Waxwing recoveries, although only five in number, are of some interest. Two were reported from southeastern Louisiana, and one each from North and South Carolina. The fifth was found at Beverly, Massachusetts. Redwings make a similarly small showing in numbers, and with less wide distribution. One was taken at Walkertown, Virginia, and one at Riverside, New Jersey—both shot. It may be worth mentioning that a Redwing banded at the Austin Station on Cape Cod in August, 1934, was reported to me when at Summerville, S. C., in late 1934 as having been shot near that town, indicating a further south trend than would appear from my own recoveries.

It may be of some interest, though perhaps rather discouraging to the beginner, to compare the numbers recovered of each of the nine species covered in this article with the total number of birds banded. As already mentioned, the number of Song Sparrows banded within the period 1930-1950 inclusive, was 6,109—the largest number of individuals of any one species. This has yielded the lowest percentage of recoveries at distances of over 20 miles—only slightly over one-tenth of one percent. Recovery percentages of the other species are: Grackle 1.9%, Starling 1.68%, Purple Finch 1.51%, Waxwing 1.24%, Redwing .9%, Robin .67%, Tree Sparrow .387% and Junco .188%.

If small bird banding depended wholly on recoveries for worthwhile information, it would be discouraging indeed for those just starting. Fortunately there are of course many other lines of investigation which are open to the bander, such as returning tendencies, life spans and plumage changes, as well as mating habits, and diseases and parasites, which yield larger returns in proportion to the number of birds banded. And while occupied with these studies the persistent bander gradually builds up data on recoveries which, combined with those from other stations, are sure to prove of importance in the study of migration.

Footnote to last sentence.

In connection with the foregoing, it may be of some interest to new banders to read my articles in the July, 1929, number of *The Bulletin of the Northeastern Bird-Banding Association,* and in the April, 1933, issue of *Bird-Banding,* for data on returns, parasites, etc., accumulated in those days of the operation of this station, Also articles by my able assistant for many years, Edwin A. Mason, in *Bird-Banding* for July, 1936; January, 1938; and July, 1942, especially the last, which deals with recoveries from the flock of migrating Grackles banded between April 9 and 18 in 1939.

Groton, Massachusetts.

TURNOVER RATIOS

BY CHARLES H. BLAKE

In the search for numerical values to use in connection with that sort of migration rate which is equivalent to length of stay, it appeared that the turnover ratio and other ratios associated with it had some value. There are a number of possible interpretations of the bare term "migration rate." For our immediate purposes we are concerned with a transmigration rate which arises from the rates at which birds arrive at and leave a given point. Such a rate tells nothing of the rate of movement between stops nor of the rate of advance of the margin of occurrence of the species. These are still other migration rates.

The raw data for the ratios employed are tallies over any desired period of the number of banded individuals of a species present on each day, the number of arrivals and the number of birds not present beyond the end of the period. These data deal solely with banded birds and do not use any estimates of total population. It is, however, assumed that an individual is present on all the days intervening between actual trappings unless there is some reason to believe it actually absent from the region.

To illustrate the mode of calculation, we take the data for the White-throated Sparrow for the period 1-5 May and combine the figures for six years, 1947-1952. The numbers of birds present on each day are respectively two, five, four, 11, and six, a total of 28 bird-days or an average of 5.6 birds per day. Over the same period there were 16 arrivals and 12 departures which give daily averages of 3.1 and 2.4. The daily arrival ratio as a percentage is 3.1 x 100/5.6 or 55% and the daily departure ratio is 47%. Hence the daily turnover is (55 + 47)/2 or 51%. The total turnover for the five-day period is 255%. Since the daily turnover ratio is 51%, it is evident that a complete change of population, if each bird behaves like the average bird, requires two days. This is the reciprocal of the daily turnover expressed as a decimal fraction (0.51). It can also be calculated as twice the daily average number of birds divided by the sum of the daily averages of arrivals and departures, i.e., in this example 2 x 5.6/(3.1 + 2.4). This latter method is more accurate.

To avoid distortion all the averages used in any one calculation must be computed over the same period of time. The total turnover for a period will depend on the daily turnover and the length of the period. Differing period lengths may be used if the effect on the total turnover is recognized. For relatively short periods the effect of mortality is likely to be small compared with departures of live birds. Mortality acts to increase the departure ratios.

We may now take a look at some results derived from six years of banding operations in Lincoln, Mass. The first example is the spring migration of the Eastern Fox Sparrow (Table I, part 1).

From part 1 of Table I we see that the peak rate of transmigration occurs in the first period but there is an excess of arrivals over departures through the first three periods and hence the population peak occurs in the third period. The population shifts from incoming to outgoing at the end of this period. The average turnover times are consistent with length of stay computed by another method (see Blake, 1950).

Part 2 of Table I displays similar statistics for the spring migration of the White-throated Sparrow. The last two periods are based on so few data as to be quite untrustworthy. Perhaps we should regard any Whitethroat trapped after 15 May in Lincoln as probably a delayed migrant and abnormal in its actions. The real peak of transmigration is the second period. The first period has the highest average population and is the only period in which the population is incoming.

By way of contrast let us consider data for part of the stay of adult Red-eyed Towhees and the data for immatures. Here we are

TABLE I

PART 1. EASTERN FOX SPARROW—SPRINGS 1947-1952

Period	Daily Arrival Ratio, %	Daily Departure Ratio, %	Daily Turnover, %	Total Turnover, %	Aver. Turnover Time, days
21-25 Mar.	90	82	86	430	1.2
26-30 Mar.	65	61	63	315	1.6
31 Mar.-4 Apr.	67	65	66	330	1.5
5-9 Apr.	13	37	25	125	3.6
10-14 Apr.	29	43	36	180	2.8

PART 2. WHITE-THROATED SPARROW—SPRINGS 1947-1952

Period	Daily Arrival Ratio, %	Daily Departure Ratio, %	Daily Turnover, %	Total Turnover, %	Aver. Turnover Time, days
1-5 May	55	47	51	260	2.0
6-10 May	71	91	81	405	1.2
11-15 May	41	41	41	205	2.4
16-20 May	50	50	50	250	2.0
21-23 May	100	100	100	300	1.0

dealing with slow moving or actually resident birds. The necessary figures are shown in Table II.

It seems clear that the spring migration of adults is small and involves only the first three periods. From 21 May to the end of July we have an essentially static summering population. The apparent amount of migration is somewhat diminished by a tendency of the summering birds to arrive before the transmigrants. Beyond 20 August the available data are very scanty but point to a departure of the last summering birds during September but no transmigration of adults in the fall.

In Table II, part 2, the whole material on immature towhees is set out. Throughout the movement is nearly as rapid and mostly more rapid than that of adults in spring. The rate fluctuates somewhat but it is not evident that this is due to the appearance of successive broods of young. It is not unlikely that the rapid movement of the very young fledglings taken in the last eight days of June is occasioned by these birds being led about by their parents. They may not get a chance to settle down for a while until they achieve independence. At all events, the picture is one of a ceaseless but variable flow of immature birds. This is not necessarily a true migration. The recorded return of four percent of these immatures indicates that they form some attachment to the area and do not subsequently behave like transmigrants.

Some more general comments on this method are in order. I am indebted to Prof. Douglass V. Brown of M.I.T. for a discussion of turnover rates in labor statistics. In such work the lower of either arrival or departure ratios is used. This biasses the turnover by always taking the lowest possible value. The result is the amusing case of a biassed statistic which makes both parties in interest happy. Some turnover rates are based on mid-point population rather than average population. I have chosen the latter because there was no assurance of a linear change of population with time within each period. Because all my calculations are based on daily number the maximum ratios are unity or 100 percent. This sets a minimum of one day for the

TABLE II

PART 1. ADULT RED-EYED TOWHEES—SPRING AND SUMMER 1947-1951

Period	Daily Arrival Ratio, %	Daily Departure Ratio, %	Daily Turnover, %	Total Turnover, %	Aver. Turnover Time, days
26-30 Apr.	20	0	10	50	10.0
1-10 May	19	6	12½	125	7.8
11-20 May	9	5	7	70	14.7
21-31 May	0	2	1	11	95.0
1-10 June	0	2	1	10	95.0
11-20 June	1¼	2½	2	20	53.0
21-30 June	1½	1½	1½	15	70.0
1-10 July	0	2	1	10	126.0
11-20 July	0	0	0	0	∞
21-31 July	0	2	1	11	104.0
1-10 Aug.	2	2	2	20	51.0
11-20 Aug.	0	5	2½	25	40.0
	PART 2. IMMATURE RED-EYED TOWHEES				
22-30 June	100	100	100	900	1.0
1-10 July	15	6	10	100	10.0
11-20 July	20	24	22	220	4.5
21-31 July	7	13	10	110	10.0
1-10 Aug.	38	27	31	310	3.1
11-20 Aug.	14	11	12	120	8.1
21-31 Aug.	9	7	8	88	12.5
1-10 Sept.	8	7	7	70	13.9
11-20 Sept.	8	10	9	90	10.8
21-30 Sept.	16	32	24	240	4.1
1-8 Oct.	27	40	33	260	3.0

turnover time. If one could achieve a more accurate timing of arrival and departure (this is possible in industry) higher maxima would be possible. It is not improbable that daily rates in excess of 100 percent actually occur during very rapid migration. The total turnover during a period of time tells us nothing that is not already shown by the daily turnover. Finally our estimates of the true values of these ratios will be affected by sample size in a manner similar to the effect of sample size on other statistical estimates.

Some uses of turnover ratios are already evident. They may serve to denote numerically the rate of flow of migration and hence measure its variation both geographically and from year to year. Banding is here a more precise counting tool than is simple field observation. These ratios serve also to distinguish change of population size from movement of population. Lastly we may use turnover to distinguish predominantly migrant parts of a population from the resident parts. Doubtless still further uses will appear in due course.

REFERENCE

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