



Migration of Mallards *Anas platyrhynchos* in Hungary: migration phenology, the origin of migrants, and long-term changes

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Hungarian wetlands are internationally important staging and wintering places for many Eurasian waterfowl. However, published data on migration are scarce or completely lacking for the majority of waterfowl species from the region. In this study we investigated the migration phenology and the origin of Mallard *Anas platyrhynchos* populations during the non-breeding season in Hungary. A large-scale monitoring study conducted on Lake Balaton and Kis-Balaton between 2003 and 2007 showed that population sizes fluctuated seasonally and peaked during winter months (December–January), with around 10,000 birds staying in some years on Lake Balaton. Using both Hungarian ringing data and recoveries of 14 other European countries we found that Mallards migrated to Hungarian wetlands most frequently from breeding populations in Russia, Lithuania and Poland. Recoveries of birds coming from northern and western European countries were rare, suggesting limited movements between these and central European populations. Finally, Mallards now tend to migrate to Hungarian wetlands from shorter distances away than in earlier years and the direction of their migration has also changed significantly, which may indicate changes in the geographical location of source populations.

Hungarian wetlands are internationally important staging and wintering places for many Eurasian waterfowl. For example, these wetlands support a substantial part of the European wintering populations for several geese (eg Bean Goose *Anser fabalis* and Greater White-fronted Goose *A. albifrons*; Madsen *et al* 1999) and duck species (eg Mallard *Anas platyrhynchos* and Goldeneye *Bucephala clangula*; Scott & Rose 1996). The network of large natural lakes (eg Balaton, Fertő and Velence), fishponds (eg Hortobágy), marshes (eg Kis-Balaton) and rivers (eg Danube) provide favourable gathering and roosting places, and birds (eg geese) can use the extensive agricultural areas around these waters for foraging. Many of the Hungarian wetlands holding the largest waterfowl populations are protected. Despite the importance of these wetlands for waterfowl, published data on migration are scarce or completely lacking for the majority of species from the region (but see Faragó 1995 for geese). However, it is important to analyse which Eurasian breeding populations use the region's wetlands and to investigate the migration phenology of these populations, for several reasons. Firstly, conservation efforts to save migratory waterfowl species require international cooperation in most cases, and the success of such actions relies heavily on appropriate knowledge about the size and connectivity of populations (eg Lorentsen *et*

al 1998). Secondly, such information is also necessary for predicting future population changes, which may occur, for example, due to changes in climate or agricultural land-use (van Eerden *et al* 2005). Finally, current awareness due to the spread of some epidemics (eg the highly pathogenic avian influenza virus) has generated special interest in bird migration pathways (Gilbert *et al* 2006). Since wild birds including waterfowl may be involved in transmitting such disease (Olsen *et al* 2006), information about their movements is important both for the evaluation of sources and for predicting potential future spread of the disease.

In this study we investigated the migration of Mallard, one of the most common waterfowl species in both Eurasia and Hungary (Scott & Rose 1996, Haraszthy 2003). We had three main aims: first, to study the species' migration phenology using monitoring data from Lake Balaton and Kis-Balaton. These two sites are among the most important staging and wintering places of Mallards and other waterfowl species in the region (eg Keve 1968, 1969, 1982, 1983, Faragó 1995, Scott & Rose 1996). Our second aim was to investigate the origin of Mallards migrating to and wintering in Hungary, by analysing ring recoveries. To do this, we analysed the whole Hungarian ringing database for Mallards collected from the beginning of the last century until 2003. Furthermore, to corroborate results gained from the relatively small number of Hungarian recoveries, we also analysed recoveries of 14 other European countries

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using a large data set compiled by EURING. In the latter analyses we investigated how many recoveries of birds ringed in specific countries occurred in Hungary or the wider geographic area of the Carpathian Basin. Finally, we used recovery data to study whether migration behaviour (as measured by distance and direction of movements and time until recovery) of Mallards wintering in Hungary has changed during the last century.

METHODS

Population monitoring on Lake Balaton and Kis-Balaton

At 594 km² Lake Balaton in western Hungary is the largest waterbody in central Europe. It is a shallow lake consisting mainly of open water, with only limited vegetation (mainly reed *Phragmites australis*) along some parts of the shoreline. Its former basin, the Kis-Balaton is situated to the southwest and is directly connected to Lake Balaton by the Zala River. The total area of Kis-Balaton is 75 km², of which 32 km² is open water divided into several artificial lakes. The rest of the area is covered by dense marshy vegetation (eg reed beds) or is seasonally flooded.

The populations of waterfowl on Lake Balaton and Kis-Balaton were monitored between 2003 and 2007. Censuses were carried out on Lake Balaton each month. On Kis-Balaton, censuses in 2003 and 2004 were conducted only between September and April, whereas during 2005–07 monthly monitoring activities covered the whole year. During the migration and wintering period (between September and April) monitoring on both sites was undertaken fortnightly (two censuses per month) whereas during the nesting periods (from May to August) only one census per month was conducted, in mid month. During each census, waterfowl counts were carried out within a single day, from the shore around the whole Lake Balaton and from the dikes on Kis-Balaton, by seven observers working simultaneously, using x20–60 or x15–45 telescopes. The number and locations of the sampling points were fixed throughout the study, and the locations of these sites were designed to allow the surveying of all major water surfaces at both sites. Different observers counted birds at different sampling sites. The activities of the observers were synchronised, starting from early morning, and took 4–6 hours depending on the number of birds present. At each sampling point, the total number of individuals was recorded for each waterfowl species, including birds which either stayed on the water or were flying opposite to the observer's moving direction. Only geese used the open water far from the shores, whereas other bird species (including Mallard) mostly utilised the closer, more easily observable inshore regions. The number

of individuals for each species, the date of the census and the WGS 84 coordinates of the observation points were entered in an Access-based GIS database using ArcView version 3.3. Monthly population size data for Mallards were calculated separately for Lake Balaton and Kis-Balaton, as the sum of the number of birds recorded at all sampling points. We used average values when two censuses per month were conducted.

Analyses of ring recoveries

Hungarian ringing data were provided by the Hungarian Bird Ringing Centre. This data set contained all recoveries of Mallard rings from Hungary, between 1924 and 2003 (n = 108 recoveries). We omitted birds that were recovered from outside the current border of the country. We also obtained ringing data for 14 other European countries from the EURING databank. The raw data set included more than 53,000 birds ringed in these countries, which were recovered between 1909 and 2006. We omitted birds that were hand-reared or manipulated in other ways, or were moved between sites before ringing or recovery (see the 'Manipulated' and 'Moved' sections in the EURING exchange-code 2000; Speek *et al* 2005). We also removed duplicated and incomplete data from the raw data set. For birds recaptured more than once we included only their last recapture.

For the purpose of the analyses, we defined the Mallard breeding season as the period between May and August. This period probably corresponds to the peak brood-rearing season of the species in Europe; thus, birds ringed during this period are likely to be on their breeding grounds. For example, in the EURING data set, 98.6% of Mallard chicks were ringed during these four months (18.0%, 37.5%, 34.6% and 8.5% respectively; n = 4,652). Although the Mallard's real breeding season (including incubation period) spans a longer period in many populations, the status of birds is more uncertain outside this period because breeding and migration may overlap extensively (Perrins 1998). Moulting movements have been reported for some Mallard populations (Perrins 1998), so it is possible that some birds had bred in an area different from that where they were ringed. However, we had no information on the moulting state of birds at the time of ringing, and thus we cannot control for this potential bias in the analyses. We defined the non-breeding season as the period between September and January, when birds probably cease reproduction in most populations (the proportion of chicks ringed during these months varied between zero and 0.8% per month, with 1.1% in total for the whole non-breeding period).

In the analyses, we simply categorised the birds' ringing and recovery locations according to the country where they were ringed and recovered, without reference to the

exact geographic positions of the places. The records were assigned to countries by their place codes, according to the current EURING exchange-code (Speek *et al* 2005). Although this did not permit fine-scale spatial analyses, it was suitable for capturing the main migratory tendencies. In some analyses where there were too few recoveries from Hungary, we used the Carpathian Basin as the area of recovery. Since the area of Carpathian Basin overlaps with several countries, but cannot be defined by their borders, we defined it as the area within the following geographic coordinates: latitude 45–49°N, longitude 16–25°E. The distance between the ringing and recovery sites (in km), the direction of migration (in degrees), and the time elapsed between ringing and recovery (in days) were taken from the data sets as provided by the above organisations, or were calculated by ourselves when these were lacking (or were incorrect). The direction of migration was measured on a 360° scale, from the ringing location towards the recovery site, 0° meaning northward, 90° eastward, 180° southward and 270° westward movements. In the statistical analyses, we used Spearman rank correlation because the distribution of the variables deviated from normal distribution. All statistical tests were two-tailed, and conducted using SPSS 11.

RESULTS

Migration phenology on Lake Balaton and Kis-Balaton

Monthly counts indicated large seasonal fluctuations in Mallard population size on both study sites. During spring and summer, low numbers (< 500) were counted at both Lake Balaton and Kis-Balaton (Fig 1). At Lake Balaton, population size typically started to increase in September. Maximum counts were recorded during the coldest months, December and January: the average number of Mallards was around 5,000 during these months, although peak numbers were higher (eg close to 10,000 in January 2006). Population size dropped greatly in February (around 1,000 birds) and declined further during the spring months. Counts at Kis-Balaton showed a less regular pattern than at Lake Balaton, although similar seasonal fluctuations were evident in some years (eg winters 2004/05 and 2005/06: see Fig 1).

The origin of Mallards recovered in Hungary

Recoveries in Hungary, accumulated over the last century, suggest that Mallards arriving from other parts of Eurasia have comprised a significant proportion of the Hungarian population (Fig 2). Since most recoveries were from the period between September and January ('non-breeding season' hereafter) and Mallards were present in

highest numbers during this period on several important Hungarian wetlands (see above), we focused the following analyses on the non-breeding season.

Table 1 summarises the origin of Mallards that were recovered during the non-breeding season in Hungary. For birds ringed during the breeding season (*ie* likely to be on their breeding ground; $n = 41$), we found that about 40% were local breeders ringed in Hungary (Table 1a). Most non-local breeders came from northern and eastern regions (Russia, Lithuania and Poland), whereas only a few had migrated from western Europe (Table 1a). The arrival of birds from foreign breeding grounds starts early and migrants can reach the Hungarian wetlands quickly: eg a female ringed in Lithuania on 8 August 1973 was recovered seven days later in Hungary, 819 km south (see also Fig 2 for the high number of recoveries from abroad in August). Table 1b shows those Hungarian recoveries that involved birds ringed during the non-breeding season (*ie* probably on migration or on their wintering grounds; $n = 25$). In contrast with those ringed during breeding, these birds originated mostly from southern and western European countries (Table 1b); they were ringed in highest

Table 1. Origin of Mallards recovered in Hungary during the non-breeding season (September–January). Birds were ringed either (a) during the main European breeding season (May–August; $n = 41$) or (b) during the non-breeding season ($n = 25$). Values represent % of the total number of Hungarian recoveries, and are given for each country with at least one recovery (% were calculated separately for (a) and (b)). Data were provided by the Hungarian Bird Ringing Centre.

Country of ringing	(a) % recoveries, ringed during the breeding period	(b) % recoveries, ringed during the non-breeding period
Hungary	41.5	20.0
Russia	19.5	0
Lithuania	12.2	0
Poland	9.8	0
Czech Republic	4.9	8.0
UK	4.9	8.0
Belarus	2.4	0
Slovakia	2.4	0
Spain	2.4	0
Italy	0	32.0
Switzerland	0	8.0
Sweden	0	4.0
Belgium	0	4.0
France	0	4.0
Austria	0	4.0
Croatia	0	4.0
Serbia	0	4.0

number in Italy (32%), and only 20% were ringed locally in Hungary.

Analyses of the much larger number of recoveries of birds ringed in 14 European countries corroborated most of the above results (Table 2). For birds ringed during the breeding season, Lithuania and Poland had the highest proportions of non-breeding recoveries both in Hungary and the whole Carpathian Basin (data were unavailable from Russia). Such recoveries were very few (negligible) for most other European countries, despite the large number of birds ringed there during the breeding season (Table 2a). For birds ringed during the non-breeding season, Italy and Switzerland had the highest proportions of recoveries from Hungary, whereas Lithuania, Italy and Switzerland had the highest proportions of recoveries from the Carpathian Basin.

Long-term changes in the origin of migrants

Using Hungarian recovery data, we analysed whether the origin of Mallards migrating to and wintering in Hungary had changed during the study period (1924–2003). First, we analysed recoveries of birds ringed abroad during breeding (*ie* excluding Hungarian breeders; Table 3). We found that the distances these birds moved between their ringing and recovery sites tended to decrease during the study period (*ie* birds from more recent years tended to arrive from closer breeding areas: Fig 3a). Furthermore, there was a significant

change in direction of movements: the average direction from which the birds arrived shifted from more easterly to more northerly (Fig 3b). For birds ringed during the non-breeding period, we also found a significant change in migration direction: they now appear to come from more southerly locations than in earlier years (when they came from more westerly/northwesterly locations: Fig 3c). This tendency remained marginally significant when we left out one bird with an extreme (above 300°: see Fig 4c) direction value ($r_s = -0.446$, $P = 0.064$, $n = 18$). There were no significant changes in migration distance of birds ringed during the non-breeding season, nor in time elapsed until recovery (Table 3).

DISCUSSION

Both Lake Balaton and Kis-Balaton are internationally recognised staging sites for Mallards but, except from data on some peak counts (*eg* Scott & Rose 1996), we are not aware of recently published information on the current size of these populations and their seasonal changes (*see* Keve 1969 and Bankovics 1985 for earlier data). We found that during the study period the size of the Mallard population showed a regular seasonal change on Lake Balaton. The lake seems to support a relatively low breeding population, as indicated by the low monthly counts (usually < 500)

Table 2. Proportion of Mallards ringed in 14 European countries that were subsequently recovered, either in Hungary or in the Carpathian Basin, during the non-breeding season (September–January). Birds were ringed either (a) during the breeding (May–August, $n = 13,860$ recoveries) or (b) during the non-breeding season ($n = 22,233$ recoveries). Values were calculated as % of the total number of recoveries of a given country (separately for (a) and (b)). Data were provided by EURING; countries with at least 100 recoveries are included.

Country of ringing	Total recovery number, ringed during		(a) ringed during breeding, % recovered in		(b) ringed during non-breeding, % recovered in	
	breeding	non-breeding	Hungary	Carpathian Basin	Hungary	Carpathian Basin
Lithuania	90	15	5.6	7.8	0	6.7
Poland	892	40	0.4	1.1	0	0
UK	5,092	13,314	<0.1	<0.1	<0.1	<0.1
Sweden	1,195	1,652	0	0.3	0.1	0.1
Germany	845	726	0	0.1	0	0
Italy	162	667	0	0	1.2	2.1
Switzerland	229	276	0	0	0.7	0.7
Belgium	1,632	828	0	0	0.1	0.2
Netherlands	1,571	2,248	0	0	0	<0.1
Denmark	1,027	2,185	0	0	0	0
Finland	236	41	0	0	0	0
Ireland	242	123	0	0	0	0
Spain	211	24	0	0	0	0
Latvia	392	39	0	0	0	0

Table 3. Temporal changes in migration distance, direction, and time between ringing and recovery for Mallards recovered in Hungary during the non-breeding period (birds ringed in Hungary excluded). Results are shown separately for birds ringed during the breeding ($n = 24$) and non-breeding season ($n = 19$). Table gives Spearman correlation coefficients, and associated P values in parenthesis, for bivariate correlations between the year of recovery and the study variables (distance, direction or time).

Changes in	Ringed in the breeding season	Ringed in the non-breeding season
migration distance	-0.382 (0.065)	0.219 (0.353)
migration direction	-0.506 (0.012)	-0.516 (0.024)
time elapsed between ringing and recovery	0.254 (0.232)	0.072 (0.764)

from spring and summer. During autumn the population size increased strongly and reached its peak in December and January, when typically 5,000–10,000 Mallards were present. Kis-Balaton had similar migration phenology in some periods, but showed less regular changes in others (eg see 2006, when there was less difference between the breeding and non-breeding seasons). The difference between the two sites may be related to their differences in habitat characteristics, eg because the more vegetated Kis-Balaton site may support a larger breeding population relative to its area, or because the much larger water surface of Lake Balaton has ice-free areas for longer periods hence may be preferred by migrants and wintering Mallards. Similarly to Kis-Balaton, less-marked seasonal changes in Mallard population sizes have been reported for some other important wetlands in Hungary (eg Faragó 2003, 2005, 2006).

On the one hand, the large non-breeding populations at both places are likely to include non-migratory birds coming from the surrounding wetlands, especially in the cold months when smaller waters are covered by ice while these lakes still have open water. This is corroborated by our analyses showing that around 40% of the Hungarian

recoveries from the non-breeding season are of local birds (ie ringed in Hungary during the breeding season). Earlier studies also suggested that some parts of the central European breeding populations are non-migratory (Scott & Rose 1996, Perrins 1998). On the other hand, a significant proportion of the non-breeding populations of these lakes may consist of migrants coming from breeding areas further away. It would be interesting to estimate the proportion of birds that come from these two different sources (ie local versus migrant birds), but currently we have too few recovery data to do this reliably. For example, Mallards and other waterfowl are ringed in relatively small numbers in Hungary (9–158 Mallards were ringed annually between 1978 and 2007, Zsolt Karcza, pers comm; see also Karcza & Marosi 2006). This may lead to a low proportion of locally ringed birds, compared to some other European countries, resulting in an underestimate of the proportion of non-migratory local birds in the wintering population (ie their proportion may exceed 40%). Second, the overall sample size of recoveries from Hungary was also small, so that it may increase the uncertainty in such estimates (eg there were only 41 recoveries of birds ringed during breeding). The reasons for this may include both the low number of

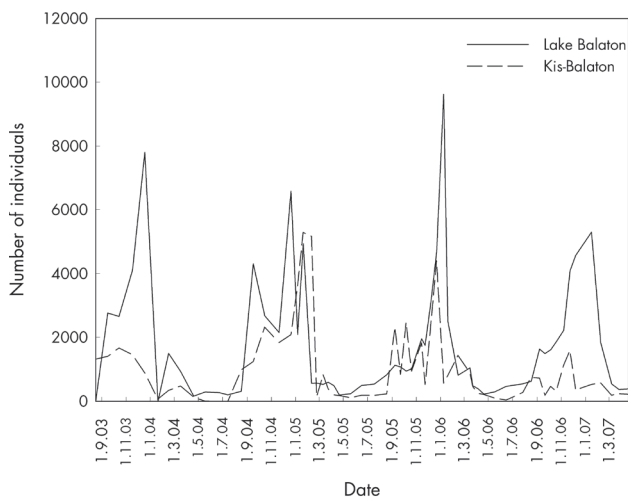


Figure 1. Migration phenology of Mallards on Lake Balaton (solid line) and Kis-Balaton (dashed line) between September 2003 and April 2007.

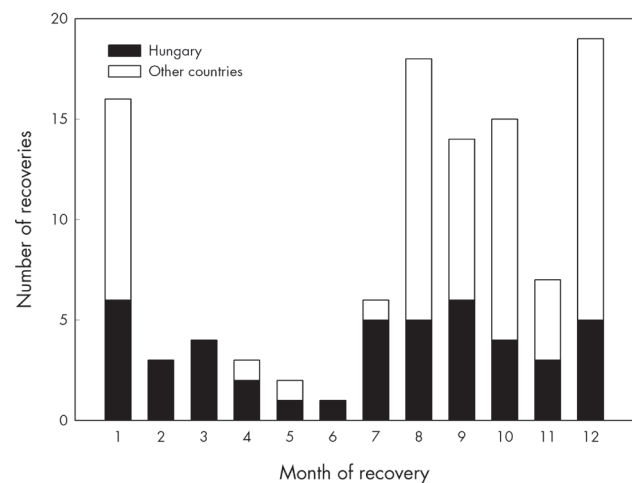


Figure 2. Monthly distribution of Mallard recoveries in Hungary. Birds were ringed either in Hungary (solid bar, $n = 45$) or in other countries (open bar, $n = 63$).

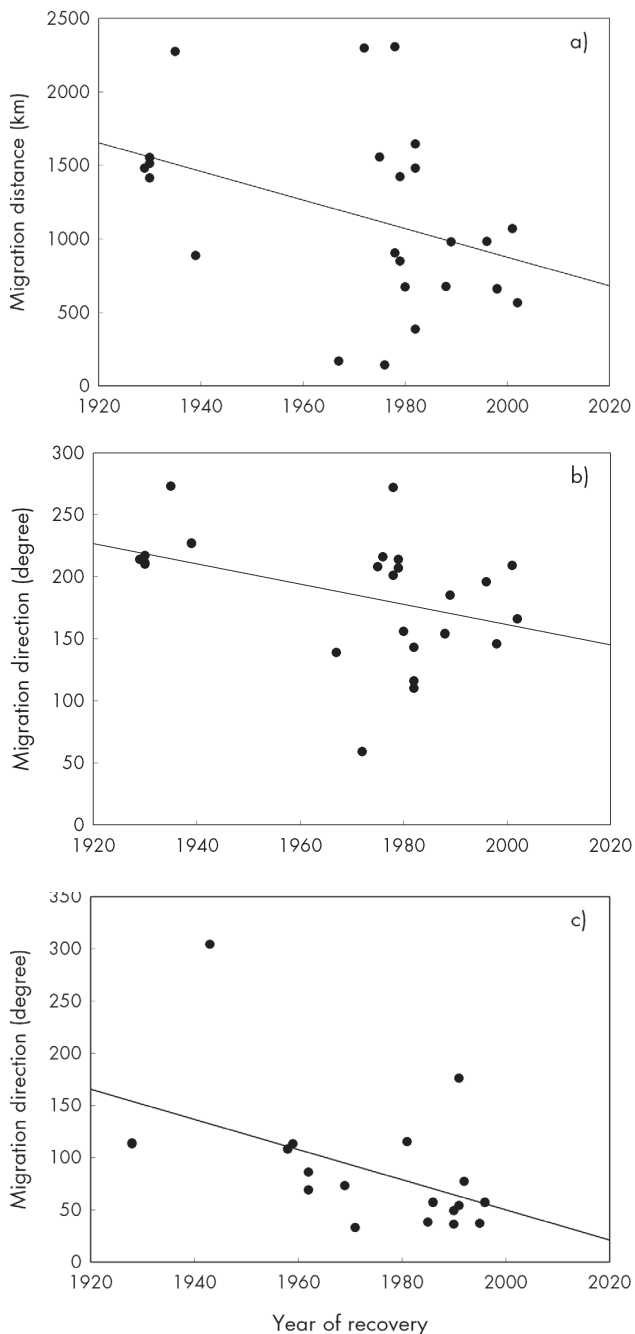


Figure 3. Temporal changes in (a) distance and (b) direction of movements of birds ringed during breeding, and (c) direction of movements of birds ringed during the non-breeding season (see Table 3 for statistical results). All birds were ringed abroad, and recovered in Hungary during the non-breeding season.

ringed birds in the population (due to the low local ringing effort described above, and because most migrants also come from regions with low ringing activity), and a low reporting rate of ringed ducks, *eg* by hunters. Although a large number of wild Mallards are shot annually by hunters

in Hungary (*eg* around 50,000 individuals in 2007; Csányi 2008), the proportion of ringed birds that is reported to the Hungarian Bird Ringing Centre is unknown.

Hungarian recovery data suggest that the most important sources of migrants are the breeding populations of eastern and northern countries (*eg* Russia, Lithuania and Poland). This result supports the general view that birds from these breeding populations usually migrate to western and southern areas during the non-breeding period (Scott & Rose 1996). Obviously, this list of important 'source countries' may not be complete, *eg* because ringing activity may be low in some areas from which a substantial number of migrants may come. The recoveries from the countries listed may represent individuals that either overwinter on Hungarian wetlands or use these sites as staging places during their movement to more southerly areas. These results were corroborated by the analyses of the ring recoveries held by 14 European countries, which showed that the above countries had the largest proportions of recoveries from both Hungary and the Carpathian Basin. It should be noted, however, that the actual proportions of Mallards migrating to Hungary and the Carpathian Basin from these countries (shown in Table 2) may be underestimated if the chance for recovery or reporting is lower in Hungary than in other countries. Even if we accept the values presented in Table 2, the total number of Mallards coming from northeastern areas may be significant because these countries support large breeding populations (*eg* Lithuania 70,000–100,000 pairs, Poland 200,000–400,000 pairs: Burfield & van Bommel 2004).

The origin of Hungarian recoveries ringed during the non-breeding season differed from those ringed during breeding: most of them came from southern and southwestern areas (*eg* Italy). These birds probably include Hungarian breeders that migrated to winter in the Mediterranean region, which has been suggested as the main wintering area of this population (Scott & Rose 1996, Haraszthy 2003). Only a few birds had been ringed in western countries (*eg* Switzerland, UK, Belgium, France), suggesting that movements between west European and central European wintering places are rare in this species.

An interesting result of our study was that we detected long-term changes in the origin of Mallards that migrated from other countries to Hungarian wetlands. First, there was a tendency for a decreasing migration distance in birds ringed during breeding, *ie* in recent years they tended to come from closer areas than they had earlier. Second, the direction of migration has changed significantly: birds ringed during breeding arrived from more northerly (as opposed to easterly) areas, whereas those ringed during the non-breeding season now come from more southerly (as opposed to more westerly) directions. The reasons

for these changes are currently uncertain, and may have both biological and methodological bases. First, changes in migration distance may be related to environmental changes: for example, recent mild winters may reduce the birds' migration activity, as has been shown for the Lithuanian Mallard populations (Svazas *et al* 2001). However, a reduction in migration distance cannot in itself explain changes in migration direction. Second, it is possible that there has been a geographic shift in ringing effort during the study period: eg a decrease in ringing of breeding birds in eastern countries or non-breeding birds in western countries may contribute to the observed temporal changes. Clearly, further studies are needed to evaluate these hypotheses, including more intense ringing of Mallards and other waterfowl species in Hungary.

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