls at his station on a single morning. One lighthouse keeper reported that he had killed twelve of the owls in the course of a week. Mr. Ernest Joy, warden at Kent Island, saw 16 of the Snowy Owls at one time on October 18, the first day that they arrived. Mr. Joy examined the stomach contents of eleven of the owls killed by hunters in the vicinity of Kent Island and reported that two were empty; one had a mass of unidentifiable matter; one, green algae; one, barnacles and green grass; one, feathers and parts of a Herring Gull; one, a Purple Sandpiper; and four contained remains of Dovekies.

Mr. Robey Tufts, Chief Federal Migratory Officer, Wolfville, Nova Scotia, writes: "One reporter states that approximately 150 Snowy Owls appeared suddenly on Seal Island which is located at the most southerly point of Nova Scotia. This island is two and a half miles long and a mile wide. The island has been infested with house rats which live among the rocks and boulders above the high water mark. The owls have all but exterminated the rats on the island for which the people living on the island are very grateful." In a second letter dated March 1, 1946, Mr. Tufts writes: "Generally speaking, Snowy Owls have been found more abundant along the coastal areas where broad meadows and treeless plains exist than in the wooded interior of the province. On Bout Island, a small marshy area of 1,000 acres, adjacent to the shore of Minas Basin, Kings County, a flock of twenty Hungarian Partridges were seen during the middle of November. There was a pair of Snowy Owls present and when the island was visited again a month later the owls were again seen but the flock of partridges had been reduced to two birds. Clusters of feathers frozen in the ice and snow were seen in several places suggesting the birds had been killed there, presumably by the Snowy Owls." Mr. Tufts also states that a reliable observer from Antigonish County saw a Snowy Owl catch and kill a Black Duck in flight. Mr. Tufts examined the stomach contents of five birds of which two were empty, one contained a large house rat which had been swallowed whole within a few minutes before it was shot, one contained small mammals, either mice or moles, and another contained feathers of a Black Duck. One Snowy Owl was seen to fly up from the remains of a freshly killed hen pheasant. The examinations by Tufts and Joy and those of others confirm the variable nature of the food of the Snowy Owls, both favorable and unfavorable as judged from the standpoint of the interests of man (*see* Gross, 1944, 'Food of the Snowy Owl'). There are extreme cases

of behavior that clearly indicate the desperation to which the owls are driven in securing food when they arrive in a semi-starved condition after the strenuous migratory flight. A Snowy Owl made a swoop at an automobile near Baranga, Michigan, and made off with a squirrel's tail flying from the car's aerial. A warden writes that a Snowy Owl made repeated attempts to get his fur hat, and a hunter reports that he captured one of the owls alive when the bird flew at him and grasped his glove. A Maine trapper reports that on two occasions he found Snowy Owls in his steel traps set for wild cats.

During the major invasions, a considerable number of the Snowy Owls find their way into the midst of our populous cities, a strange environment compared to that experienced in their nesting haunts on the Arctic tundra. Some of them take perches in conspicuous places such as roof and chimney tops, flag poles and church spires where they never fail to attract general attention. The presence of the owls has even caused traffic jams, and at Lewiston, Maine, the police were called upon to shoot the victim that had inadvertently caused the trouble by attracting so many onlookers. Often the owls were stoned or harassed by boys who seem to have an instinctive urge to torment such creatures.

The persecution of the owls by the many hunters in the field during the open game season, a time when the migration is at its height, is most severe. This killing goes on even in states where the Snowy Owl is supposed to be protected by law. Some of the hunters feel they are contributing a service to their sport by killing all hawks and owls, an attitude encouraged by certain sports writers in their newspaper columns. Others kill these large, white, conspicuous birds out of mere curiosity or to satisfy a lust for killing. Out of 2043 Snowy Owls reported for New England, more than half, or 1120, had been killed (*see* Table 2). It is obvious that few of these attractive visitors pass the gauntlet of killers, and fewer of them ever live to return to the Arctic in the spring. This is borne out by the reports of the marked decline in the Snowy Owl population in the Arctic in the years following major invasions. Some observers in the middle-west have reported evidences of a return migration of the birds in the spring, but to my knowledge, no marked indication of such a movement has been observed in New England.

DATES OF ARRIVAL

During the 1945-1946 migration, some unusually early dates, as compared with those of previous invasions, were reported for New England. These dates are also earlier than the earliest reports from

the other regions of the present invasion. The earliest date of first appearance for New England was of a Snowy Owl taken at Kezar Falls, Maine, on September 15, 1945. The second earliest record was of one seen at Stratton, Maine, on September 29, 1945. On October 1 the first Snowy Owl appeared at Mt. Desert Rock lighthouse station. Mr. E. M. Horne, taxidermist of Hallowell, Maine, received the first owl for mounting on October 3, 1945. There are three records for October 10, as follows: a female shot at Caribou, Maine, one shot at Blaine, Maine, and another killed at Winthrop, Massachusetts. All three birds were preserved by taxidermists. There are 28 New England records for the last two weeks of October. Great numbers of the owls made their appearance during the first part of November but the peak was not reached in Maine until the last week of November and in southern New England the first week of December. Many were present through December and January, but after February and March there was a sharp drop in the number of reports. Whether this decline means a return migration had taken place or that the owls had been killed off cannot be determined; probably that both factors are involved. There are 14 records of Snowy Owls seen in April and four during the month of May. The last owl reported was one seen at Portland, Maine on May 14, 1946. Similar late dates were reported in New York State but not in the western sections of the invasion area in the United States. No June records were received for New England.

Dr. John B. May writes: "On June 17, 1946 I saw and took colored movies of an old, male Snowy Owl at Coin du Banc, about five miles from Percé, Quebec." Captain Duval reported that two or three Snowy Owls were on Bonaventure Island all spring. Mr. Burt Harwell informs me that he photographed one of the Bonaventure owls in June. Mr. Robert L. Grayce, a member of the MacMillan Expedition, saw a Snowy Owl at Gannet Clusters, Hamilton Inlet, Labrador, on July 9, 1946, and heard the call of another on July 10. There is of course no way of ascertaining whether or not these birds were returning from a visit farther south.

SNOWY OWLS AT SEA

As during past major Snowy Owl invasions, a large number of the owls have been reported as taking refuge on ships at sea. The following are typical of those that have come to my attention. E. M. Reilly, Jr., in a letter dated January 14, 1946, writes of two Snowy Owls which came aboard the troop transport U. S. S. General Le Ray Eltinge while traveling the Great Circle route between Gibraltar and New York City, on the morning of November 8, 1945. The ship at

the time was 1300 miles from New York City and 320 miles from Newfoundland. Mr. Reilly states the owls preferred the mattress radar aerial, mounted high on the mast, as a perch, where they created no little disturbance to the delicate instruments. Swinging the mattress had little effect but blasts from the whistle would cause them to fly. At such times the birds would circle the boat for an hour or more before returning to their perch on the aerial. When away from the boat the birds flapped their wings regularly but soared in the trough of the sea, and only when circling the ship for a landing would they arise more than fifteen feet above the water. Occasionally they seemed to drag their talons in the water but were never seen to feed on anything.

A Snowy Owl landed on the foremast of the transport James Parker on March 9, 1946, when the ship was 300 miles southeast of Newfoundland. It remained on its lofty perch for two days before it was finally captured alive and brought to New York City. Pictures of this bird were given wide publicity in the daily newspapers.

Chief Officer Barth F. Reed of the M. V. Acorn Knot, writes that on April 15, 1946, while on a voyage from Halifax, Nova Scotia, to Reykjavik, Iceland, a Snowy Owl came aboard when they were at 44° 41' N. and 42° 35' W., approximately 500 miles from the nearest land. Mr. Reed states that he does not believe the bird was blown out to sea by the winds.

I have received twenty-four reports of Snowy Owls which were observed on ships at sea and it is reasonable to suppose that many others took refuge in this manner, but it is probable that vastly greater numbers perished on the broad expanses of the ocean. Two lighthouse keepers stationed on extreme outer coastal islands of Maine reported seeing Snowy Owls flying from their islands or over their islands in a direction away from the mainland. These birds probably never lived to return. There is no way of ascertaining how many of the owls meet disaster in this way, but it must be great—greater than anyone has supposed. It reminds one of the fate of the lemmings at the time of their periodic migrations in northern Europe when hordes of these rodents are said to perish by rushing headlong into the sea.

A few of the owls succeed in surviving until they have traveled great distances over the Atlantic, perhaps by taking rides in turn on a number of ships along the main shipping lanes. Murphy and Chapin (1929) reported a Snowy Owl that was collected at Fayal, Azores, on January 14, 1928. It would be impossible for a land bird such as the Snowy Owl to survive such a long, continuous flight at sea. This bird undoubtedly took refuge on a ship or a number of ships or it may

have been carried in captivity on one of them from the western side of the Atlantic, as suggested by the authors, since the primaries of the specimen, now in the American Museum, are greatly frayed.

RELATION OF THE SNOWY OWL INVASIONS TO THE LEMMING CYCLE

The peaks of Snowy Owl abundance have been correlated with the years of periodic maximum numbers of Arctic foxes and other predators in the north (Gross, 1931, 1946). Both foxes and Snowy Owls are predators of mice, especially of the lemmings, and are dependent on them as their primary source of food. It is now generally accepted that the underlying cause of Snowy Owl invasions is the well-known cyclic fluctuations in the lemming and mouse populations.

In the barren lands of Arctic America there are at least seven kinds of mouselike rodents of which the lemming is the largest and most important. It weighs about 75 to 100 grams, about twice the size of the smaller voles and mice. The lemming has a short fur, a stumpy tail and a dark-colored dorsal stripe. The pelt of the lemmings belonging to the genus *Dicrostonyx* turns white in winter but that of *Lemmus* does not change color. The lemming is very edible, not only for predatory birds and mammals, but also occasionally for Eskimos, and even Arctic explorers have been known to eat them when food was scarce. The lemming is a voracious feeder and has extraordinary powers of reproduction and ability to increase, even after a period of scarcity.

Dr. Charles Elton (1942) has worked out the details of the lemming cycle in Ungava and Labrador. Similar conditions prevail in Baffinland and the western side of Hudson Bay, a great area of millions of square miles including the entire breeding area of the Snowy Owl. The lemmings increase over a period of three to five years—an average of approximately four years—from a low ebb to a maximum. The year of maximum abundance of lemmings is also a good year for the predators. The Snowy Owl fits into the picture somewhat as follows. The owl lays from six to eight eggs, and some nests have been found to contain as many as thirteen. When the eggs hatch, it requires a tremendous amount of food to feed such a large family. Ordinarily the mortality is great, with only two or three of the owlets reaching maturity. If the lemmings are scarce, the owls may not even attempt to nest. In a good lemming year, practically all of the large families survive, and thus the Snowy Owl population is built up to a peak along with that of the lemming. The same might be said of the other predators. Then with abruptness the 'crash' comes.

The predators such as the foxes and the Snowy Owls that depend

primarily on lemmings for food must do one of two things—they either starve to death or they must find other sources of food. The foxes are able, by their cunning and adaptiveness, to secure other food, but many of them die of starvation and disease as the Hudson Bay records clearly indicate. The Snowy Owl, however, since it is able to fly, wanders far and wide, in years of extreme general scarcity of lemmings, even coming down as far as northern United States. It is clear that the migration of the owls is due to two factors: first, the great increase of the Snowy Owl population; and, second, the abrupt disappearance of their chief food, the lemmings.

Other predators of the lemming also exhibit, though not in such a spectacular way as does the Snowy Owl, the influence of the lemming cycle. Gyrfalcons, Rough-legged Hawks, Short-eared Owls, Ravens, shrikes, and others have usually been noted in increased numbers during the times of the Snowy Owl invasions. The lemming cycle exerts a profound influence on the ecology of the Arctic barrens. It is not only the basic cause of periodic migrations of predatory birds, but it also vitally affects the fur-bearing animals and thus the whole economy of the Arctic fur industry.

So intimately are the Snowy Owl migrations tied up with the lemming cycle that the migrations can be predicted if we have a knowledge of the status of the lemming. In August, 1945, I received a letter from Roland C. Clement, who had been spending a year at Indian House Lake, an enlargement of the northward-flowing George River which empties into Ungava Bay, northern Quebec. The area is typical Hudsonian Zone or semi-barrens. He told of the lemming crash and predicted well in advance the Snowy Owl invasion of 1945–1946. Mr. Clement is writing a most interesting paper on the natural history of Indian House Lake, P. Q., in which he gives an account of his observations of the lemming during the year of the crash. He has kindly allowed me to take extracts from a section of his manuscript, which has not yet been published, which are of interest in connection with the present invasion of Snowy Owls. Mr. Clement writes that in the fall of 1944 lemming burrows were numerous, and in places there were veritable colonies built into the banks above the bogs. These concentrations usually faced southward or southeastward away from the prevailing wind and they were consequently covered with drifted snow throughout the winter. The records of the activity of the lemmings on the snow revealed that they occurred wherever loose rocks were liberally scattered on good soil. Very flat fell-field or pure gravel beds which occurred locally were untenanted. The abundance of the rodents is strikingly revealed by such notes as those of two lemmings

found in a freshly-dug post hole, of three which were found in a sleeping bag of a man sleeping on the ground, and of mice that were found in trout and salmon cleaned by the cook.

Mr. Clement made a trace census during October of a series of forty-eight samples one meter square. Later, when the snow had been on the ground a while, he found 240 mouse trails across this thirty-two-hundred-foot course, of which 180 were made by *Dicrostonyx*, 40 by other Microtines and 20 by *Peromyscus*. After the snow appeared, lemmings seemed particularly active and evidently engaged in much wandering or random exploration because they often went out on the lake ice where they invariably were picked up by raptorial birds. Little piles of intestines gave evidence of their fate throughout October and November. During the first autumn, three instances of non-predatory mortality among mice were found. On October 20 a dead lemming was found on the tundra, on October 31 an uninjured lemming was found dead on the moss in thick spruce woods, and on November 21 a specimen of *Phenacomys* was found lying on the ice near the station. On December 1 Mr. Clement caught a lemming which died two days later after going through a series of nervous convulsions that suggested some form of encephalitis.

In late April, the melting snow revealed a labyrinth of tunnels but very few fresh signs of life. Only one fresh lemming trail was seen during the entire month. From May to August hardly one of Mr. Clement's walks, if extended a mile or more, failed to reveal at least one or two lemmings that had died under the snow. All of these were sprawled out flat and were in the gray coat, though most of them had the enlarged fore claws of winter. These half-dry carcasses were scattered here and there over the tundra. In August he found the skeletal remains of four lemmings at the base of a bluff. By trapping tests and by examining many sites that were populated the preceding year, Mr. Clement discovered striking evidence of the marked decline. No mice or lemmings were found in any of the salmon and trout caught in 1945 as there were the year before. Since all the lemmings found dead were in the gray phase, Mr. Clement thinks this may be interpreted as evidence of a spring crash.

In discussing the relationship of climate to the cycle, he states there were no weather records for comparison, prior to the year he was at the station, but at Chimo, on Ungava Bay, for example, there was an excess of temperature of about 14 degrees and a precipitation deficiency of about 11 inches in the period from September, 1944, to June, 1945. The actual snowfall recorded at Indian House Lake during this period was 35.4 inches, 10.8 inches of which fell in January during a freak

storm. The January, 1946, snowfall was less than three inches. Mr. Clement comments: "Although it is logical to expect low snowfall and consequent exposure to affect the over-all picture, it may be well to recall that the heaviest concentration[s] of lemmings were in areas that were protected by several feet of drifted snow, and these colonies nevertheless appeared to bear the heaviest mortality."

Because of our lack of a complete knowledge of the life history of the lemming in the different regions of the Arctic and since no one as yet had been able to observe conditions continuously during the period of an entire cycle, there are at present conflicting opinions concerning the underlying causes of the cyclic fluctuations of the lemming population. Disease has been suggested by Elton and others as a possible factor and Clement's observations in northern Quebec, of finding many dead and some disabled mice at the time of the crash, lend weight to this view.

Sunspots have been advanced as a possible basic cause of the periodic outbreaks of disease and conditions of the weather and thus as influencing the cycle. The Lockyers (1901-1902) have shown that there is a definite "four-year" cycle. Dr. Ralph DeLury's theory of the mechanism is that the hotter high-level prominences' faculae and flocculi are relatively great emitters of ultra-violet light, which by ionizing our upper atmosphere cause much of our electro-magnetic disturbance, followed by development of haziness, cloudiness, precipitation, and barometric and temperature variations. These in turn affect all forms of living things and their food. In a recent letter from Dr. DeLury of the Dominion Observatory, he states that he favors the idea of the meteorological effects, so evident in the four-year period determined by the Lockyers, as being a profound factor in the lemming cycle. However, V. E. Shelford (1943) states that there appears to be little correlation between large numbers of lemmings and sunspot numbers of ultra-violet light as observed at Mount Wilson. But he adds that no valid conclusions can be drawn from such a short period of observation.

Dr. Shelford (1943) has presented some interesting tentative conclusions, based on observations in the Churchill area, concerning the relation of weather to lemming populations. Increase depends upon: "The occurrence of more than average snowfall so distributed as to afford protection throughout the winter, in combination with temperatures above or near normal in the cold months. Two favorable years in succession are usually necessary to build up a peak population." In a recent letter received from Dr. Shelford he states further: "The lemming I now know breeds throughout the winter when there is snow,

and apparently fails to breed and suffers greatly from predation when there is little snow." He believes that no other explanation is necessary to account for the periodic crashes. (Shelford states that he has never found many dead lemmings!) Shelford's prey-predator hypothesis could explain the cycle if it were a simple oscillation of the Lotka-Volterra type, but he fails to account for a 'crash' that is unaccompanied by a high-predator population. (Mr. Clement reports very few raptores at Indian House Lake throughout the winter and spring.) Nor does the hypothesis take into account the natural mortality which Clement also found so marked at the time of the last crash in northern Quebec. It is highly probable that several decimating factors are at work, but that one of them is dominant under the conditions existing at the time of any particular cycle. The effect would be to mask the subordinate factors which, in some other year, might become the dominant ones.

The over-all picture is still hazy and there remains much more work to be done in the Arctic before it becomes crystal clear.

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Bowdoin College

Brunswick, Maine