

single pair* remained in the town until about the twentieth of November, nearly ten weeks after the rest of the flock had gone. No trace was seen of them after that date and it is feared they froze to death.

The following table, taken from the records of the Greencastle Nature Club and its successor The Franklin County (Pa.) Nature Club shows the arrival and a few of the departure dates of the Purple Martin at Greencastle over the period of seven and a half years from 1915 to 1922:

Year	Date When First Bird Was Seen	Departure Date
1915	April 7	Sept. 11
1916	March 31	Sept. 7
1917	March 21	August (?)
1918	March 30	August 20
1919	March 17	August 6
1920	March 26	_____
1921	March 8	August 10
1922	March 21	_____

Greencastle, Franklin Co., Pa.

BIRD BANDING AS AN AID TO THE STUDY OF MIGRATION.

BY HARRY C. OBERHOLSER.

MUCH importance attaches to an accurate and thorough knowledge of bird migration. The solution of the many interesting scientific problems presented by this mystery of the bird world is of practical value in such matters as the protection and increase of migratory birds. These problems have long attracted attention, and many ornithologists, among them Palmén in Finland, von Middendorff, Severzoff, and Menzbier in the Russian Empire, Homeyer in Germany, Winge in Denmark, Gätke in Helgoland, Herman in Hungary, Rössler in Croatia, Clarke and Whitlock in Great Britain, and Baird, Cooke, and Brewster in North America, have contributed much to our knowledge of bird migration. The

* This circumstance is the more peculiar because both birds were adults and entirely able to fly.

chief methods by which these men sought to throw light on this subject consisted in observations of the movements of day migrants, the amassing and tabulation of information regarding the times and localities of the appearances and disappearances of birds, and the collection of all possible concomitant data,—biological, meteorological, and geological. Regarding many phases of migration much is to be learned from a tabulation of arrivals and departures and by other similar methods. The discrimination of subspecies often furnishes valuable clues to the origin of migrants. Although we may learn much by these means, most of them have a serious drawback, that they deal with the species as a whole, not with individual birds, and that consequently a considerable part of the conclusions must be reached through negative evidence.

Recent years have seen the development of another method of bird migration study, that of bird banding. This furnishes the means of following the movements of the individual bird, and thus of obtaining absolutely accurate data thereon. It seems to be the long sought for key to many of the difficulties that have hitherto beset the student. It is not, however, sufficient to know the beginning and the end of the migration journey, for we need information regarding the bird while passing between these two points. Therefore, valuable as is the banding of birds in which reliance is placed on a single capture of the bird, the banding of birds by systematic trapping has enormous advantages over the other method.

One of the most important facts to be learned is the direction of migration. This was formerly supposed to be from north to south or vice versa, but Gätke tried to prove a theory of general east and west movement. In so doing he assumed that individuals of some species came to Helgoland from as far east as Lake Baikal, or even the eastern coast of Siberia, which, however, would not be capable of proof without the banding of individual birds. A similar theory of east and west migration, based partly on negative evidence, has been formulated for certain species in North America, but now this is in some cases proved by banding to be actually true.

It was formerly supposed that birds took but a single direction or route when migrating, and exceptions to this rule were explained

by Gätke on his theory of a broad migration front rather than a series of more or less constricted migratory routes. A few cases, such as the Marbled Godwit in North America, which moves both east and west from its breeding ground, and the Thick-billed Sparrow, which migrates southeast, southwest, and northwest from its breeding area, were worked out apparently with accuracy but no one was prepared for the further really astonishing revelations of the variety of routes extending in even opposite directions pursued in many cases by birds of the same species, that bird-banding has disclosed. For instance, European Woodcocks banded near St. Petersburg in Russia have been found to take three entirely different migration routes which lead to three different and widely separated winter quarters.¹ Likewise ducks banded at Great Salt Lake, Utah, were found to have moved both west, north, east, and south during the autumn migration season. Black Ducks banded at Lake Scugog in southern Ontario pursued two distinct migration routes, one down the Mississippi valley, the other down the Atlantic coast, as already shown by Mr. F. C. Lincoln.²

Furthermore, the length of the migratory route of individuals is only in a very general way determinable except by bird banding. In fact, Whitlock says:³ "It may be questioned whether it is possible to prove that any species in central Germany migrates to the southern parts of Africa to winter there."

Nevertheless, examples proving practically this very thing are to be found in the results obtained by systematic banding. For instance, the White Storks that nest west of the Weser River in western Germany migrate to Spain, those that summer east of this river winter in southern Africa.⁴ Furthermore, examples of exceptional migration or wandering are found in the Black-headed Gulls banded at Rossitten in northern Germany that were recovered in the island of Barbados, West Indies, and off the State of Vera Cruz, Mexico; and in the Common Tern banded in Maine that was found in the Niger River in western Africa.

¹ Lucanus, *Rätsel des Vogelzuges*, 1922, p. 48.

² *The Auk*, XXXIX, 1922, p. 329.

³ *The Migration of Birds*, 1897, p. 125.

⁴ Schenk, *Aquila*, XXVIII, 1921, p. 152.

Closely connected with the length of the migration route is the difference in the length of this route followed by individuals of the same species when all travel over practically the same territory. The data afforded by different subspecies¹ of a species have shown that in some cases at least the individuals breeding farthest north winter farthest south, and it has been assumed from this that such is usual. In most species this fact is determinable, however, only by banding; and it is quite possible that this may in other, if not in most cases, turn out not to be so.

Fully as important is the tracing of the exact routes followed by migrating birds; also whether or not this is the same year by year, as well as whether or not it is the same for both adults and young. Here, again, much can be learned by banding that would otherwise be entirely unsuspected. In fact, it is practically impossible, without this means of following the movements of individuals, to work out accurately the trails that birds follow.

Bird banding results to date in both Europe and North America indicate that in determining unknown routes little can be safely inferred from the movements of species already known, and that each must be worked out separately. One of the most interesting developments is the discovery that so many birds, contrary to what has been supposed, follow very circuitous routes in their migration journeys.

The speed at which birds travel while on migration has been the subject of much controversy. Gätke asserted that the Hooded Crow, a bird of ordinarily slow flight, made the migration journey from Helgoland to the eastern coast of England, a distance of some 325 miles, in three hours, a speed of over 100 miles per hour; and that the Northern Blue-throat passed from Egypt to Helgoland in a single night, a distance of about 1600 miles, which would give an average speed of 180 miles per hour. These figures are, of course, obtained by inference, partly from negative evidence, but could be definitely proved or disproved by sufficient banding operations. The question of migration speed involves not only the actual flight velocity of the bird, but also the length of time

¹ In the identification of non-breeding specimens of subspecies that are based on average characters there is, of course, a margin of error, due to such individual variation as overlaps the subspecific differences.

consumed in the entire journey, the actual rate per day and between stops, the rate of advance of the vanguard of the species, that is, the "first arrival," the regularity or irregularity of this, and whether or not the rate increases as the bird passes northward. On these points, through the painstaking work of Professor W. W. Cooke we have some light, but final proof is yet to come through bird banding.

The manner of migration is intimately related to its speed, and includes the determination of how far birds go in continuous migratory flight, particularly over land; how often they stop; whether they go fast and stop seldom, or slow and stop often; how far apart are these stops, and whether or not they are the same on successive migration journeys; whether individuals travel every day, or stop for several days before moving on; how long are these stops; how much time individuals occupy in the total journey between the breeding ground and the winter home; how long they remain on the nesting ground, and how long in winter quarters; whether males, females, and young travel together or separately; which individuals arrive earliest in spring, the summer residents of the locality or migrants on their way to the north; which arrive earliest in autumn, the winter residents or migrants bound farther south; which leave first in the autumn and spring, residents or migrants; and whether adults and young occupy the same or separate winter quarters. On all of these problems bird banding is destined to throw much light.

Another migration subject on which much has been said is the return of adult and young individual birds to the same spot or the immediate vicinity of the previous year's nest to breed. Popular assumption from a few instances has credited birds with a regularity of return that is doubtless beyond the facts. Bird banding experiments show that in certain species at least some individuals do return even to the same spot, but not nearly so often nor as regularly as has been supposed. Whether or not the cause of this irregularity, however, is the well-known high mortality in bird life remains yet to be proved. Frequently a bird occupying a nesting site that was in use during the previous year is found on examination of its band not to be the same individual. Bird-banding operations, notably those of Mr. S. Prentiss Baldwin,

have shown that birds of certain species return with comparative regularity to a restricted winter home, but further investigations are needed definitely to establish this regularity for other species.

The effect of weather, particularly storms, on the migratory movements of birds is undoubtedly considerable, and it is one of the more difficult, but none the less important, questions. Mr. Baldwin's interesting observations on the effect of storms in causing migrant White-throated Sparrows to depart from a migratory way station where they had remained for several days is exceedingly suggestive in this connection, and indicate how much may be learned regarding this from bird banding.

Bird migration "waves," or "rushes" as they are called by British writers, may be intimately related to weather conditions, and we look to bird banding to explain their characteristics, as for instance, whether they are made up of the same individuals over a considerable distance and period of time, or are constantly undergoing changes.

In the case of the extension of range by birds it would be difficult by any other method than bird banding to ascertain by what route the extension takes place, whether by the breeding birds in contiguous territory or by others farther away, and whether performed by adults or by young of the previous year. Likewise in this connection the question of the permanency of migration routes, and whether or not they follow the course originally chosen by birds invading a new territory may also be determined by bird banding work.

From what has been said by the many writers on the subject, it is evident that bird banding, and especially that performed through systematic trapping as developed by Mr. Baldwin, has given a new impetus to the study of bird migration. Judging from what already has been accomplished, it is, we think, safe to predict that many of the baffling problems of bird migration will sooner or latter be solved by this new means of investigation.

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