

# To filter or not to filter: assessing the exclusion of hunting and persecution data in ringing recovery studies

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In recent years, ringing recovery records in Europe have been identified as a potential important source of data for assessing the impact of climate change and other long-term changes on wintering population distributions of migrating birds. As with any voluntarily-gathered data, however, there are clear sources of bias that might impact results if researchers are not selective. Conversely, methods that exclude data should not be universally applied without proper assessment of their impact on final results. We examine the specific and seemingly conventional method of excluding data collected from hunted or intentionally killed individuals in studies of winter distributions of migrating European birds, to evaluate whether the exclusion or inclusion of this data does indeed affect the outcome of the analysis. We find that the exclusion of these data is warranted for many species, however may impact the power of statistical analyses unjustifiably for others. Our findings showed that wintering range sizes of species are similar when using data of killed or non-killed birds, although there may be latitudinal differences. Furthermore, we did not find evidence that wintering ranges of investigated 37 species would have moved northwards in general as would have been expected due to climate change. We suggest that rather than a universally-applied method of exclusion, these contributed data should be analyzed in context of the hunting history of the species in question and the time frame being considered, and give guidelines on how to most efficiently utilize this important data resource.



## 1. Introduction

The use of ringing recovery records in studies on long-term patterns in distribution of species in Europe has a long history. Several European countries, including Finland, have been conducting ringing and recovery studies for over 100 years (Wernham *et al.* 2002; Bønløkke *et al.* 2006; Saurola *et al.* 2013). Data on migrating birds

ringed in Finland and other northern countries during summer and found (recovered) elsewhere in Europe in the winter have been used in particular to study patterns of migration (e.g., Ashmole 1962; Österlöf 1977; Hedenström & Pettersson 1987; Newton & Dale 1996; Thorup *et al.* 2014). These data form a useful and important resource for studies focusing on how migration patterns might be changing due to climate, land-use or pol-

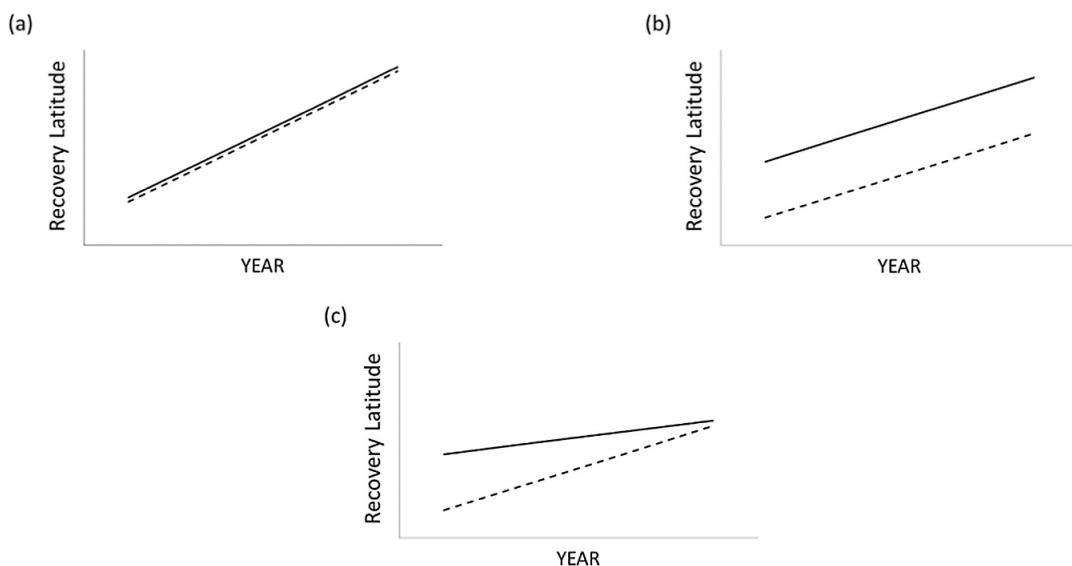


Fig. 1. Simplified illustrations of the projected patterns of the three hypotheses in the predicted scenario of winter populations of birds moving northwards over the last fifty years that would be demonstrated by scatter plots of our data: (a) shows the outcome if there is no difference in recovery latitude between killed (dashed line) birds and not killed (solid line) birds over time; (b) shows the outcome if there is an effect of killed status on the overall recovery latitude of the species, but no interaction between killed status and year; (c) shows the outcome if there is a significant interaction between killed status and year, whereby the slope of latitude of killed birds is different from that of other birds possibly due to differential patterns of killing in certain countries over time.

icy changes across the continent (Saurola 1985; Aebischer *et al.* 1999; Fiedler *et al.* 2004; Lehikoinen *et al.* 2010; Calladine *et al.* 2012).

The use of ringing recovery data does not come without challenges, however. Ringing recovery reports are voluntary and opportunistic, factors that often introduce large amounts of variation and potential bias, with the probability of recovery varying with location, year, species or condition of the animal (Greenwood *et al.* 1986; Fiedler *et al.* 2004). Importantly, because ringing recoveries include a wealth of situational data (e.g., the condition of the bird found, cause of death) we can often selectively include or exclude certain datapoints that might introduce further bias. A specific example of this selectivity can be found in studies utilizing winter ringing recoveries as part of long term datasets of dead birds, for which it is becoming more common to discard recoveries from intentionally killed or hunted individuals (Visser *et al.* 2009; Lehikoinen *et al.* 2010; Sauter *et al.* 2010; Potvin *et al.* 2016). However, this may cause a large reduction in the sample sizes especially for

game species, meaning that researchers must decide whether it is worth the risk of potential biases in the data by including such birds (Lehikoinen *et al.* 2008; Sauter *et al.* 2010; Gunnarsson *et al.* 2012).

The reasons for excluding intentionally killed birds are related to differential patterns of hunting and persecution across Europe on a temporal and spatial scale. Since the 1980's hunting activity has decreased significantly in Europe, especially for raptors (McCulloch *et al.* 1992). Traditionally high levels of hunting in the Mediterranean (Woldhek 1979; Magnin 1991; McCulloch *et al.* 1992; Brochet *et al.* 2016) have also decreased for some species groups that have gained protection (McCulloch *et al.* 1992; Barbosa 2001). However, there are still many birds that are legally hunted around Europe – and some for whom protection legislation is locally dependent (or excused; Hirschfeld & Heyd 2005). Of course, it has been suggested that the decrease in ringing recovery rates for hunted birds that have gained protection is due to decreased reporting of such killings rather

than a decrease in killings *per se* – although this is unlikely to explain 100% of the changes observed (Aebischer *et al.* 1999; Barbosa 2001).

As yet, there has not been a systematic assessment of whether discarding recovery datapoints associated with hunting activities is warranted for all species, or if discarding them is decreasing sample sizes without decreasing bias, affecting the statistical power of such studies. Furthermore, discarding such samples may in fact introduce bias, since presence data might be lost from entire countries where hunting is legal, leading to type II error (i.e., the false assumption that a species does not occur in an area where it is hunted). The aim of this paper is therefore to assess whether the practice of excluding hunted birds from analyses of temporal winter distribution patterns or evaluation of range sizes might be unnecessary. We use 55 years of ringing recoveries of Finnish breeding migratory bird species to investigate this. We focus on the winter distribution of birds that were originally ringed in Finland in the breeding season and found dead during wintering season, to see if spatial patterns (especially latitude) over time, or if the estimation of winter ranges of migratory species are affected by the inclusion or exclusion of data gathered from intentionally killed birds.

Overall, we could expect that Northern Hemisphere species might generally be wintering at more northerly latitudes due to climate change (La Sorte & Thompson 2007; Visser *et al.* 2009; Heath *et al.* 2012; Lehikoinen *et al.* 2013; Pavón-Jordán *et al.* 2015; La Sorte *et al.* 2016; Morganti *et al.* 2017; Rotics *et al.* 2017). For some species this is indeed true (Rotics *et al.* 2017), however, we have previously shown (using a reduced pool of data from the same Finnish ringing centre repository) that overall trends of wintering location over the past 55 years are species-specific and difficult to predict based on habitat, body size or phylogeny (Potvin *et al.* 2016). For that previous study, we excluded hunted or intentionally killed birds, following the protocol of similar published work.

The aim of this current study, therefore, is to investigate the likelihood that such data exclusion may present the following scenarios:

1) Birds that are traditionally not killed in large numbers (guillemot species for example;

Valkama *et al.* 2014) would have few intentionally killed individuals, therefore the inclusion of such individuals would likely not alter observed patterns across time or space (Fig. 1a). This scenario also applies to birds that are killed in equal numbers across Europe or those that have gained protection across Europe, thus showing a decrease in hunted individuals over time but no latitudinal differences over time.

- 2) Other species that are mainly hunted in southern latitudes but rarely in northern latitudes because of differences in cultural tradition (for example thrushes in the Mediterranean; e.g., Payevsky & Vysotsky 2003; Valkama *et al.* 2014), may show a significant effect of “hunted” status on latitude (with hunted birds being recovered at more southerly latitudes) across the entire timespan (Fig. 1b).
- 3) We might see an interaction effect of time and hunted status, whereby a species that has traditionally been hunted in more southerly latitudes (but not northerly latitudes) is now protected (for example raptors; Martínez-Abraín *et al.* 2009): for these species we would likely see that the inclusion of killed birds would initially severely decrease the recovery latitude, but over time this effect would lessen (Fig. 1c). Comparing each subset of data with the combined pool of data from each species may also provide insight as to whether patterns are being altered more or less by either group (killed or non-killed birds).

Finally, we can also look at the entire wintering range of the birds recovered over time (using both longitude and latitude of recoveries) to understand whether estimates of the range sizes may differ when using different datasets (killed or non-killed birds). This information is crucial when e.g. determining key wintering ranges of species based on ringing recovery data. Our aim was to present guidelines for filtering data, by highlighting when to exclude or include killed birds in ringing recovery studies.

## 2. Material and methods

We used data collected from 1960 onwards of birds ringed in Finland during the breeding season

Table 1. Species included in the study, listed by whether the species showed no significant effect ( $P > 0.05$ ) of "Killed status" on latitude (Hypothesis 1, Fig. 1a), Significant effect of "Killed status" on latitude ( $P < 0.05$ ), but no interaction effect (Hypothesis 2, Fig. 1b) or significant interaction effect ( $P < 0.05$ ) between "Killed status" and year (Hypothesis 3, Fig. 1c, Fig. 2) in the ANCOVA model. Number of individuals included in the analysis are presented, as well as F-value (partial) of "Killed status" (Hypothesis 1 and 2) or interaction effect of "Killed status" and "Year" (Hypothesis 3). Symbols between brackets in the first column indicate the direction (North, Northeast, Northwest, South, East, West) of any significant effect of year on recovery position ( $P < 0.05$ ; Power score  $> 0.5$ ). Detailed statistics can be found in Supplementary Tables (S1, S2, S3). Also shown are species that were excluded from statistical analyses due to sample size, but that demonstrate discrepancies between sample sizes of killed and non-killed birds.

Species name	Number of individuals		F-value
	Killed	Not killed	
Hypothesis 1 – no change or effect of killed status			
Goldeneye ( <i>Bucephala clangula</i> ) (NE)	143	35	0.471
Lesser Black-backed Gull ( <i>Larus fuscus</i> )	28	16	0.768
Goosander ( <i>Mergus merganser</i> ) (E)	15	19	0.573
Osprey ( <i>Pandion haliaetus</i> ) (S)	156	154	1.607
Hypothesis 2 – effect of killed status but no interaction			
Razorbill ( <i>Alca torda</i> ) (S)	15	115	21.376
Mallard ( <i>Anas platyrhynchos</i> ) (NE)	258	29	13.427
Golden Eagle ( <i>Aquila chrysaetos</i> )	34	78	6.622
Short eared Owl ( <i>Asio flammeus</i> )	10	12	4.201
Tufted Duck ( <i>Aythya fuligula</i> )	105	28	4.08
Common Buzzard ( <i>Buteo buteo</i> )	64	120	24.231
Black Guillemot ( <i>Cephus grille</i> )	13	68	5.248
Black-headed Gull ( <i>Chroicocephalus ridibundus</i> )	125	169	19.81
Carrion Crow ( <i>Corvus corone</i> )	302	22	23.78
Jackdaw ( <i>Corvus monedula</i> )	50	52	11.611
Peregrine Falcon ( <i>Falco peregrinus</i> )	19	54	3.598
Chaffinch ( <i>Fringilla coelebs</i> )	46	33	17.675
Mew Gull ( <i>Larus canus</i> )	410	255	24.725
Eurasian Curlew ( <i>Numenius arquata</i> )	140	11	3.452
Great Cormorant ( <i>Phalacrocorax carbo</i> )	360	157	5.973
European Starling ( <i>Sturnus vulgaris</i> )	68	91	13.763
Song Thrush ( <i>Turdus philomelos</i> )	583	16	14.611
Hypothesis 3 – Interaction effect of killed status and year			
Goshawk ( <i>Accipiter gentilis</i> )	555	803	8.037
Sparrowhawk ( <i>Accipiter nisus</i> ) (SW)	93	699	16.371
Raven ( <i>Corvus corax</i> ) (E)	177	30	5.309
Reed Bunting ( <i>Emberiza schoeniclus</i> ) (E)	166	17	6.436
European Robin ( <i>Erithacus rubecula</i> )	183	135	3.836
Merlin ( <i>Falco columbarius</i> )	11	17	4.220
Kestrel ( <i>Falco tinnunculus</i> ) (S)	41	137	3.570
Caspian Tern ( <i>Hydroprogne caspia</i> )	96	67	4.569
Herring Gull ( <i>Larus argentatus</i> ) (NE)	393	232	11.338
Great Black-Backed Gull ( <i>Larus marinus</i> )	38	26	8.463
Great Tit ( <i>Parus major</i> ) (N)	21	986	3.59
Common Eider ( <i>Somateria mollissima</i> ) (SW)	1,407	261	15.686
Redwing ( <i>Turdus iliacus</i> )	1,072	45	4.563
Eurasian Blackbird ( <i>Turdus merula</i> )	62	98	8.608
Fieldfare ( <i>Turdus pilaris</i> )	619	51	4.195
Lapwing ( <i>Vanellus vanellus</i> ) (NW)	372	13	5.306
Other species in dataset, excluded from ANCOVA due to sample sizes			
Northern Shoveler ( <i>Anas clypeata</i> )	38	1	
Eurasian Teal ( <i>Anas crecca</i> )	218	5	

Table 1, continued

Bean Goose ( <i>Anser fabalis</i> )	63	2
Grey Heron ( <i>Ardea cinerea</i> )	8	17
Long eared Owl ( <i>Asio otus</i> )	8	81
Rough-legged Buzzard ( <i>Buteo lagopus</i> )	23	9
Stock Dove ( <i>Columba oenas</i> )	111	7
Wood Pigeon ( <i>Columba palumbus</i> )	88	3
Greenfinch ( <i>Chloris chloris</i> )	3	221
Rook ( <i>Corvus frugilegus</i> )	21	6
Blue Tit ( <i>Cyanistes caeruleus</i> )	3	222
Whooper Swan ( <i>Cygnus Cygnus</i> )	2	28
Mute Swan ( <i>Cygnus olor</i> )	5	31
White Tailed Eagle ( <i>Haliaeetus albicilla</i> )	4	63
Velvet Scoter ( <i>Melanitta fusca</i> )	24	8
Honey Buzzard ( <i>Pernis apivorus</i> )	19	3
Eurasian Woodcock ( <i>Scolopax rusticola</i> )	216	3
Common Tern ( <i>Sterna hirundo</i> )	15	5
Arctic Tern ( <i>Sterna paradisaea</i> )	2	14

(April–June) and recovered as dead during the winter season (November–January). We conservatively omitted months that might have included potentially migrating individuals of any species in order to make sure we were capturing wintering and breeding grounds only (Saurola *et al.* 2013; Valkama *et al.* 2014). We classified each recovery as having come from a bird that was killed intentionally by humans, i.e., EURING finding conditions codes 1 or 2 and circumstance codes 10 through 29; (du Feu *et al.* 2012) or found dead by other means, i.e., EURING finding condition code 2 and circumstance codes 30 through 78. Individuals for whom this classification was unknown, for which time of death or circumstance of death was unknown, or found alive and released were all removed from the dataset (du Feu *et al.* 2012). Of these, we continued statistical analysis only on those species that had a sample size of 10 individuals or higher in both “killed” and “not killed” categories, in order to be able to identify potential interaction effects (see below), resulting in analyses being performed on 37 species in total (Table 1).

### 2.1. Effects of killed status on winter recovery location

For each species separately we conducted a General Linear Model using SPSS V.22, using “killed status” (killed or not killed) as the fixed independent variable, recovery latitude as the dependent variable and recovery year as the covariate. We

first centered all spatial and year data for ease of interpretation. We used one-way MANOVA to test whether there was a significant interaction between year and killed status that affected ringing recovery location patterns over time (e.g., Ambrosini *et al.* 2016). For those species ( $n = 21$ ) for which there was no significant interaction, we conducted a MANOVA to assess the relative contributions of year and killed status to recovery position. We then conducted these analyses pooling all species in the study together, building a GLMM with a random intercept and slope that allows for an effect of “Year” and “Species” in the intercept but also for different slopes (interaction between “Species” and “Killed status”). This latter analysis was conducted in R 3.3.2 (R Core Team 2015) using the `glmmTMB`-package (Magnusson *et al.* 2016). Our random intercept and slope full model is of the form

$$\text{Lat}_{i,j,k} \sim \text{Killed}_{i,j,k} + \text{Year}_{i,j,k} + \text{Killed}_{i,j,k} \times \text{Year}_{i,j,k} + a_j + b_k \times \text{Killed}_{i,j,k} \quad (1),$$

where  $\text{Lat}_{i,j,k}$  is the  $i^{\text{th}}$  observation (latitude of ring recovery) of species  $k$  in year  $j$ ,  $\text{Killed}_{i,j,k}$  refers to the killing status of the  $i^{\text{th}}$  observation of species  $k$  in year  $j$  (i.e., intentionally killed or not) and  $\text{Year}_{i,j,k}$  is a continuous variable to account for temporal trend.  $\text{Killed}_{i,j,k} \times \text{Year}_{i,j,k}$  denotes the interaction term between these two main effects. The terms  $a_j$  and  $b_k$  are the random intercept and random slope, respectively, which are assumed to be normally

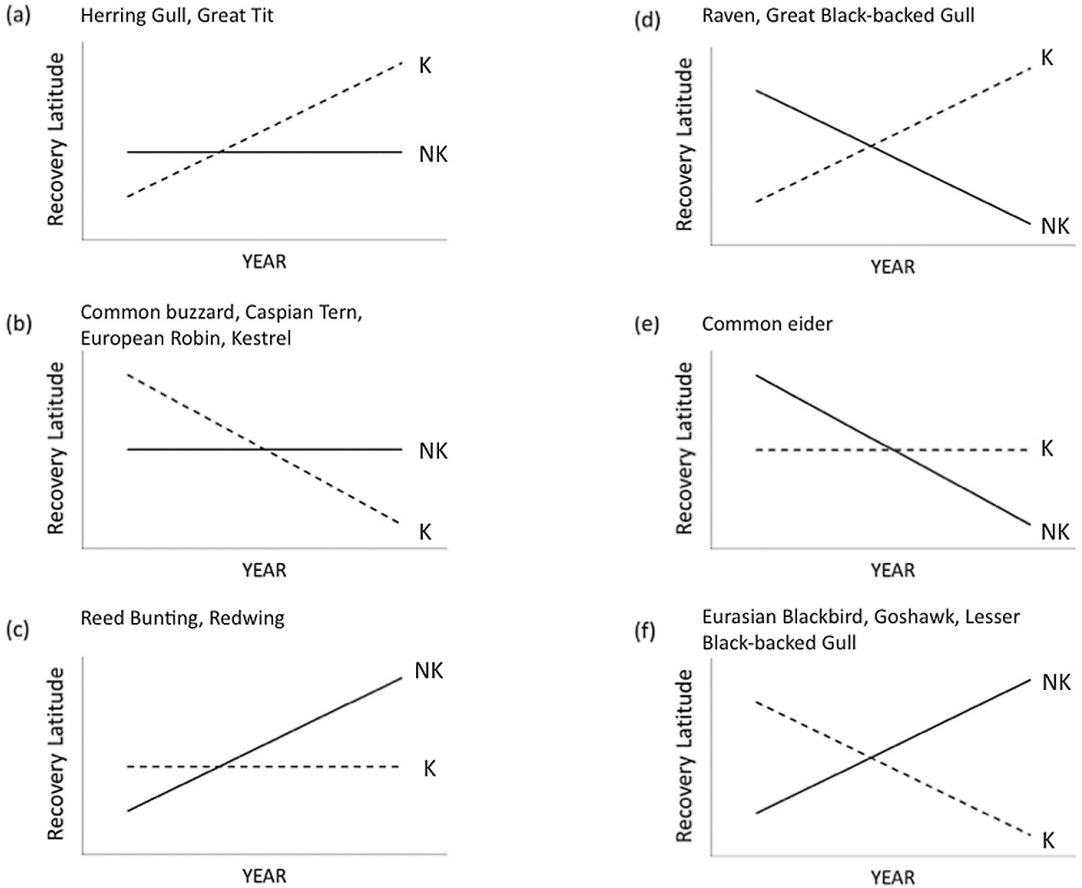


Fig. 2. Simplified diagrams of all interaction effects between killed status and year found in the study. Species correspond to those found in Table 1, Hypothesis 3.

distributed with mean 0 and each term has each own variance ( $\sigma^2_{\text{year}}$  for the random intercept and  $\sigma^2_{\text{species}}$  for the random slope; see e.g., Zuur & Ieno 2016a).

We only performed model selection on the interaction term (Killed  $\times$  Year) because this appeared to be non-informative but left both main terms (even if they were not significant) at the 5% level (see Pinheiro & Bates 2000; Bolker 2008; Bolker *et al.* 2009; Zuur & Ieno 2016b). We removed the interaction in order to be able to properly estimate parameters and confidence intervals of the main terms (Bolker *et al.* 2009). The resulting data gave us three groups of species: those for which there was no effect of “killed status” on recovery location, those for which there was a significant effect of killed status but no interaction with year, and those for which there was a significant

interaction between year and killed status. The effects of killed status or the interaction between killed status and year (when significant) can be found in Table 1.

In order to understand whether the recovery position patterns were due to shifts in latitude or longitude, we also performed ANCOVA analyses on longitude and latitude separately for all species.

Post-hoc, we performed power analyses and used logistic regression in SPSS to analyze whether sample size of the infrequent group (killed / non-killed) could predict a significant versus non-significant result, to make sure that our estimate of minimum sample size was not too small to detect significant patterns in the data. We also tested how sample size could influence the detection of differences between killed status groups using data of six of the species with the largest samp-



Table 2. Comparison of the slopes obtained plotting the full dataset, killed birds only dataset and nonkilled birds only dataset for each species included in the study. Bolded rows indicate very high correlations between the slopes of three datasets. For these species, we recommend using the full dataset when investigating winter latitude shifts over time. For all other species, we recommend following the flowchart included in the manuscript (Fig. 6) for guidance when deciding whether to include killed individuals or not in a ringing recovery analysis.

Species	Slope Full dataset	Slope Killed birds	Slope Non-killed birds	Difference between slopes Killed vs All	Difference between slopes Non-killed vs All	CI test
Goshawk ( <i>Accipiter gentilis</i> )	0.03	0.01	0.03	0.02	0	N
Sparrowhawk ( <i>Accipiter nisus</i> )	-0.03	-0.14	-0.07	0.11	0.04	N
Razorbill ( <i>Alca torda</i> )	-0.03	-0.1	-0.04	0.07	0.01	N
Mallard ( <i>Anas platyrhynchos</i> )	0.06	0.06	-0.04	0	0.10	N
Golden Eagle ( <i>Aquila chrysaetos</i> )	0.11	0.11	0.03	0	0.08	N
Short eared Owl ( <i>Asio flammeus</i> )	0.009	-0.04	-0.08	0.049	0.089	Y
Tufted Duck ( <i>Aythya fuligula</i> )	-0.02	-0.03	-0.08	0.01	0.06	N
<b>Goldeneye (<i>Bucephala clangula</i>)</b>	<b>0.08</b>	<b>0.08</b>	<b>0.08</b>	<b>0</b>	<b>0</b>	<b>Y</b>
Common Buzzard ( <i>Buteo buteo</i> )	0.07	-0.1	0.04	0.17	0.03	N
Black Guillemot ( <i>Cepphus grille</i> )	-0.02	0.02	-0.1	-0.04	0.08	N
Black-headed Gull ( <i>Chroicocephalus ridibundus</i> )	0.03	0.06	-0.00098	-0.03	0.031	Y
Jackdaw ( <i>Corvus monedula</i> )	0.03	-0.01	-0.008	0.04	0.038	N
Carrion Crow ( <i>Corvus corone</i> )	0.02	0.01	-0.04	0.01	0.06	N
Raven ( <i>Corvus corax</i> )	0.02	0.05	-0.04	-0.03	0.06	N
Reed Bunting ( <i>Emberiza schoeniclus</i> )	0.04	-0.02	0.08	0.06	-0.04	N
European Robin ( <i>Erithacus rubecula</i> )	0.09	-0.11	0.01	0.20	0.08	N
Merlin ( <i>Falco columbarius</i> )	0.006	-0.27	-0.09	0.28	0.096	N
Peregrine Falcon ( <i>Falco peregrines</i> )	0.15	0.06	0.09	0.09	0.06	N
Kestrel ( <i>Falco tinnunculus</i> )	-0.02	-0.24	-0.008	0.22	-0.012	N
Chaffinch ( <i>Fringilla coelebs</i> )	0.16	-0.01	0.1	0.17	0.06	N
Caspian Tern ( <i>Hydroprogne caspia</i> )	-0.004	0.01	0.02	-0.014	-0.024	N
Mew Gull ( <i>Larus canus</i> )	0.04	0.06	0.0004	-0.02	0.04	N
Less. Black-backed Gull ( <i>Larus fuscus</i> )	-0.04	-0.83	1.13	0.79	-1.17	N
Great Black-Backed Gull ( <i>Larus marinus</i> )	-0.0008	0.06	-0.11	-0.061	0.11	N
Goosander ( <i>Mergus merganser</i> )	0.05	0.12	0.02	-0.07	0.03	N
Eurasian Curlew ( <i>Numenius arquata</i> )	0.02	0.01	0.1	0.01	-0.08	N
Osprey ( <i>Pandion haliaetus</i> )	-0.25	-0.3	-0.03	0.05	-0.22	N
Great Tit ( <i>Parus major</i> )	0.003	0.13	0.002	-0.13	0.001	N
<b>Great Cormorant (<i>Phalacrocorax carbo</i>)</b>	<b>0.11</b>	<b>0.12</b>	<b>0.1</b>	<b>-0.01</b>	<b>0.01</b>	<b>Y</b>
Common Eider ( <i>Somateria mollissima</i> )	-0.0096	-0.004	-0.03	-0.0056	0.02	N
European Starling ( <i>Sturnus vulgaris</i> )	0.035	-0.01	0.02	0.045	0.015	N
Redwing ( <i>Turdus iliacus</i> )	0.01	-0.004	0.07	0.014	-0.06	N
Eurasian Blackbird ( <i>Turdus merula</i> )	0.03	-0.16	0.07	0.19	-0.04	N
Song Thrush ( <i>Turdus philomelos</i> )	-0.005	-0.01	0.07	0.005	-0.075	N
Fieldfare ( <i>Turdus pilaris</i> )	0.02	0.01	0.05	0.01	-0.03	N
Lapwing ( <i>Vanellus vanellus</i> )	1.61	1.5	3.4	0.11	-1.79	N

le sizes in each hypothesis group (Table 1). We did this by randomly taking 10, 20, 50 or 100 subsamples (or 10, 20, 30 and 45 if the other killed category did not have more than 50 observations) from both killed status groups and ran the analyses (latitude = killed status + year + killed status ×

year). We ran the analyses for each of the randomly chosen subsample sizes 100 times and investigated what the P-values of the interaction were between killed status and year.

For each species we also created a plot of all data, focusing on latitude and highlighting which

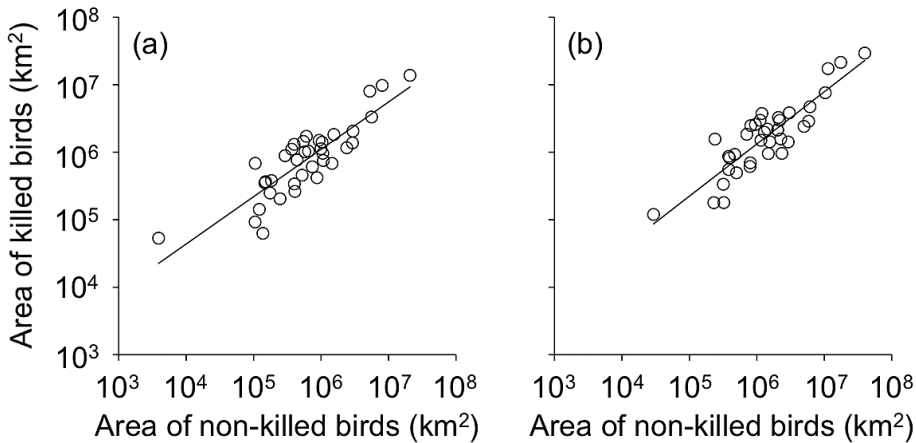


Fig. 3. Connection between (a) 50% and (b) 75% Kernel winter range sizes based on killed and non-killed birds. Note the log-scale of the axes (see also Supplementary Table 1).

recoveries were from killed birds and which were from non-killed birds. We included a line of best fit across the entire dataset, as well as two lines indicating the mean slope of each subset. We could then visualize whether the slopes of either subset group (killed or not killed) were congruent with the overall mean (i.e., within the 95% confidence intervals of the overall mean). This provided us with more information about whether the killed or non-killed data was contributing most to the skew (i.e., “pulling” the overall mean northwards or southwards) in the overall dataset. We also used the difference between the slopes of the three lines as an indicator as to whether including or not including subsets of data would alter results.

## 2.2. Effects of filtering on winter range estimation

We calculated the wintering ranges of each species by calculating the 50% and 75% kernel density contour (Worton 1989; see also Mellone *et al.* 2011) of the ring recoveries with the package “adehabitatHR” in R 3.3.2 (R Core Team 2015). To assess whether including “killed” recoveries in the analysis could lead to (statistically) different results and therefore spurious conclusions, we first calculated the kernels using only “not killed” recoveries for each species (NK Kernel), then using only “killed” recoveries (K Kernel) and, lastly, us-

ing all recoveries. We determined the area ( $\text{km}^2$ ) of the species-specific polygon for further comparison between the three methods (i.e., “killed” vs “not killed”, “killed” vs “All” and “not killed” vs “All”). Lastly, we performed a repeatability test (i.e., Intra Class Correlation Coefficient (ICC) test) to determine the percentage of the total variation in the data (i.e., log-transformed area of the kernel polygon) that is due to differences among the three methods; this is, the contribution of the method to the overall variance (Wolak *et al.* 2012). The ICC was calculated using the ICC-package in R (Wolak *et al.* 2012).

## 3. Results

Fourteen out of 37 species analyzed were found to have significantly changed their wintering area over time (Table 1). Interaction effects between year and killed status on wintering location were found in 16 of the species analyzed. Since shifts solely in longitude only affected three of these species (Raven *Corvus corax*; Reed bunting *Emberiza schoeniclus* and Goosander *Mergus merganser*; Table 1), we continued more in-depth analyses on latitudinal patterns. Figure 2 shows the general patterns of interaction for each of the 16 species where an interaction between year and killed status was found to affect latitude. For the 21 species for which no interaction effect between year and



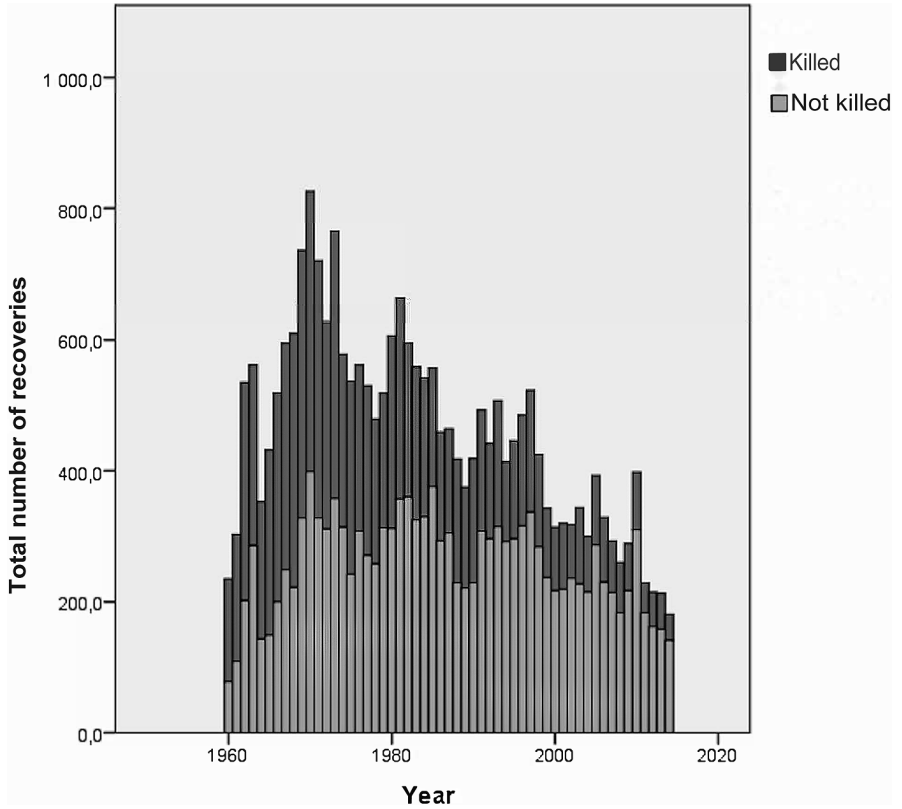


Fig. 4. Histogram of birds (all species pooled) killed intentionally by humans and those that have died naturally/unintentionally over the time period covered by the study.

killed status was found, ANCOVA identified 15 species for which killed status did still significantly affect the recovery location. All but one species in this group (Mew Gull *Larus canus*) followed the predicted pattern of more birds being killed at southern latitudes. However, by definition the patterns over years did not differ (Table 1). Importantly, sample size across all species did not appear to have an effect on whether or not a significant pattern was detected (Intercept:  $B = 0.872 \pm 0.616 SE$ ,  $P = 0.157$ ; Sample size:  $B = 0.006 \pm 0.005 SE$ ,  $P = 0.215$ ). However, when bootstrapping was performed on species with the largest sample sizes, it was found that significant differences were more likely to be detected if the sample size was  $>45$ , and those with a sample size below this should be considered carefully (Appendix 2).

### 3.1. Effects of killed status on recovery location

When focusing on overall patterns of year versus found latitude for each species, and the fit of both

killed or non-killed datasets to said patterns, we found that there were two species (Goldeneye *Bucephala clangula* and Great Cormorant *Phalacrocorax carbo*; Table 2), where neither subgroup was significantly biasing results. This conclusion was made using both methods of comparison: the slopes of both subsets of data (killed and non-killed birds) fell within the confidence intervals of the mean overall slope, and there were very small differences ( $<0.02$ ) between the slopes of both data subsets and the complete dataset (Table 2). All other species showed deviations of either (or both) slopes predicted by the subsets of data with the overall mean, suggesting further investigation into the impacts of either subset of data was warranted (Table 2, Appendix 2).

When all species were pooled we found that the proportion of birds intentionally killed generally decreased over time (Fig. 4). After removing the uninformative interaction ( $z$ -value = 0.53,  $P = 0.59$ ) from the GLMM with random intercept and slope and refit the same model but only with the main terms (see Methods section, see also Bolker

*et al.* 2008, Zuur & Ieno 2016b), the results showed a non-significant effect of killed status (intentionally killed or not) on the latitude of the recovery ( $z$ -value =  $-1.8$ ,  $P = 0.07$ ), suggesting that the probability of finding a ring at a certain latitude is not linked to whether the bird has been shot or has died by natural causes. In addition, there was no effect of year on recovery location generally. This confirms the varied results between species obtained above, and shows that no apparent overall pattern of bird killing is affecting the recovery latitude of winter birds over time.

### 3.2. Effects of killed status on winter range estimation

The repeatability analysis (ICC test) performed suggested that only 8.9% (ICC = 0.911, CI = 0.852–0.949) of the total variation in the area of the 50% Kernel polygons and 7.5% (ICC = 0.925, CI = 0.876–0.958) of that of the 75% kernel polygons within a species is due to the method used to calculate it (“Killed”, “Not Killed” or “All”) and, consequently, most of the total variation (91.1% and 92.5% for the 50% and 75% Kernel polygons, respectively) in our data was due to differences among species. Therefore, the contribution of the method to the total variation in the estimated area of the range can be considered low, compared to the total variation among species (Wolak *et al.* 2012).

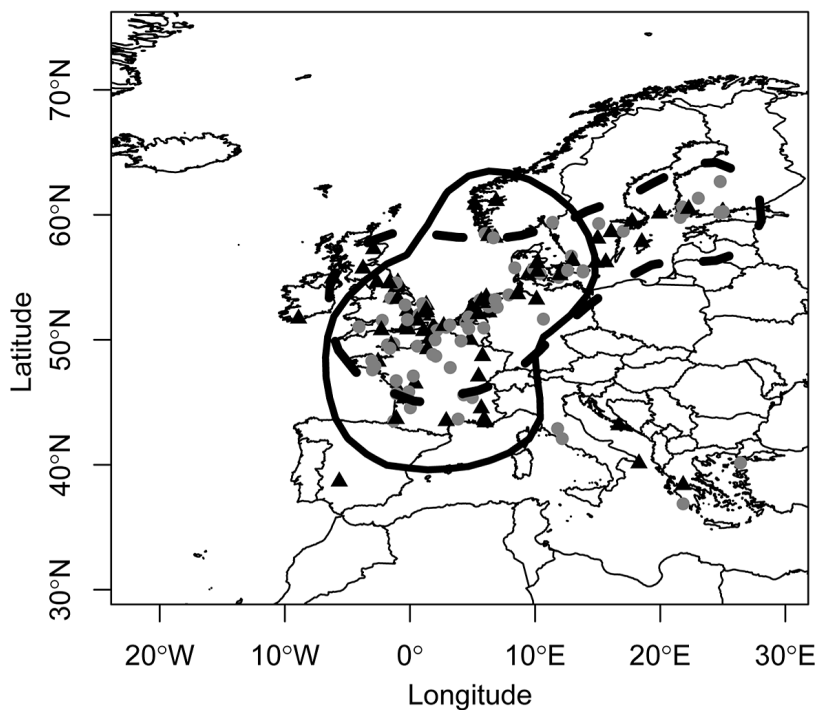
Only some species showed large differences in the range size depending on methodology. The extreme examples were Common Eider *Somateria mollissima* (range size based on killed birds was only 7% of the range size based on non-killed birds in 50% Kernel polygons) and Reed Bunting *Emberiza schoeniclus* (range size based on killed birds was 15% of the range size based on non-killed birds in 50% and 75% Kernel polygons). In the rest of the cases this ratio varied between 30–215%. An example of the species-specific range sizes can be found in Fig. 5, and data/comparative range maps for all species can be found in Appendix 1.

## 4. Discussion

We found that the common practice of excluding hunted birds from studies of winter distribution in Europe may be warranted for some species but not others. Indeed, our model including all birds in the study found no overall pattern applicable to all species, however species identity was a major factor in determining whether killed birds were more likely to be found in different locations to those found after natural death. When focusing solely on whether the slopes of recovery latitude over year from killed or non-killed birds deviated from that of the overall mean, only two species – Goldeneye and Great cormorant – were found to have similar slopes between all three datasets. However, sixteen of the 37 species included in our study did show significant interaction effects between year and killed status, impacting observations of winter location over time (Table 1). For five of these species, including killed birds in the analysis increased the slope of winter latitude over time, making it seem as though these birds might be shifting their winter distribution northward (or remaining stable) at a faster pace than they likely are (Fig. 2). The other nine species in this group demonstrated the opposite effect: interactions between killed status and year resulted in recovery latitudes seemingly moving southward or remaining stable when this may not be the case for all species or populations (Fig. 2). In reality, it is probable that intentional killing of these species was traditionally low in Northern Europe, but high in Southern Europe, however over time these killing practices or reporting of killed birds have decreased in frequency (Martínez-Abraín *et al.* 2009). For these 16 listed species, we recommend removing intentionally killed birds from the data set when attempting to analyze patterns or natural causes of winter distribution shifts over time.

In contrast, we also found four species that showed no difference in winter latitude over time whether an individual was killed intentionally or not (Table 1). Congruent with our original hypothesis, this did not only include birds that are protected or not traditionally killed anywhere in Europe (e.g., Goosander *Mergus merganser*) but also birds that are hunted across Europe likely at similar rates, and those that were hunted or persecuted in the past but have now seen a reduction in kill-

a) *Turdus merula* – Kernel 75%



b) *Turdus iliacus* – Kernel 75%

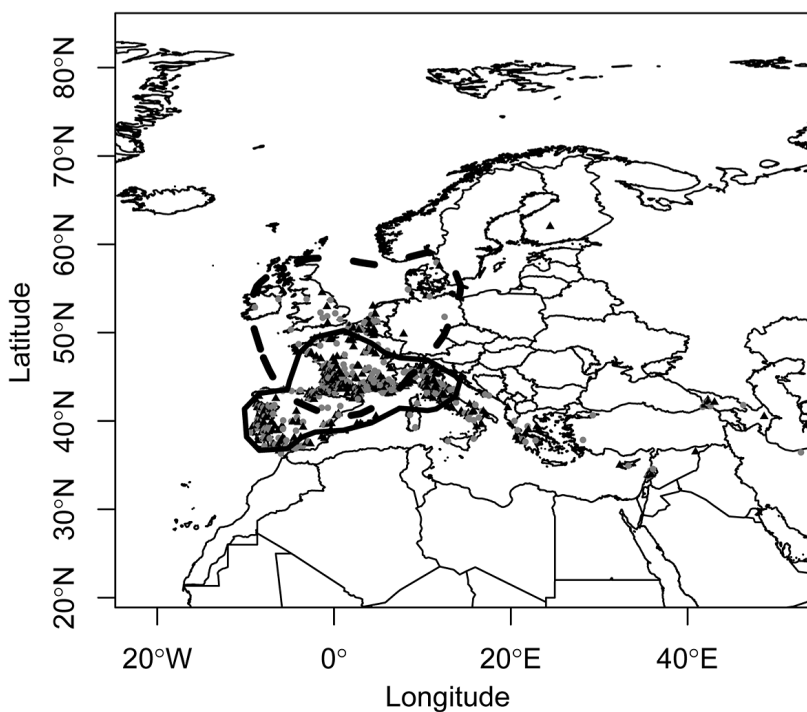


Fig. 5. Maps (examples) of the 75% Kernel estimates of the winter ranges of a) Eurasian blackbird (*Turdus merula*) and b) Redwing (*Turdus iliacus*) comparing the use of ringing recovery datasets of intentionally killed birds (K, solid lines, black dots) and birds simply found dead (N, broken lines, grey triangles). Maps of all species included in the study can be found in Appendix 2.

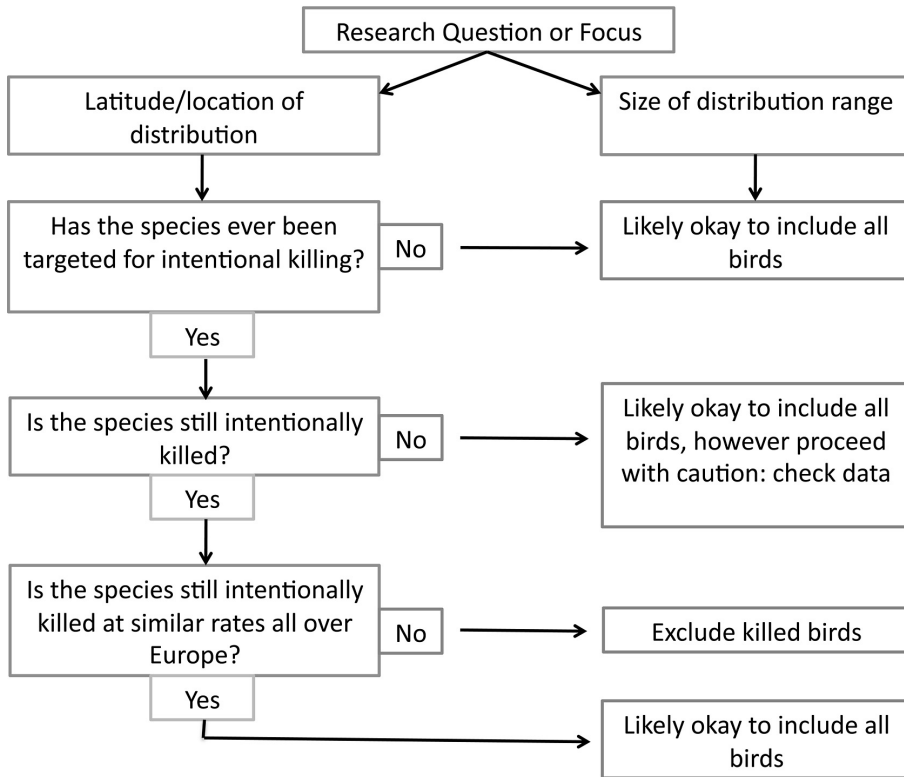


Fig. 6. Flowchart based on research question and data characteristics for helping researchers decide whether or not to include or exclude killed birds from ringing recovery analyses.

ings over time across the whole continent (e.g. Osprey *Pandion haliaetus*; Saurola 1985). For these species, it appears as though any patterns, especially of wintering latitude shift over time, are not impacted by the inclusion or exclusion of intentionally killed birds. Thus, there may not be ample reason to discard these datapoints in such analyses, especially since for some species the exclusion of killed birds reduces the sample size so drastically that statistically relevant analyses of winter shifts would include a lot of uncertainty (e.g. Goldeneye; Table 1) or even force researchers to drop the species from any analysis.

Thirdly, we identified 17 species in our analysis whose wintering location was significantly explained by whether or not they were intentionally killed, but whose slope of shifting latitude or longitude over time was not affected by killed status. In other words, for these species the pattern of shifting winter location – of which seven displayed changes in winter latitudinal distribution

over time – were similar whether an individual was killed or not killed. When performing analyses on winter distribution shifts in these species, we would recommend including all individuals if the focus of the study is on the relative slope of the shift, since sample sizes will be increased and statistical analyses will likely have more power to detect changes. However, if researchers are interested in absolute values (detailed information on the particular locations or latitudes of the shifts), it would be prudent to remove birds that are intentionally killed, or include killed status as a covariate in the analysis. We did not find an overall significant shift in the wintering location across 37 bird species, although nine species showed significant long-term movement northwards and eight species showed corresponding movements southward. This indicates that wintering areas of migratory bird species have not necessarily universally shifted significantly (for more detail see Potvin *et al.* 2016), despite recent studies that certain duck

and wader species in particular have shifted their central gravity of wintering distribution northwards based on census data (Maclean *et al.* 2008; Lehikoinen *et al.* 2013; Pavón-Jordán *et al.* 2015). Otherwise, based on our study, including killed birds could result in estimates of mean recovery latitude being biased towards the south for European wintering species. In addition, if both data types are included in the analyses, care should be given to identify whether the proportion of killed birds has changed over time: a pattern apparent in the Finnish data (Fig. 4).

Studies using kernel estimators based on ring recoveries have previously been able to identify range patterns based on migration (Calenge *et al.* 2010), demonstrating the usefulness of this methodology as a tool when testing hypotheses such as ours (that including or not including killed birds for some species datasets may affect any estimates of winter range). Our analyses of wintering ranges (kernels) suggested that there is no *a priori* reason for excluding data of intentionally “killed” birds when analyzing the size of home ranges. However, some species showed relatively large differences in position (e.g., European Robin *Erithacus rubecula*) and size (e.g., Fieldfare *Turdus pilaris*) of wintering ranges based on these two different types of data. Thus if researchers are interested in the actual location of the range, it would be good to exclude killed birds, as killed birds are mainly found at more southern latitudes than not-killed individuals. However, one thing for researchers to consider when removing killed birds from analyses is where these records are coming from, and whether the range estimation is affected by this removal. In other words, if the only recoveries of a certain species in a particular region or country are those of killed birds, then removing these data will erroneously indicate that the species does not occur in that region. This problem may already arise from birds dying and not being recovered at all due to lack of human presence in the area. These patterns warrant further investigation, and we suggest multi-national datasets be used to better understand how the circumstances of recovery might affect the accuracy and precision of our range estimates for migratory species.

With data on 37 migratory bird species, we have thus identified several potential consequences of including or excluding hunted or inten-

tionally killed birds in studies using ringing recovery data. We are aware that our study uses data only of Finnish breeding birds, and therefore our specific recommendations of which species-studies should include or not include hunted birds can likely only be applied to the Nordic countries. We have, with these data, identified a few key attributes that may mean excluding hunted data is unnecessary, namely 1) If the species has never been targeted for intentional killing; and 2) If the species is/has been intentionally killed at similar rates across the continent. If a species has been historically killed but may not be anymore, then examining the data would be helpful before deciding whether to exclude killed birds or not in subsequent analyses. Importantly, if rates of killing differ between nations either historically or at present, it would likely be prudent also to exclude data from killed birds. However, the aim of this study was not to necessarily provide a specific guide detailing which species should have all data included or not in European latitudinal studies. Instead, we used these particular data and set of analyses to showcase the impacts of general data exclusion rules (Fig. 6), especially when such rules are based on theories that may not be universally applicable.

We believe that our results show the importance of testing datasets in any study on recovery data, regardless of location. Given that ringing recovery data is by nature opportunistic, many other possible factors can bias data (e.g., human presence and activities). While it is important, therefore, to consider these biases, it is equally important not to manage these biases simply by filtering our datasets – to do this for all potential biased factors, we would likely end up with very little data. We have attempted to show one very simple example of a method that can be employed to help determine whether the inclusion or exclusion of certain datapoints may be necessary. There are, of course, other means of reducing bias in ringing recovery studies. For example, in analyses on particular species, models can be used to predict the likelihood of recovery specifically for hunted birds: by employing differential probability models to different types of species or individuals one might be able to calculate distributional shifts with much more accuracy – although we understand that these methods may not be feasible for all studies (Magnin 1991; Newton & Dale 1996). Comparing



the results of analyses performed on different subsets of a particular dataset may also provide information on the robustness of that dataset. We have used winter distribution changes over time as our theoretical framework because of the current trend in climate change analyses to use these types of records to analyze distributional shifts of species (Fiedler *et al.* 2004). Nevertheless, we believe that the outcome of our study is likely of wider importance: we are attempting to highlight that suggested methods for reducing bias may or may not be universally practical or warranted in all cases, and that prior to employing such methods we as scientists should consider the context of our data and the potential consequences of our methodology when performing any such analysis.

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### **Tulisiko tapetut yksilöt poistaa rengaslöytöanalyseistä talvialueita tutkittaessa?**

Rengaslöytöaineisto on tunnistettu Euroopassa viime vuosina mahdollisesti tärkeäksi aineistoksi tutkia mm. ilmastonmuutoksen vaikutuksia muuttolintujen talvilevinneisyysalueissa. Kuten moni muukin vapaaehtoisten keräämä kansalaistieteen perustuva aineisto, myös rengaslöydöt pitävät sisällään mahdollisia aineistovinoumia mikäli tutkijat eivät valitse aineistoa huolellisesti viinonmien välttämiseksi.

Aineiston valinta analyysiin ei kuitenkaan tarvitse olla lähtökohtaisesti sama kaikilla alueilla tai lajeilla, vaan aineiston valinnan vaikutuksia tuloksiin tulisi arvioida hyvissä ajoin ennen lopullisia analyysejä. Rengaslöytöaineistossa yksi keskeinen aineistoa vinouttava tekijä on, onko löydetty lintu kuollut metsästyksen tai muun tahallisen tappamisen takia, koska metsästyksen ja lintujen laittoman tai laillisen tappamisen intensiteetti vaihtelee voimakkaasti alueellisesti. Esimerkiksi lintujen tappaminen on yleisempää Etelä- kuin Pohjois-Euroopassa. Tämän takia usein on ehdo-

tettukin tapettujen lintujen poistamista analyyseistä.

Tässä työssä selvitimme, miten tapettujen lintujen pois jättäminen vaikuttaa lajien talviaikaisen löytöjen painopisteen mahdolliseen ajalliseen siirtymiseen tai löytöjen perusteella laskettuun talvialueen kokoon. Tutkimuksessa käytimme aineistoa 37 lajin yksilöistä, jotka oli rengastettu pesimäaikaan ja löydetty kuolleena talviaikaan. Tuloksemme osoittavat, että tapettujen lintujen poistaminen on perusteltua useiden lajien osalta, sillä tapettujen ja muuten kuolleena löydettyjen lintujen aineistot antavat erilaisia tuloksia. Tapettujen yksilöiden poistaminen analyyseistä voi kuitenkin pienentää olennaisesti analyyseissä käytävän aineiston määrää joillakin lajeilla. Sen sijaan talvehtimisalueiden koot eivät poikenneet erilaisista aineistoista huolimatta suurella osalla lajeista toisistaan.

Yleisesti tutkimuslajeilla ei havaittu ajallista siirtymistä talvilöytöjen painopisteessä kohti pohjoista, kuten olisi ollut odotettavissa ilmastonmuutoksen näkökulmasta. Tulosten perusteella ehdotamme, että tapettujen lintujen poistaminen analyyseistä ei tulisi tehdä ilman etukäteisarviointia aineiston poiston mahdollisista vaikutuksista. Lisäksi esitämme ohjeet miten aineiston valinta tulisi tehdä, jotta aineistoa voitaisiin käyttää mahdollisimman tehokkaasti.

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### Online supplementary material

Appendix 1. Graphs showing data summarised in Table 1 in the main text.

Appendix 2. Maps for each species included in the study (all years), showing the winter range and Kernel distributions.

Supplementary Tables:

S1, S2 and S3, showing all statistical results by species for recovery latitude (S1), longitude (S2) and Latitude/Longitude combined (S3). S4, all spatial recovery data used in Kernel Analysis.