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Are common bird monitoring schemes and opportunistic observations appropriate for estimating raptor trends?

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ABSTRACT

Capsule: Transect-based common bird monitoring methods and opportunistic data from citizen scientists are not equal alternatives to mapping of raptors in study plots.

Aims: To analyse the efficacy of common breeding and wintering bird monitoring schemes, as well as databases of casual bird observations, in providing population trends for raptors.

Methods: We estimated trends for three raptor species using data from Estonian common bird monitoring schemes and a database of casual observations, and compared these with those resulting from special raptor monitoring programmes.

Results: Significant trends for all three species were only detected using the specialized scheme Monitoring of Breeding Raptors in study plots, whereas Monitoring of Wintering Raptors showed some significant yearly fluctuations of the Common Buzzard *Buteo buteo*. However, Common Breeding and Wintering Bird Monitoring schemes provided uncertain trends, although results suggested a decline in the breeding Goshawk *Accipiter gentilis* population. Casual observations suggested recent declines in wintering populations of the Goshawk and Sparrowhawk *Accipiter nisus*, but data from more years are needed to validate this.

Conclusion: Special monitoring schemes are most effective in monitoring raptor populations. Such schemes can be used to monitor trends of common and uncommon raptor species and provide additional information for their research and conservation.

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Monitoring provides up-to-date information on species' abundance and can enable predictions of their future, hence it is fundamental to successful conservation planning and optimal management decisions (Yoccoz *et al.* 2001, Nichols & Williams 2006). Ideally monitoring should cover the ecosystem completely, but broad-scale surveys require high expenditure of effort and resources and, moreover, many species are hard to detect or count. A cost-effective approach is to follow changes in indicator species, which efficiently reflect the quality of the ecosystem (Paoletti 1999, Markert *et al.* 2003).

Top predators, such as birds of prey, are good indicators of biodiversity (Sergio *et al.* 2005, 2006). Raptors are easy to observe and dynamics of their abundance (or reproductive success) reflects well the population dynamics of their prey (Newton 1979), which in turn respond to changes at lower trophic levels (Korpimäki *et al.* 2004). In conservation terms, diverse raptor populations indicate a viable ecosystem. Top predators also tend to accumulate chemical contaminants in the trophic food chain (Newton 1979), thus they effectively indicate pollution levels in the environment (Furness 1993, Becker 2003). Last but not least, raptors have been historically heavily persecuted by humans (Bijleveld 1974) and, although some species have recovered, many are still threatened and monitoring is essential for efficient conservation of these species (Burfield 2008, Vrezec *et al.* 2012).

Raptor populations often exist at low densities whereby individuals occupy large home ranges. This has caused difficulties in estimating their numbers and therefore various special methods are designed for raptor surveys (Andersen 2007). Mapping of nesting territories and nests within a defined area is probably the most widely used and most reliable method for monitoring of breeding birds of prey (Hardey *et al.* 2009). An excellent example is the Finnish raptor grid programme, which involves monitoring of raptor numbers in many standardized study plots (Saurola

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1986, 2008). Similar approaches have been later adopted in other countries, for example, Estonia (Lõhmus 1994, Nellis 2012), Germany (Stubbe *et al.* 1996) and Poland (Sielicki & Mizera 2012). However, other methods, such as road transects from vehicles or aerial surveys of nesting aggregations, have also been used to monitor raptor populations during various phases of their annual cycle (Kenward *et al.* 2000, Andersen 2007, Hardey *et al.* 2009).

For most numerous raptor species, population trends can also be obtained from monitoring schemes targeting all common bird species. For instance, Pan-European Common Bird Monitoring Scheme (PECBMS) has published trends for the European Sparrowhawk *Accipiter nisus*, Common Buzzard *Buteo buteo*, Marsh Harrier *Circus aeruginosus* and Common Kestrel *Falco tinnunculus* (European Bird Census Council 2016). However, the European estimates strongly depend on the quality of national surveys, from which continental population indices are calculated (Gregory *et al.* 2008). Hence, to evaluate reliability of large-scale population trends, the quality of national trends should be verified.

Here, as an example, we assess the efficacy of common bird monitoring schemes in Estonia in providing national trends for three raptor species, and compare these trends with those resulting from special raptor monitoring schemes. We analyse separately trends in the breeding season, which is important for reproduction, and those in winter, which is the season when mortality strongly influences raptor populations (Newton 1979). Charismatic and relatively uncommon birds of prey are popular among birdwatchers and nowadays many raptor observations are uploaded to public databases of bird records. These opportunistic databases hold a huge potential for avian research and conservation in the future (Sullivan *et al.* 2009). Therefore we also compile casual observations of the same three species from an Estonian database of bird records, estimate the trends and compare these with those provided by conventional monitoring programmes.

Methods

The study was conducted in Estonia (57.5°–59.6°N, 21.8–28.2°E; 45 227 km^2), a flat lowland country situated in northeastern Europe at the border between the nemoral and boreal environmental zones (Metzger *et al.* 2005). The Estonian landscape is a heterogeneous mosaic of various landscape types. In total, approximately 50% of Estonia is covered with forests and 25% with agricultural land. There are 28 species of raptors (including owls) breeding and 20 species wintering in Estonia (21 and 15 species, respectively, on a regular basis). In the current study we analyse trends of three species, the Goshawk *Accipiter gentilis*, European Sparrowhawk and Common Buzzard, which are among the most numerous and widespread raptor species in Estonia during the breeding and/or wintering seasons (Table 1).

We assess the efficacy of four Estonian bird monitoring schemes, of which three have been included in the Estonian national bird monitoring programme since 1994 and one since 2014. In all schemes, transects or study plots are selected by observers and are usually, due to logistics and long-term sustainability, located in surroundings of their residence. This, however, has not prevented a rather even distribution of transects and plots across the country, with no concentration to good or poor bird areas, and the major land cover classes (according to the CORINE land cover classification) are sampled adequately (Lõhmus 2004, Kuresoo *et al.* 2011).

Common Breeding Bird Monitoring is based on point counts along transects (see Kuresoo *et al.* 2011 for the detailed description and results of the scheme). Each transect consists of 20 points with intervals of at least 200 m. At each point birds are counted for 5 minutes and no distance bands are set. The counting usually starts at sunrise and is normally completed within 5 hours. One counting visit per season, between 25 May and 20 June, is required. The scheme has been running since 1983 and its results are used in the international PECBMS programme. Here we analyse data collected during 1994–2015, when the number of transects ranged from 20 to 53 (mean 33.6; Figure 1).

Common Wintering Bird Monitoring (Common Winter Bird Counts) follows the principle developed for the well-known Christmas Bird Count (Audubon 2017). The exact method applied in Estonia is described by Elts (1995). Continuous line transect counts without distance bands are used. The recommended length of transect is 10 km. Each transect is visited three times during a winter, but in the current analysis only results of the Christmas count (from 25 December to 7 January) are used. The scheme was launched in winter 1987/88. In the current study we include data from 1993/94 to 2015/16 when the mean number of transects per winter was 34.9 (16–48; Figure 1).

Table 1. Population sizes of the three studied raptor species in Estonia, according to Elts *et al.* (2013).

	Breeding pairs	Wintering individuals
Goshawk *Accipiter gentilis*	400–600	800–1200
European Sparrowhawk *Accipiter nisus*	2000–3000	1000–3000
Common Buzzard *Buteo buteo*	6000–7000	200–1000[a]

[a]500–3000 according to Elts *et al.* 2009, 1000–3400 according to Väli *et al.* (2014).

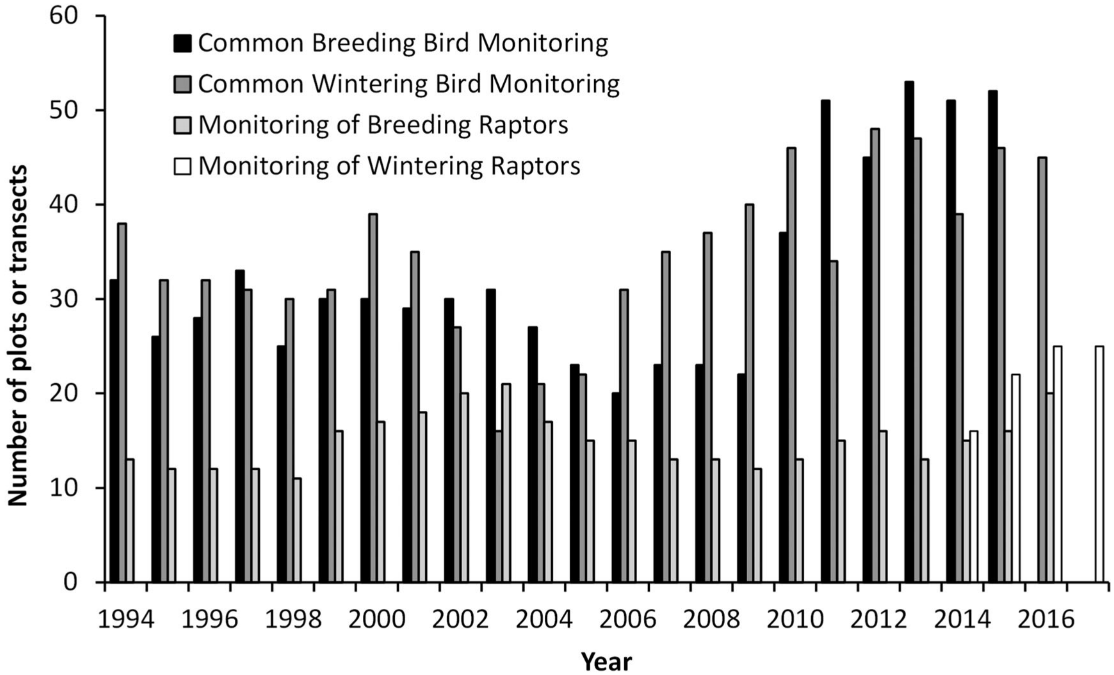

Figure 1. Numbers of studied transects (Common Breeding Bird Monitoring, Common Wintering Bird Monitoring) or study plots (Monitoring of Breeding Raptors, Monitoring of Wintering Raptors).

During the *Monitoring of Breeding Raptors*, nesting territories of all raptors in permanent study plots are mapped, therefore fieldwork is conducted throughout the breeding season. Also nests are searched for, which validates the existence of nesting territories and, moreover, enables the monitoring of reproductive success. The scheme started in the late 1980s (Lõhmus 1994), although a few plots were also studied for decades earlier (Lelov 1991, Tuule *et al.* 2011). Systematic surveys across Estonia started in 1994, since when 11–21 (mean 15; Figure 1) plots of size 25–200 km^2 (mean 86 km^2) have been monitored annually. The recommended plot size is 100 km^2, which could be effectively studied by 2–3 voluntary observers, but due to the shortage of volunteers some smaller plots, and due to historical continuity two larger plots are included too. Most study plots are bordered by the Universal Transverse Mercator (UTM) grid.

Monitoring of Wintering Raptors aims to monitor all raptors in farmland at permanent study plots, which are mostly the same as those covered in the breeding season. Annually, the monitoring is conducted as a single count in mid-winter (second half of January). The scheme started only in 2014 (Väli *et al.* 2014). The annual number of studied plots has ranged from 16 to 25 (mean 22; Figure 1) and the area of studied farmland in plots is between 4.1 and 42 km^2 (mean 18.5 km^2).

E-biodiversity (http://elurikkus.ut.ee) is an online database where Estonian birdwatchers upload their bird records. The database was introduced in April 2011 and thereafter the number of uploaded observations has been increasing rapidly. For example, the number of observations made in January increased in 2012–17 from 2651 to 8444 and those made in June in 2012–15 from 3695 to 15 347 (but decreased to 8062 in 2016 when the new input module was implemented). In the current study we use observations from these two months as this enables the most direct comparisons with Common Wintering and Breeding Bird Monitoring programmes. As the probability for multiple observations is low in common species, and probably not changing significantly over the years, we did not account for it. To compensate for the increasing activity of birdwatchers, we use the proportion of observations of particular species from the total number of observations in particular year.

We used the software TRIM 3.53 (Pannekoek & Van Strien 2006) to estimate population trends from the monitoring schemes. To generate imputed population indices from annually counted numbers, we applied time series model where over-dispersion and serial correlation were accounted for. Common Breeding Bird Monitoring results from 2001 were missing and had to be excluded as potential change points in trend estimation. Significant changes in slope were identified by the linear model and stepwise elimination of change points with enter/removal significance level 0.05 using the Wald test. To estimate the significance of the trend in opportunistic observation data, we tested the significance of the slope of linear regression.

Results

Common Breeding Bird Monitoring detected steepest slopes in the three studied raptors (Table 2), but, due to the limited sample size and substantial variance among annual indices, all trends were classified as uncertain (Table 2, Figures 2 and 3(A)). In contrast, *Monitoring of Breeding Raptors* provided significant estimations of the trends for all three species. According to this scheme Goshawk was significantly declining 1994–2016 (Table 2) while European Sparrowhawk and Common Buzzard numbers were stable (Table 2, Figures 2–4(B)). More specifically, there was a steep (but still moderate) decline of the Goshawk (slope = –0.12 ± 0.02 (se), $P < 0.01$) between 1998 and 2004, while the population was stable before and after that. A similar tendency for Goshawk to decline after 1999 was suggested by *Common Breeding Bird Monitoring* (Figure 2(A)), although the total population trend was uncertain.

Based on visual patterns, *Common Wintering Bird Monitoring* suggested stable numbers for all three species (Figures 2–4(C)), but statistical analysis classified all trends as uncertain. A significant increase of Common Buzzard was detected in 2009, but the numbers decreased again the subsequent year (Figure 4 (C)). Large standard errors and the short study period of the *Monitoring of Wintering Raptors* hampered estimating a certain trend for Goshawk (Table 2, Figure 2(D)) and prevented any trend estimation for European Sparrowhawk (Table 2, Figure 3(D); no birds were recorded in 2014). However for the Common Buzzard, a steep decline was suggested (Table 2), which, given the short study period, only indicates significant between-year differences in winter abundance (Figure 3(D)).

Based on the opportunistic observations from *E-Biodiversity* in 2012–17, only the proportion of Goshawk ($b = -0.11$, $F_{1,4} = 20.6$, $P = 0.011$) and European Sparrowhawk ($b = -0.06$, $F_{1,4} = 8.9$, $P = 0.040$) observations made in January decreased significantly while all other trends were non-significant (Table 3).

Table 2. Mean (± sd) number of yearly observed individuals or pairs (MBR), mean (± sd) annual number of transects or plots with observations, additive slope (± sd) and trend class provided by TRIM for the three studied species according to *Common Breeding Bird Monitoring* (CBBM, 1994–2015), *Monitoring of Breeding Raptors* (MBR, 1994–2016), *Common Wintering Bird Monitoring* (CWBM, 1993/94 to 2015/16), and *Monitoring of Wintering Raptors* (MWR, 2014–17).

	Number of birds	Number of transects or plots	Slope	Trend
Goshawk – breeding				
CBBM	3.0 ± 3.9	1.6 ± 2.1	–0.26 ± 0.23	Uncertain
MBR	19.0 ± 4.6	13.5 ± 2.6	–0.04 ± 0.01	Moderate decline
Goshawk – wintering				
CWBM	2.3 ± 1.3	2.3 ± 1.4	0.01 ± 0.04	Uncertain
MWR	3.5 ± 1.7	3.0 ± 0.8	0.00 ± 0.34	Uncertain
European Sparrowhawk – breeding				
CBBM	2.3 ± 2.2	1.4 ± 1.3	–0.08 ± 0.10	Uncertain
MBR	46.2 ± 11.5	13.4 ± 2.5	0.00 ± 0.00	Stable
European Sparrowhawk – wintering				
CWBM	4.1 ± 2.6	3.7 ± 2.2	0.02 ± 0.03	Uncertain
MWR	3.3 ± 2.5	2.5 ± 1.7	NA	NA
Common Buzzard – breeding				
CBBM	13.6 ± 7.0	6.3 ± 3.1	0.03 ± 0.03	Uncertain
MBR	183.2 ± 36.4	13.6 ± 2.6	0.00 ± 0.00	Stable
Common Buzzard – wintering				
CWBM	3.2 ± 2.8	2.7 ± 2.3	0.00 ± 0.05	Uncertain
MWR	36.8 ± 12.6	15.3 ± 2.6	–0.24 ± 0.08	Steep decline

Discussion

In the current study we compared raptor trends provided by common bird monitoring and specialized raptor monitoring methods, as well as those generated from casual observations uploaded by citizen scientists. Although common and specialized monitoring methods showed visually similar population dynamics, only the special raptor monitoring detected significant estimations of trends. The inability of common bird monitoring methods to detect changes, or indicate stability, resulted mainly from small sample sizes, which lowered the power of analysis. This is due to the low breeding density of raptors, but, in the case of *Common Breeding Bird Monitoring*, also by methodological issues, because common birds (mostly passerines) are counted early in the morning, which is not an appropriate time for detecting raptors (Andersen 2007). In countries with numerous birdwatchers some of these deficiencies may be bridged, but in small countries with a limited number of transects the sufficient number of observations is usually not obtained. However, trends of no more than four raptor species are presented at the pan-European level by the PECBMS programme (European Bird Census Council 2016). PECBMS trends are calculated from national indices and thus may be affected by uncertainty and sometimes even bias of national indices with low sample size. Probably this effect is somewhat compensated for by the fact that such non-significant trends from several countries within a geographical region are aggregated and so trends might

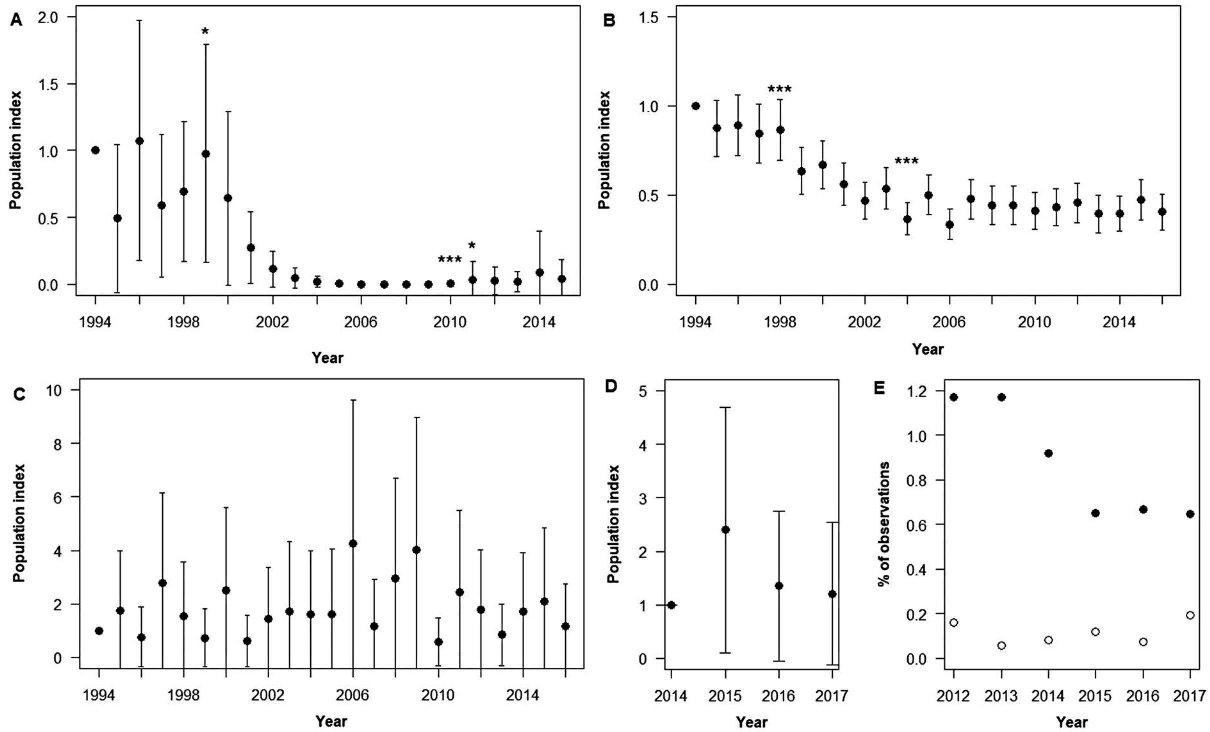

Figure 2. Population dynamics of the Goshawk according to *Common Breeding Bird Monitoring* (A), *Monitoring of Breeding Raptors* (B), *Common Wintering Bird Monitoring* (C), *Monitoring of Wintering Raptors* (D), casual observations from *E-Biodiversity* (E; observations made in January are presented as filled circles and those made in June as empty circles). In A–D, whiskers indicate standard errors. Significant changes in slope are indicated by asterisks (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; test results are presented in the text).

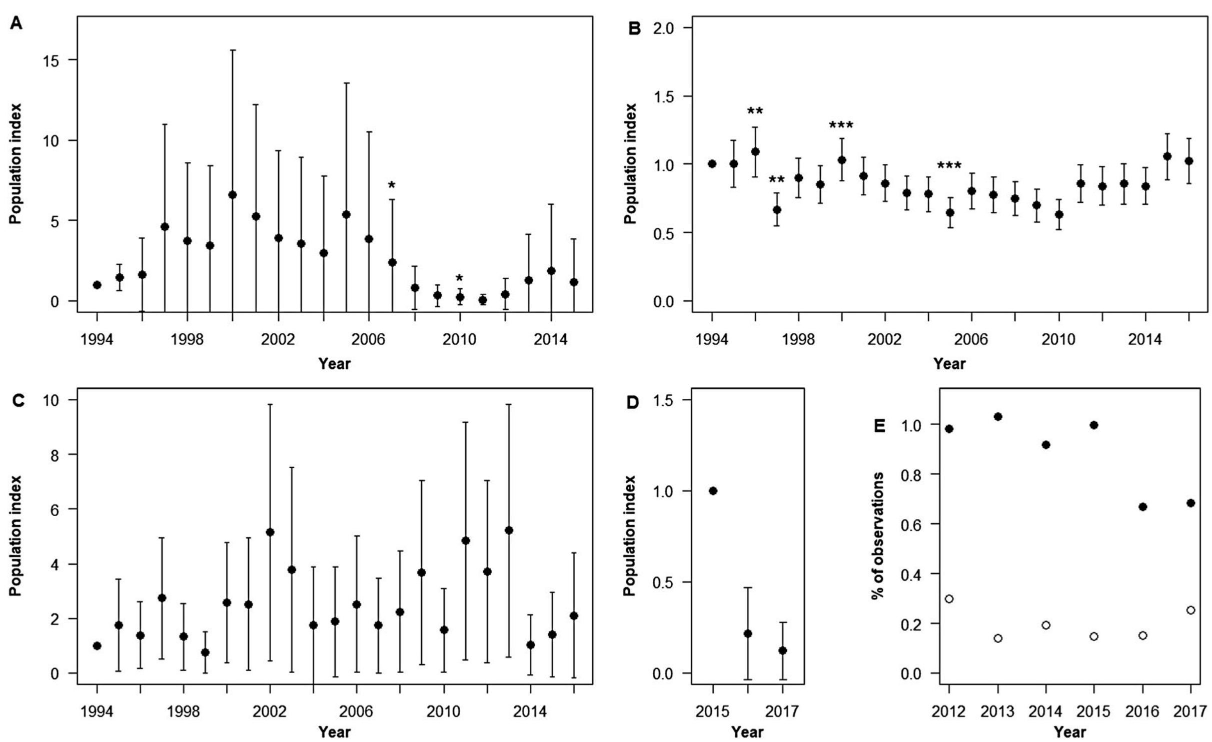

Figure 3. Population dynamics of the European Sparrowhawk according to *Common Breeding Bird Monitoring* (A), *Monitoring of Breeding Raptors* (B), *Common Wintering Bird Monitoring* (C), *Monitoring of Wintering Raptors* (D), casual observations from *E-Biodiversity* (E; observations made in January are presented as filled circles and those made in June as empty circles). In A–D, whiskers indicate standard errors. Significant changes in slope are indicated by asterisks (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

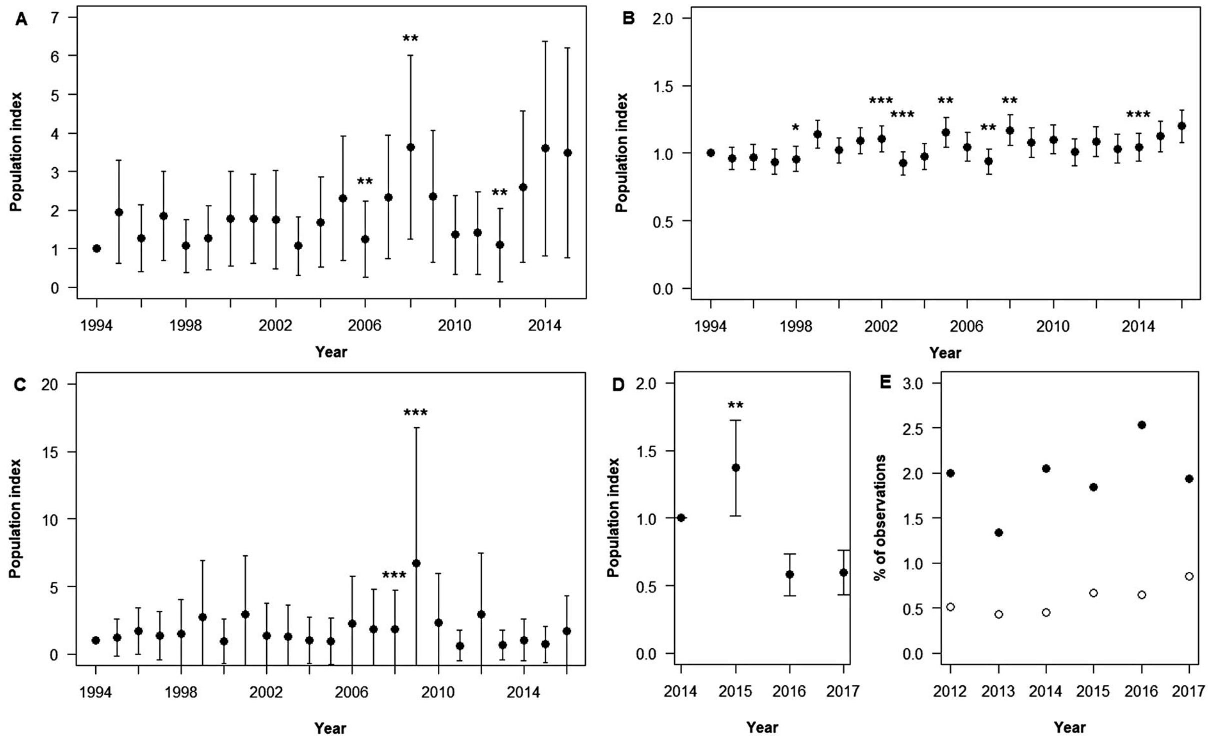

Figure 4. Population dynamics of the Common Buzzard according to *Common Breeding Bird Monitoring* (A), *Monitoring of Breeding Raptors* (B), *Common Wintering Bird Monitoring* (C), *Monitoring of Wintering Raptors* (D), casual observations from *E-Biodiversity* (E; observations made in January are presented as filled circles and those made in June as empty circles). In A–D, whiskers indicate standard errors. Significant changes in slope are indicated by asterisks (*P < 0.05, **P < 0.01, ***P < 0.001; test results are presented in the text).

Table 3. Mean (± sd) number of observed individuals, mean (± sd) proportion from all bird observations, slope, *F*-statistic and significance of the slope of linear regression according to the observations from *E-Biodiversity* in January (2012–17; total number of observations 5702 ± 2531 (sd)) and June (2012–16; 8171 ± 4739).

	Number of observations	% of all bird observations	Slope	F	*P*
Goshawk					
January	45.3 ± 9.9	0.9 ± 0.2	−0.11	20.6	0.010
June	13.2 ± 8.6	0.2 ± 0.0	−0.01	1.8	0.274
European Sparrowhawk					
January	48.8 ± 19.6	0.9 ± 0.1	−0.06	8.9	0.040
June	24.2 ± 10.3	0.3 ± 0.1	−0.02	0.7	0.453
Common Buzzard					
January	116.7 ± 63.0	2.0 ± 0.4	0.11	1.1	0.356
June	81.0 ± 53.7	1.0 ± 0.3	0.12	2.7	0.196

become detectable at larger scales. Additionally, an update of the TRIM software, which enables the combining of results obtained from the analysis of regions into a single new output with a combined trend, indices and standard errors (European Bird Census Council 2017), also helps to overcome the problems of uncertainty at a national level and increase the number of raptor species covered by the PECBMS programme.

It is very difficult to conclude much from the winter trends given the large differences in the time periods covered, and the fact that Monitoring of Wintering Raptors is conducted only on farmland. Moreover, for the Common Buzzard especially, winter populations are very different from breeding populations (Table 1, Väli & Vainu 2013, 2015) so they are unlikely to relate to each other in great extent. Our preliminary analysis of opportunistic data suggested significant trends for Goshawk and European Sparrowhawk in winter but the veracity is hard to estimate due to the lack of certain trends from *Common Wintering Bird Monitoring* and the too short study period of *Monitoring of Wintering Raptors*.

Opportunistic recording systems have provided valuable input for bird monitoring and conservation in recent years (McCaffrey 2005, Greenwood 2007, Wilson *et al.* 2013) and their role is likely to grow exponentially in the future (Sullivan *et al.* 2009). Even in a small country such as Estonia, high numbers of casual observations are now uploaded to online databases of bird records. Such databases are well known to contain biases (geographical, habitat, observer behaviour, etc.) that affect interpretation unless they are accounted for. Although there are statistical tools available to handle these errors, achieving the full potential of opportunistic recording systems is not easy (Bird *et al.* 2014, Isaac *et al.* 2014). In this study, effort is accounted for using the proportion of records per year, but observer behaviour can change and would better be accounted for using the proportion of inclusion of each species on complete lists from bird recording visits, if these were available. Nevertheless, the observation databases create a huge potential for monitoring raptors and other birds, which are hard to assess by common monitoring methods and whose special monitoring is time-consuming and costly.

We conclude that, at least currently, only special raptor monitoring programs are able to detect significant trends of raptors in a small country such as Estonia. In addition to the three common raptor species analysed here *Monitoring of Breeding Raptors* provides trends for 13 other raptor species in Estonia (Lõhmus 2004), beyond the capability of any common breeding bird monitoring programmes in Europe. *Monitoring of Wintering Raptors* also provides trends for several other Estonian species other than those included in the current study (Väli *et al.* 2014). However, the latter scheme is targeted on farmland species while forest-dwelling species remain poorly covered, as illustrated by the results for Goshawk and European Sparrowhawk in the current study.

The quality of special raptor monitoring has its price. Whereas there is no large difference in cost-effectiveness between a common and a special method for wintering raptors, mapping of breeding territories of raptors is very time-consuming. Given the different timing of breeding among raptor species and the requirement of several visits for adequate results, fieldwork on breeding raptors requires prolonged effort (Hardey *et al.* 2009). However, once conducted, mapping provides not only population trends, but also precise population densities that can be used to estimate population size, which in turn are needed for various conservation decisions and action plans (BirdLife International 2004, Burfield 2008). Moreover, reproductive performance can also be estimated and habitat selection analysed if additional effort is put on nest searching. In long-lived species such as most raptors, changes in reproductive success indicate pressures and threats earlier than abundance trends (Newton 1979). Knowledge of habitat selection is an essential prerequisite of successful conservation planning (Noss *et al.* 1997). Information on foraging habitat use is an additional benefit from special raptor monitoring programmes. This is particularly easy to record during winter when farmland birds of prey are often sedentary at their foraging sites. Finally, raptor monitoring at the same plots during winter and breeding seasons creates possibilities to analyse causal links between abundance across seasons (e.g. land use, carry-over effects, etc.). This further helps to identify factors affecting numbers and to develop proper methods for their conservation.

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