EURING Eurasian-African Bird Migration Project

Report

to the Convention of Migratory Species (CMS)

on

Historical changes in migration patterns

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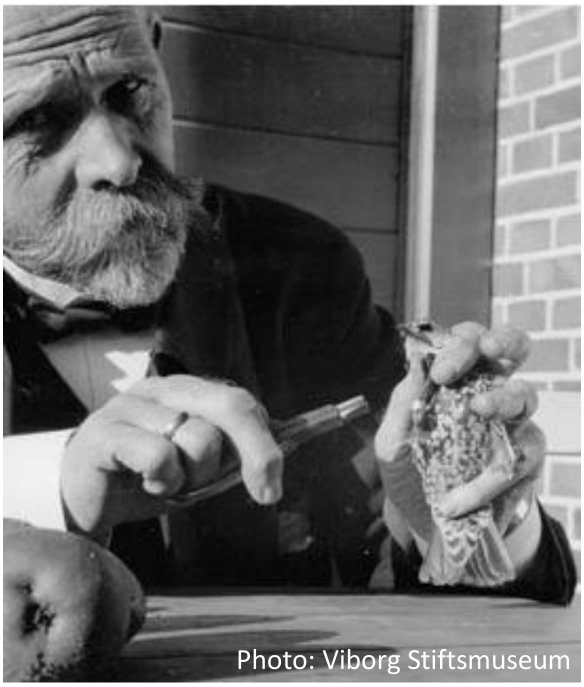
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Monitoring changes in movement patterns is important for conservation and management of bird populations. Such changes might affect the seasonal distributions of populations and might lead to increases or decreases in population sizes. For example, warming climate could lead to more migrants wintering further north or moving shorter distances; land use change could cause populations to respond to large-scale changes in feeding opportunities such as open dumps or other feeding opportunities arising from anthropogenic activities, or habitat loss. Past changes in movement patterns provide an essential source for investigating and understanding the causes and thus forecast changes. Ringing data provide a unique source of such information with the standardised method of bird ringing having been undertaken mostly by amateurs for more than a century.

To assess historical changes in bird movements, we present ring recovery distributions for a set of 128 species with a sufficient number of recoveries (more than 50). We only present recoveries of birds found dead to avoid the substantial bias in recapture and resighting probabilities. We focus on two data sets – one of all recoveries and one of birds ringed during breeding and recovered during winter (breeding period defined as June-July and wintering period as December-February for all species). Identifying true changes in movement patterns from ring recovery distributions is complicated by variation in ringing efforts across populations and countries as well as spatiotemporal variation in recovery probability. We assess some of these potential biases by (i) separating hunted individuals from those dying of natural causes and (ii) developing two measures of correcting for biases in spatiotemporal variation in recovery probability. At the European level, population level changes might easily be masked by the merging of populations with opposing patterns of change.

In this work, we provide descriptive statistics of recovery distributions per decade and species: Decadal geographical maps (summarised in Fig. 1) and changes over time in movement parameters, such as latitude/longitude of ringing and recovery, movement distance (distance between ringing and recovery locations; Fig. 2) and sedentariness (proportion found within 100 kilometres), as well as changes over time in proportion of recovered birds killed by hunting.

The majority of species showed no significant changes. Overall, there were small changes over time in ringing sites and recovery longitudes whereas latitudes of recovery on average changed to the north. In more species, individuals had moved shorter distances than in species where individuals had moved longer and for sedentariness there was a clear pattern as in almost a third of species more individuals had become sedentary.

Consistent changes in movement patterns were observed in relatively few species. Movement distances in white storks *Ciconia ciconia* decreased steadily (74 km y^{-1}) and the spatial pattern changed from South and East Africa to a larger proportion wintering in the Iberian Peninsula and West Africa. Many waterfowl decreased migration distance but winter distributions did not change accordingly such as in barnacle *Branta leucopterus* and greylag geese *Anser anser* with large changes in both migration and sedentariness. Among raptor species, sedentariness increased in many but the changes where co-occurring with a change in proportion of hunted individuals and might not reflect true changes.

Inference at the European level is complicated not only because changes are additionally masked by decoupled changes among populations but also by changes in ringing efforts among populations and countries. Thus, more work is needed to corroborate the findings at the species- and population-specific levels. The results provide a basis for future research on relating changes in migration patterns to climate and land use changes.

Introduction

Our globe is changing at an unprecedented rate. The globe has warmed considerably while at the same time land cover use is changing dramatically across landscapes. Monitoring and understanding the effects of these changes is a central goal in biodiversity research. Understanding causes and effects of past changes, we might be able to predict responses to forecasted changes. Thus, under the current rapid global changes, the need for long-term data has exploded.

Scientific bird has been carried out across Europe for more than 100 years. The data from such activities have secured and curated by many individuals and ringing centres such that the basic ringing and recovery data exist back to the earliest applications. These data are now held in the EDB.

Ringing is widely used in both applied and basic science today. The development of robust capture–mark–recapture analyses has created a surge in the use of ringing for scientific purposes. At the same time, fast technological development has enabled us to track individual movements over long distances of migrants down to the size of songbirds. So, why do we still need large-scale ringing data.

Such data remain highly valuable for two central reasons: (i) New tracking technology cannot reveal past migration patterns and (ii) the unique broad coverage attained with a minimally invasive procedure. Ringing data can provide historical baseline data that are essential for investigating past changes and causes and for detecting and predicting changes in the future. Existing data cover individuals and species across time and space at a level that would not be feasible at least in the near future with any new methods.

Several studies have investigated changes in migratory behavior at the national level across selected species (e.g. Siriwardena and Wernham 2002, Bønløkke et al. 2006, Fiedler et al. 2004). Visser et al. (2009) found decreasing migration distance across species in the Netherlands and furthermore, correlated the changes with various environmental and climate variable. However, only in a few single-species studies have large-scale European patterns been investigated such as those on the white stork (Fiedler 2001) and barn swallow (Ambrosini et al. 2011).

The major obstacle in inferring patterns from ringing data stems from heterogeneity of ringing activity, recapture and re-sighting efforts and recovery and reporting probabilities (Perdeck 1977, Fiedler et al. 2004, Thorup et al. 2014). Dealing with changes over time, it is not necessary to know the true movement patterns and for baseline data spatial variation in these parameters can largely be ignored. However, temporal variation in these can have profound effects on the observed patterns. Changes in ringing activity needs to be carefully evaluated as causes of changes in recovery distribution. Changes in recovery probabilities are much less easy to monitor, as these probabilities are confounded with changes in locations. However, under certain assumptions it is possible to estimate such biases (e.g. Thorup et al. 2014).

Here, we focus on changes in location over time rather than phenological changes. Changes in phenology are in most cases difficult to separate from spatial changes as location is a function of season. We are analysing data for a moderate number of species with good spatial and temporal coverage. The main results are graphs and maps that provide descriptions and interpretation of spatiotemporal changes in migration patterns. The work provides a basis for future research on relating changes in migration patterns to changes in climate and landuse. In addition to the direct analyses of recoveries, we briefly assess potential biases in these analyses visually from changes in recoveries over time and known biases. We focus only on birds recovered dead to avoid the substantial geographical variation in recapture and resighting probabilities that applies to resightings and recaptures. The breeding period is defined as June-July and the wintering period as December-February for all species. Analyses are performed for species with more than 50 accurate spatiotemporal records from the season in question. Overall, we follow the data selection and analysis guidelines in Fiedler et al. (2004).

The analyses focus on temporal trends in recovery locations (latitude and longitude), movement distance (distance between ringing and recovery locations) and sedentariness (proportion found within 100 kilometres). Comparing with trends in ringing locations, recovery causes and visual inspection of decadal maps, we evaluate on a species-by-species basis whether the observed patterns likely reflect true changes or rather changes in ringing efforts or recovery probabilities. Furthermore, we develop two approaches to correct for the underlying spatial biases in recovery data.

Data and methods

We only include data available in the EURING Database (EDB; https://euring.org/data-and-codes/euring-databank-index; see also du Feu et al. 2016). Records in the EDB consist of birds reported ringed or recovered. Each record specifies an encounter event, specifying individual identity and place and time but also a description of the circumstances, the bird's condition and biometric data as well as derived data on time elapsed, distance and direction of movement between ringing and recovery.

We initially filtered the data to only include records fulfilling a standard set of criteria of spatial and temporal accuracy, consistency etc.:

Valid fields (ring, date, coordinates, circumstances) and passed EURING sense check
Ringed in Europe
Recovered dead
Have not been moved
Dates accurate to within two weeks and recently found dead
Coordinates accurate within 10 km

We ran analyses for two data sets based on the filtered data: one with all data (i.e. ringed anytime and recovered anytime) and with only those individuals where migration between breeding and wintering area has been documented, i.e. ringed during breeding and recovered during winter only. In this report, breeding is defined as ringed during June-July and wintering as recovered during December-February. Our main focus is on the breeding-wintering data set but the all data set provides a useful comparison when interpreting the data. Analyses were performed for species with more than 50 records breeding-wintering records resulting in a total set of 128 species (Fig. 1).

To formally investigate changes over time, we focus on trends in the following metrics per decade:

Average **Latitudes** of ringing sites or recovery sites, respectively
Average **Longitudes** of ringing sites or recovery sites, respectively
Average **Distance** between ringing and recovery locations in kilometres (with and without log transformation)
Sedentariness, as proportion of recoveries within 100 km of ringing

For each of the metrics, decadal averages were only included in trend calculations if a minimum of 5 birds were recovered in the decade. Trends were calculated for species where at least four decades fulfilled this criterion. Raw and log transformed distances showed similar trend patterns and for ease of interpretation we present trends based on the raw data here.

Ecological species groups were defined according to Wernham et al. (2002). However, we split the Passerines and near-Passerines into two resulting in the following groups:

SG: Seabirds and gulls
WF: Wildfowl
RO: Raptors and Owls
WD: Waders
NP: Near-Passerines
PS: Passerines

We focus on changes in migration distance. Complex changes might occur over the long time-span and large geographical area considered here. In an attempt to avoid over-interpretation, we only consider significant changes of more than 1 kilometer per year as evidence of a change. In these cases, we (1) look into changes in latitude and longitudes during ringing and recovery both from trends and visually from maps to judge whether the observed changes could be a result of changes in spatial ringing effort or recovery probabilities and (2) consult the recovery reasons to judge whether a change in reasons could have caused the change in movement patterns. In some species, the breeding distribution has expanded and the resulting increase or decrease in movement distance has been interpreted as a true change. The trends in distance are checked for whether the average distances seem to change or the trend is caused by increasing sedentariness. Additionally, we check the results of the supplementary bias-correcting approaches (see below) for potential confirmation.

The analyses are presented in the following Tables:

Average changes (Table 1)
Overall significant changes (Table 1).
Species showing significant changes (Table 2, 3).
Sub-Saharan migrants with bias-corrected estimates (Table 4).

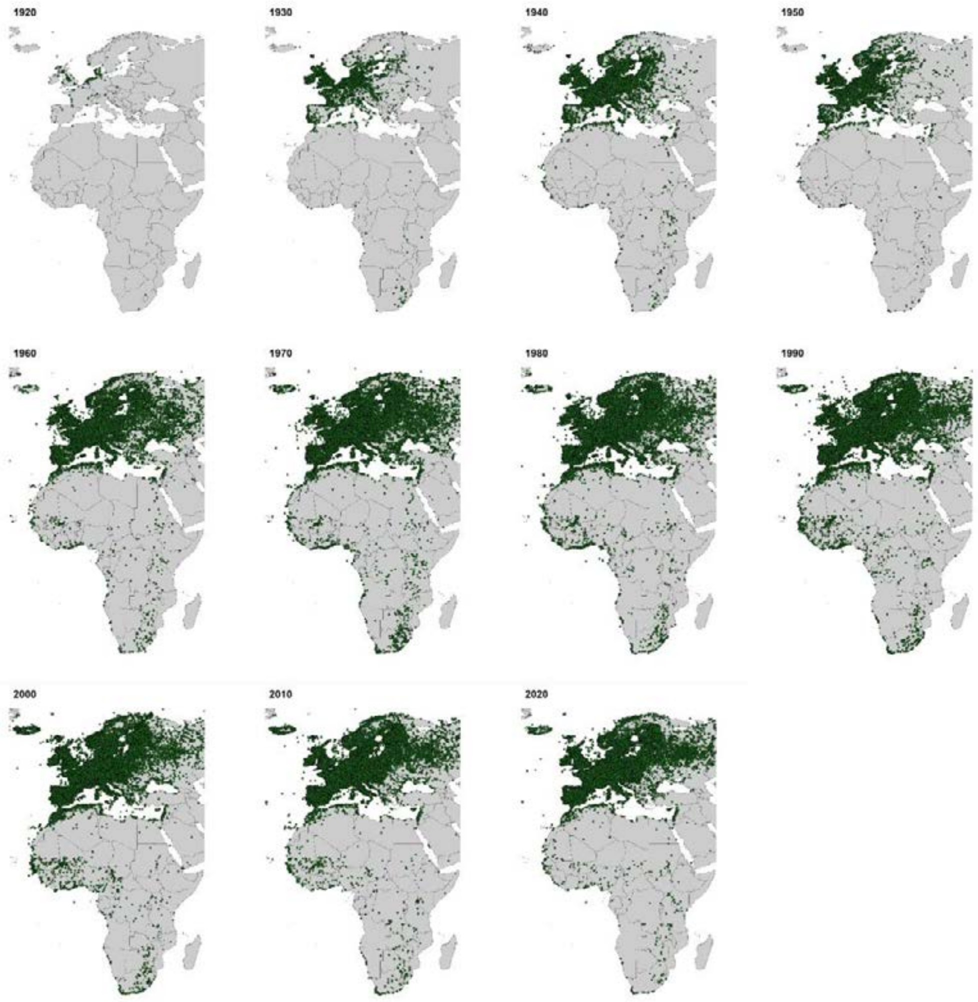

Figure 1a. *Illustration of the data in the EURING data base used for investigating changes over time. Distribution of recoveries of birds by decade. A few recoveries outside of the map range are not shown.*

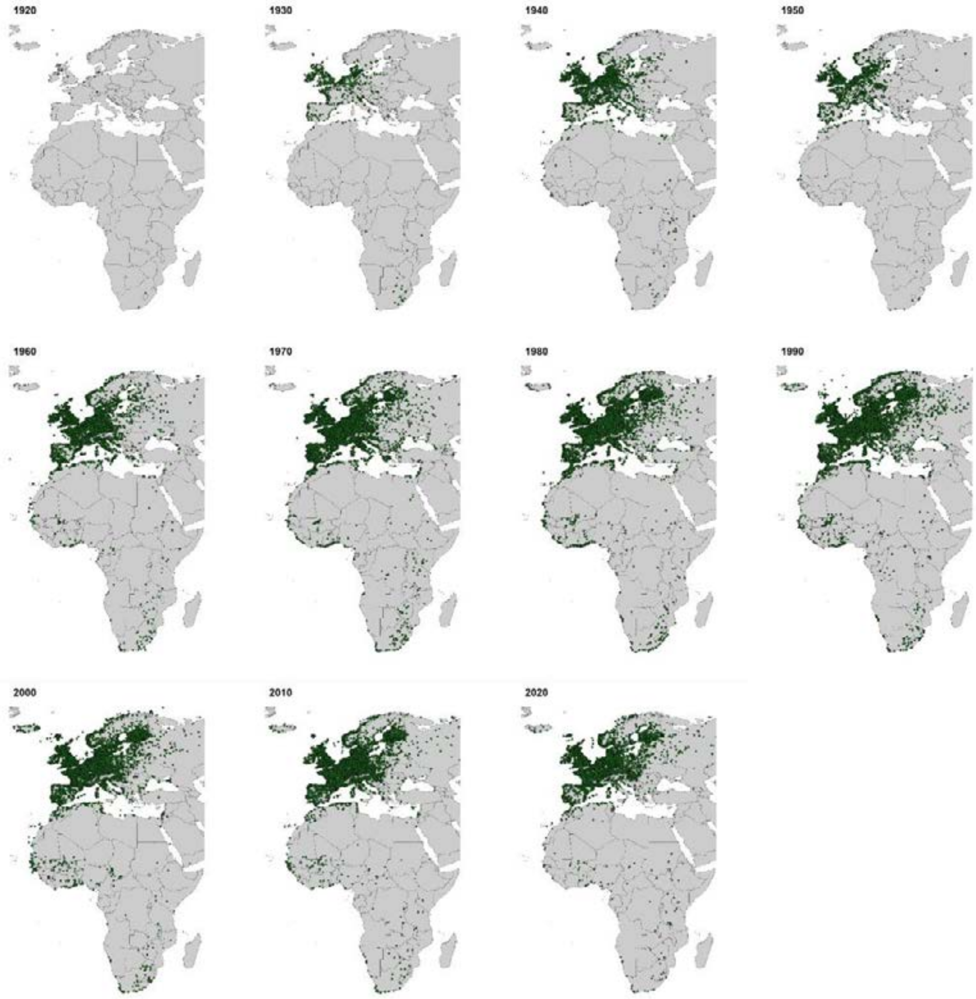

Figure 1b. *Distribution of recoveries of birds ringed during breeding and recovered during winter by decade. A few recoveries outside of the map range are not shown.*

Spatiotemporal recovery probability

There is substantial spatial variation in recovery probability at the regional level. Recovery probability is generally much lower in sub-Saharan Africa and the same applies to parts of Eastern Europe. While this is not the focus here, uneven temporal changes in these recovery probabilities will complicate inference from observed changes. These could be associated with for example hunting.

We accounted for temporal changes in geographic recovery probability using two approaches, focusing on dead recoveries only:

APPROACH 1

We assess changes over time in recovery distributions relative to other species where we assume that the probability of finding and reporting a dead marked bird as well as survival probability is similar independent of the species. If the overall distribution of ringing efforts of all species remains similar over time, changes in spatial recovery probability will affect species similarly. In this case, we will assume that recovery probabilities are similar within ecological groups.

The approach is essentially similar to the one used to quantify migratory tendency by Siriwardena et al. (2004), using latitude/longitude categories instead of distance categories and comparing with average for an ecological group instead of species-wise comparisons. In calculations of average proportional latitudes and longitudes, we compare with the total number of recoveries within each ecological group in a cell. Thus, we weigh each cell based on the percentage the recoveries of the species constitute in relation to the total number of recoveries in the cell. Hence, changes in means lat/longs are changes relative to other species with similar recovery probability.

Spatial Bias 1. Example of calculation of relative changes in average latitude between a migrant and a resident. In this approach, only the latitude/cell where both species are recovered affect the average proportional latitude. For example, at 20°latitude in Decade2, 4 migrants and 1 resident were recovered and the proportion of the migrant is thus 0.80 and of the resident 0.20.

	Recoveries		Summed latitude		Proportion migrant/resident at each latitude		Weighted latitude	
Latitude	Decade1	Decade2	Decade1	Decade2	Decade1	Decade2	Decade1	Decade2
Migrant								
30	0	0	0	0	0.00	0.00	0	0
20	0	4	0	80	0.00	0.80	0	16
10	5	1	50	10	1.00	1.00	10	10
Average			10.00	18.00			10.00	14.44
Resident								
30	4	4	120	120	1.00	1.00	30	30
20	1	1	20	20	1.00	0.20	20	4
10	0	0	0	0	0.00	0.00	0	0
Average			28.00	28.00			25.00	28.33

APPROACH 2

We assume that the recovery probability is equal for a resident and a migrant in the distribution area of resident species (for example broadly above 25°N). As a consequence of this, we will assume that for species with similar survival and recovery probabilities, where all individuals stay within the area of ringing (ie. a resident), the relationship between the total number of recoveries and those ringed during breeding and recovered in winter will be constant, p:

$BW_{res} = All_{res} * p \Leftrightarrow p = BW_{res} / All_{res}$

For a migrant species, some (or all) individuals will stay and some will leave area of ringing. Assuming the same recovery probability, F (Fidelity) is the proportion of the migrants that stays in the area of ringing:

$BW_{migr} = All_{migr} * F * p \Leftrightarrow F = BW_{migr} / All_{migr} / p$

When estimating changes over time in F, we take into account changes in recovery probability in the area of ringing by letting p vary based on the relationship in the area of ringing for resident species.

Spatial Bias 2. Example of calculation of expected proportion of breeding-winter recoveries in relation to all recoveries (p) and the resulting fidelity (F), proportion staying with the ringing area, over three decades. Note that in this approach, changes in the number of recoveries outside ringing area (>=25°N) are interpreted as changes in recovery probability outside the ringing area only and thus do not affect the fidelity estimate, F.

Recoveries		Decade1		Decade2		Decade3	
	Latitude	All	BW	All	BW	All	BW
Resident							
	>=25°	20	10	20	10	15	10
	<25°	0	0	0	0	0	0
	P		0.50		0.50		0.67
Migrant							
	>=25°	10	1	10	1	10	1
	<25°	0	1		2		2
	F		0.2		0.2		0.15

Results and discussion

For the majority of species we found no significant changes in the recovery locations, distance or sedentariness. In the majority of species, individuals moved shorter distances, wintered further to the north and in almost a third of species more individuals had become sedentary. Across species, winter latitude, distance between ringing and recovery locations and sedentariness changed significantly. On average, birds migrated shorter (distance decreased with 3.71 km year^{-1}; Fig. 2), wintering further to the north (winter latitude increased with 0.021° year^{-1}), and became more sedentary (sedentariness increased with 0.2% year^{-1}). Changes in ringing latitude and longitude and recovery longitude were smaller and insignificant.

The evaluation of the temporal trends in the ringing and recovery data revealed consistent changes in movement patterns in relatively few species (Table 2) across various groups. Changes were most obvious and pronounced for the white stork *Ciconia ciconia* where migration distance decreased steadily (74 km y^{-1}) and the general winter recovery locations shifted from being in Southern and Eastern Africa to the Iberian Peninsula and West Africa (Fig. 3).

Table 1. *Summary of the estimated changes in latitude and longitude of ringing and recovery, distance between ringing and recovery locations, latitudes and longitudes of proportional corrected recovery locations and bias-corrected fidelity to the area north of Sahara.*

Breeding-Winter	Breed lat	Breed long	Winter lat	Winter long	Dist	Sedent	Corr lat	Corr lon	Ave F
Average	-0.004	-0.025	**0.021**	-0.010	**-3.710**	**0.002**	0.018	0.024	0.001
N	128	128	128	128	128	128	132	132	95
s.d.	0.066	0.173	0.105	0.091	14.825	0.004	0.163	0.335	0.005
Positive	71	41	86	50	33	101	76	71	64
Negative	57	87	42	78	95	27	58	63	31
Significant	30	41	33	32	40	40	27	20	18
Signif positive	16	14	28	13	10	36	19	11	14
Signif negative	14	27	5	19	30	4	8	9	4

All	Ring lat	Ring lon	Recov lat	Recov lon	Dist	Sedent
Average	-0.009	-0.012	**0.017**	0.008	**-1.958**	**0.002**
N	128	128	128	128	128	128
s.d.	0.043	0.079	0.044	0.078	5.701	0.004
Positive	60	55	88	71	35	93
Negative	68	73	40	57	93	35
Significant	55	50	45	46	44	56
Signif positive	20	14	36	26	12	47
Signif negative	35	36	9	20	32	9

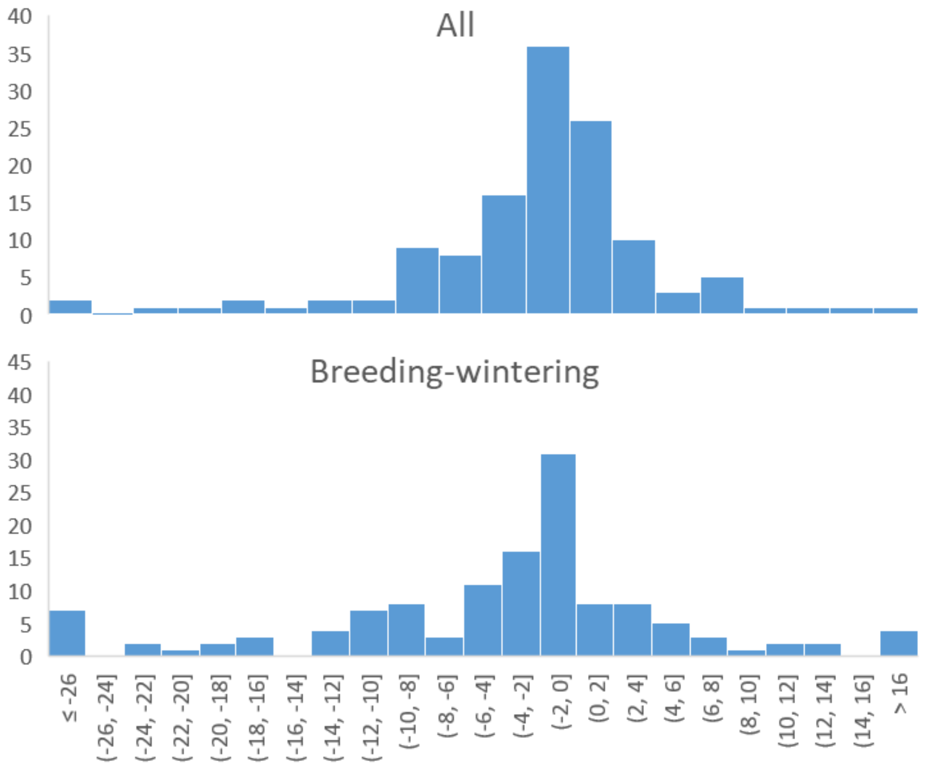

Figure 2. *On average, species migrate shorter distances over time. Change in movement distance (km* y^{-1}*) across species. In the majority of species movement distances have become shorter over time.*

In most species the observed change was in sedentariness. Changes appeared across groups (Fig. 4). Collared doves represent a remarkable example of change in sedentariness in which movements clearly changed from dispersal movements early on to being almost exclusively sedentary later (Fig. 4e). are shown In barnacle geese the shortening of migration distance of the southward expanding population is clearly shown (Fig. 4a) whereas the northwards expansion of the population in great cormorants has led to increasing migration distance (Fig. 4b). The new population of red kites in United Kingdom show shorter migration distance compared to other European populations and across the range, blackcaps migrated shorter.

In some waterfowl migration distance and sedentariness decreased without a corresponding change in winter distributions (for example barnacle *Branta leucopterus* and greylag geese *Anser anser*). Among raptor species, proportion of hunted individuals decreased and the estimated sedentariness patterns might not reflect true changes.

Table 2. *Species where changes in migration patterns over time are inferred from the ringing data. Given are trends in ringing and recovery latitudes and longitudes, distance between ringing and recovery locations, sedentariness, and bias-corrected winter latitudes and longitudes.*

Species	**Decades**	**Ring_Lat**	**Ring_Lon**	**Rec_Lat**	**Rec_Lon**	**Dist**	**Sedent**	**Corr Lat**	**Corr Lon**
Sula bassana	1940-2020	0.004	0.072**	0.113**	0.065**	-10.343**	0.001	0.129	0.070
Phalacrocorax carbo	1930-2020	0.055***	0.214**	-0.005	0.126**	7.412**	-0.001	-0.087*	0.219***
Ph. aristotelis	1930-2020	-0.021	0.024	-0.010	0.030	-0.491	0.002**	0.010	0.054
Ciconia ciconia	1930-2020	-0.061**	-0.042**	0.522***	-0.242***	-66.367***	0.003**	0.209**	-0.125**
Anser anser	1940-2020	-0.070	0.073	0.060	0.049**	-16.321**	0.009**	0.104**	-0.141
Branta leucopsis	1970-2020	-0.328***	-0.145	-0.032**	0.141**	-34.791***	0.010**	-0.074	0.124
Tadorna tadorna	1960-2020	-0.020	-0.080**	0.017	0.023	-9.210**	0.010**	0.024	0.094
Milvus milvus	1960-2020	0.029**	-0.130**	0.114**	-0.010	-13.489**	0.008**	0.056**	0.026
Circus cyaneus	1960-2020	-0.067**	-0.019	-0.062	-0.037	-1.086	0.008**	-0.184	-0.072
Accipiter nisus	1930-2020	-0.004	-0.001	0.015	0.024	-2.712**	0.002**	0.027	0.108*
Buteo buteo	1930-2020	-0.004	-0.066**	0.022**	-0.012	-4.228**	0.007***	-0.153	0.233***
Falco tinnunculus	1930-2020	-0.008	-0.006	0.004	-0.003	-1.548	0.003**	-0.102**	-0.016
Gallinula chloropus	1960-2020	-0.028	-0.026	-0.003	0.015	-4.380**	0.005**	-0.044	0.018
Stercorarius skua	1970-2010	0.004	0.046	0.185**	0.089	-18.812	0.004	0.422	0.340
Larus ridibundus	1930-2020	0.022	0.000	0.055***	-0.030**	-2.036	0.002***	0.161***	0.120*
Larus marinus	1930-2020	-0.034**	-0.069	-0.017	-0.036	-2.654**	0.003**	0.004	-0.087
Streptopelia decaocto	1970-2020	0.005	-0.070	0.009	-0.075	-2.301**	0.005**	0.022	-0.147
Asio otus	1960-2020	-0.018	-0.019	0.004	0.016	-4.165	0.006**	-0.032	0.069
T. troglodytes	1960-2020	0.017**	-0.038	0.029**	-0.014	-2.148	0.004**	0.052	-0.052
Sylvia atricapilla	1960-2020	-0.033**	-0.114**	0.073	-0.056	-11.860**	0.003	0.122	-0.119
Corvus monedula	1940-2020	0.005	-0.021	0.020	0.019	-3.617**	0.003***	0.049	0.070
Passer montanus	1940-2020	0.010	-0.035	0.013	-0.036	-0.557	0.002**	0.026	0.044
Carduelis carduelis	1960-2020	0.043	-0.205**	0.120**	-0.133**	-10.708**	0.010***	0.062	-0.241
C. coccothraustes	1960-2020	0.034**	-0.065	0.074**	-0.031	-5.475**	0.006**	0.147*	-0.091
Emberiza citrinella	1940-2020	0.038	-0.026	0.061**	-0.004	-3.133**	0.002	-0.024	-0.030

***Table 3**. Estimated changes based on changes in the observed migration patterns.*

Species	**Change of migration direction**	**Change of wintering location**	**Change in sedentariness**
Sula bassana	Shorter	Atlantic Ocean to North Sea	
Phalacrocorax carbo	Northward expansion		
Ph. aristotelis			Higher
Ciconia ciconia	Shorter	South/East Africa to West Africa/Soutwest Europe	Higher
Anser anser	Within North and West Europe		Higher
Branta leucopsis	Southward expansion	Same	Higher
Tadorna tadorna	Shorter		Higher
Milvus milvus	Shorter in new UK population		
Circus cyaneus			Higher
Accipiter nisus			Higher
Buteo buteo			Higher
Falco tinnunculus			Higher
Gallinula chloropus	Shorter within West Europe		Higher
Stercorarius skua		Further north	
Larus ridibundus		Further northwest	Higher
Larus marinus	Shorter		Higher
Streptopelia decaocto			From dispersing to sedentary
Asio otus			Higher
T. troglodytes			Higher
Sylvia atricapilla	Shorter	Further north 1	
Corvus monedula	Shorter		Higher
Passer montanus			Higher
Carduelis carduelis	Shorter	Fewer in Iberia for UK population	Higher
C. coccothraustes			Higher
Emberiza citrinella	Shorter		

1. ringing efforts also further north
2. Potentially affected by changing hunting pressure

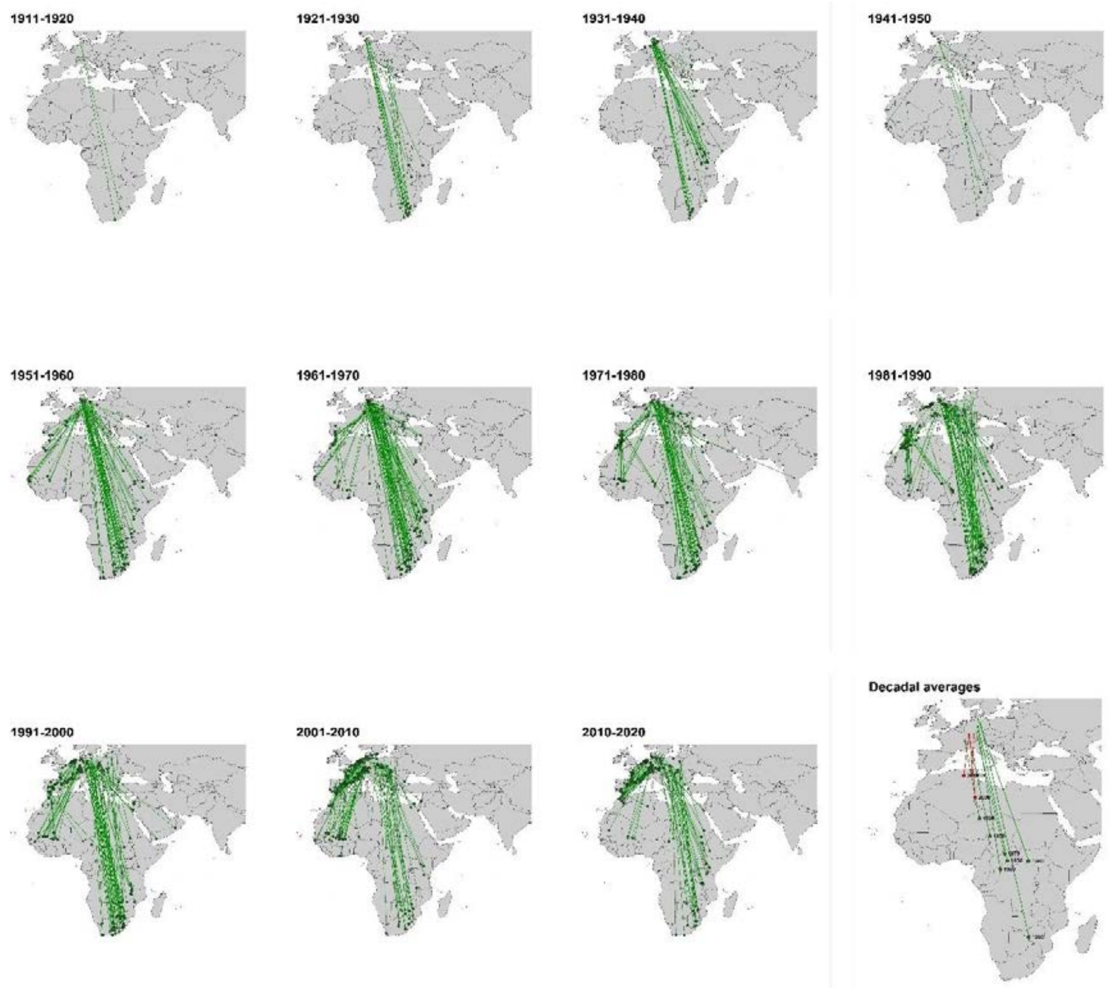

Figure 3. *The white stork is the most clear example of a species where ringing data show a changing migration pattern. Maps show the ringing and recovery for birds ringed during breeding and recovered during winter for each decade.*

Our bias-corrected estimates of trends in "Fidelity" to the area north of the Sahara showed only slight changes but that most significant changes concerned a higher proportion not crossing the Sahara over time (Table 1 and 4).

Table 4. *Trends in "Fidelity" to the area north of Sahara. The method used incorporates potential changes in recovery probability in time and space. Listed are only species with significant trends.*

Species	Mean Fidelity	Trend	Species	Mean Fidelity	Trend	
Hydrobates pelagicus	0.089	-0.004 **	*Numenius phaeopus*	0.083	-0.004	*
Ardea cinerea	0.944	0.002 **	*Tringa totanus*	0.712	0.005	*
Ciconia ciconia	0.157	0.003 **	*Arenaria interpres*	0.698	0.011	***
Anas platyrhynchos	0.924	0.002 *	*Larus ridibundus*	0.935	-0.002	*
Anas clypeata	0.874	0.004 *	*Larus fuscus*	0.420	-0.005	***
Anas querquedula	0.248	0.004 *	*Apus apus*	0.057	0.002	**
Philomachus pugnax	0.609	0.009 **	*Turdus merula*	0.932	0.002	*
Gallinago gallinago	0.951	0.002 *	*Turdus philomelos*	0.965	0.002	*
Limosa limosa	0.616	0.008 *	*Ficedula albicollis*	0.008	0.000	*

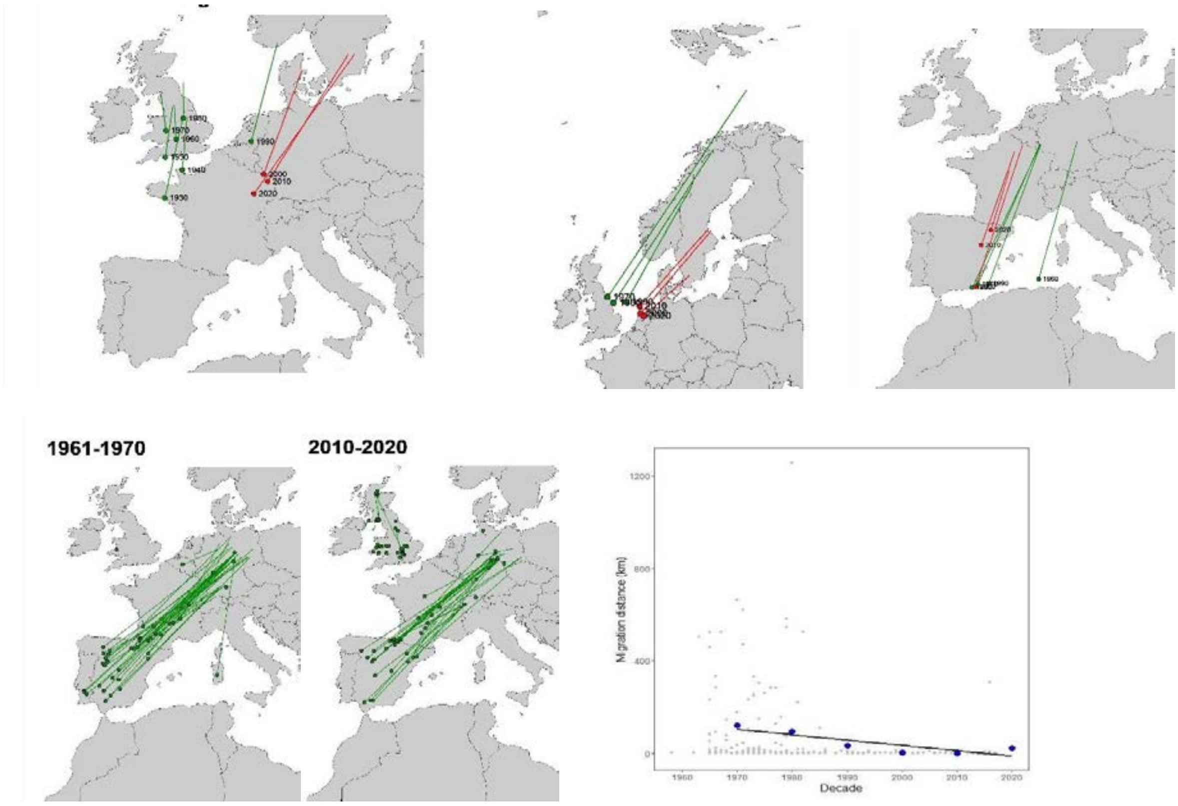

***Figure 4**. Examples of species where the ringing data document changes. (a) Barnacle goose expanding southward and shortening migration, (b) great cormorant expanding northwards and increasing migration distance, (c) blackcap migrating shorter distance, (d) red kite showing the short migration distance in the new UK population, and (e) collared dove showing change from dispersing during expansion to high sedentariness.*

Conclusion

Overall, migratory species at the European/Afro-Palearctic level migrate shorter distances and have become more sedentary though some species show opposite patterns. However, inference at continental level might mask changes occurring at the regional level where different populations may show opposing trends. Or, more complex changes might complicate inference. Furthermore, inference at the European level is complicated because of large- and smaller-scale changes in ringing efforts among populations and countries.

To corroborate and extend the findings here, studies must be undertaken at the species- and population-specific levels where more detailed analyses are possible and more factors can be taken into account. The approaches for dealing with recovery bias presented here, provide promising avenues for studying changes at a smaller scale. The “Fidelity” approach holds great promise for instance for correcting bias in estimates of sedentariness which this study clearly indicates are happening to a considerable degree. Overall, the analyses and results provide a foundation for research on past changes and lay out a framework for relating changes in migration patterns to climate and land use changes necessary for projections of migration patterns.

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APPENDICES

Table: For each species, shown are trends in ringing and recovery latitudes and longitudes, respectively, distance between ringing and recovery and sedentariness for all recoveries (“ALL”) and for birds ringed during breeding and recovered during winter (“BW”). Also shown are the proportional-corrected recovery latitudes and longitudes.

Maps: Ringing and recovery locations in each decade 1900-2020 for birds ringed during breeding and recovered during winter in (1) the six ecological groups and (2) long-distance and shorter-distance migrants. (3) Species by species (a) decadal average ringing and recovery locations for birds ringed during breeding and recovered during winter and (b) decadal average seasonal recovery locations of birds ringed during breeding.