

Fifty-year dynamics in a temperate raptor assemblage

Eet Tuule^a, Aarne Tuule^a, and Asko Lõhmus^b✉

^a Sütiste tee 3–61, 13419 Tallinn, Estonia

^b Institute of Ecology and Earth Sciences, University of Tartu, Vanemuise 46, 51014 Tartu, Estonia

✉ Corresponding author, asko.lohmus@ut.ee

Received 21 December 2010, revised 21 February 2011, accepted 1 March 2011

Abstract. Raptorial birds are popular monitoring objects worldwide; however, published data on long-term dynamics of raptor assemblages are scarce. This paper summarizes 50-year (1961–2010) raptor surveys in relation to landscape change in a 60 km² area near Saue, North Estonia. Altogether, 11 species of diurnal raptors and 7 species of owls were found nesting. Their total density stayed remarkably stable throughout the study period, but both annual species richness and Shannon diversity decreased and the species composition showed significant long-term shifts. Most importantly, small-sized species decreased and medium-sized species increased, which suggests that the assemblage was shaped by interspecific relationships and, perhaps, delayed effects of historical raptor persecution. A period of low population levels in the 1980s was particularly pronounced for insect-eating species, which may be related to extensive pesticide use during that period. Unexpectedly, trends in the raptor assemblage could not be attributed to landscape changes – contrasting trends were observed for species having broadly similar habitat requirements and, therefore, no general patterns could be detected for any ecological group. We conclude that, at the assemblage level, raptors are not particularly sensitive indicators of landscape change in temperate Europe.

Key words: bird community, landscape change, monitoring, top predator, urbanization.

INTRODUCTION

Raptorial birds of the orders Accipitriformes, Falconiformes, and Strigiformes constitute a well-known charismatic functional group of terrestrial animals, which have been popular monitoring objects for decades (Newton, 1979; Kovács et al., 2008). Because most raptors are top predators, their abundance and performance can be used for screening biotic effects of environmental contaminants, landscape change and, perhaps, general level of biodiversity (Sergio et al., 2008). The group also includes many rare and threatened species that depend on adequate conservation action (Burfield, 2008). Yet, when designing avian indicators of land-use effects on bird communities (e.g. Angelstam et al., 2004; Gregory et al., 2005; Billeter et al., 2008), raptors are frequently excluded because their low abundance, large home-ranges, and use of land mosaics instead of distinct land-cover types present special challenges for fieldwork and analysis. Therefore, most

raptor monitoring has remained voluntary work of amateur ornithologists, which also means that long-term data on raptor assemblages are both invaluable and rare worldwide and even those results are seldom published in primary scientific literature. At the same time, long time-series are valuable because the longevity of individuals causes time lags and various cumulative effects in raptor population responses (Newton, 1979).

Apart from large-scale inventories on single rare species, the main general method of raptor monitoring in Europe has been a plot-based survey of nesting territories (Kovács et al., 2008; Saurola, 2008). In Estonia, such local raptor surveys have been integrated to a national monitoring programme since the late 1980s (Lõhmus, 1994), but earlier data are very scarce. The first local census results originate from short-term surveys in the 1960s (Randla, 1976), while the single published long-term census only started in 1978 (Lelov, 1991). Because of the lack of earlier data, long-term trends in Estonian raptor populations and their relationships with environmental change have been difficult to detect (note that perhaps the most abrupt re-organization of land use only took place in the early 1990s; Palang et al., 1998).

This paper summarizes a 50-year (1961–2010) raptor survey in the surroundings of Saue, North Estonia. This is the longest continuous time-series on nesting raptor assemblages in the Baltic States and remarkable in a global perspective as well. It covers a period after decades of heavy raptor persecution (see Randla, 1976; Lõhmus, 2011) and during land-use transitions from traditional to extensive agriculture and suburbanization. Compared with the earlier overviews of raptor abundance and nesting ecology in this area (Tuule et al., 2001, 2007), we have expanded the time period and focus on the assemblage characteristics rather than individual species. We check for trends in total density, diversity, and general species composition. We then compare the trends in species with similar habitat requirements to explore whether an assemblage change reflects landscape change. Thus, although lacking spatial replication, this study complements the chronosequence approaches where temporal changes in raptor habitats have been addressed by spatial analogues (e.g. Bosakowski & Smith, 1997; Berry et al., 1998; Sanchez-Zapata & Calvo, 1999).

MATERIAL AND METHODS

Study area and field methods

The study area covers 60 km² in Harju County, northern Estonia (59°18' N, 24°34' E; see Tuule et al., 2007, for a map). The terrain is flat (on average 22 m a.s.l.); it is intersected by the Vääna and Keila rivers. The mosaic landscape is dominated by forests and agricultural lands, but the land cover has significantly changed during the 50 years (Table 1). The main negative trend (see also Kana et al., 2008) has been an over 10-fold loss of meadows. Open seminatural meadows (notably on floodplains) were completely lost during the 20th century; they were

Table 1. Land cover of the study area during the survey: relative area of the main land-cover types (%; based on analyses of topographic maps) and their annual change

Land-cover type	Relative area, %				Annual change, % ^a
	1961	1996	2000	2010	
Settlements	1.5	4.6	5.9	9.6	+3.8
Open agricultural landscape	26.2	38.3	43.5	51.1	+1.4
Seminatural meadows	10.4	0.3	0.0	0.0	-9.4 ^b
Woodlands	62.0	56.9	50.7	39.3	-0.9
incl. forests	27.3	30.3	29.4	28.5	n.a.
young stands	3.2	3.3	3.1	7.1	n.a.
wooded meadows	31.5	23.4	18.2	3.7	-4.2

^a Relative change compared with the initial area; calculated as $A_2 = A_1 * (1+k/100)^t$, where k is the annual change, A_1 and A_2 are areas in 1961 and 2010, respectively, and t is the period length in years; n.a. – no continuous trend.

^b For the period 1961–1996.

mostly replaced by cultivated areas and often artificially drained. The generally slower loss of wooded meadows accelerated considerably only recently (Table 1) due to overgrowth after abandonment. Human density, area of settlements, related networks of power and communication lines, and traffic have all increased (particularly since the 1990s), which is largely related to the vicinity of Tallinn (the capital city). Only forest cover has been rather stable; it comprises coniferous (36–38% of the total forested area; mostly *Pinus sylvestris*), mixed (33–39%), and deciduous stands (25–29%) in rather equal proportions, sparse patches of *Picea abies* and of *Quercus robur*, and a few old manor parks.

Nesting territories (an area occupied by a pair over successive years; Steenhof, 1987) have been systematically sought and mapped in the area according to raptors' territorial behaviour, repeated observations, nests, or fledglings. E. T. carried out the fieldwork and interpretation of the observations throughout the study period, accompanied by A. T. since the mid-1990s. The field effort has been generally sufficient for such an area (over 200 hours annually; cf. Löhmus, 1999), and the field methods have remained the same throughout the study.

Data analysis

Inevitably for such a long-term census, annual efforts varied and this affected the numerical results. The total number of raptor nesting territories increased along with the annual number of working days spent on the surveys ($r = 0.42$, $n = 50$, $P = 0.002$). However, that relationship was mostly due to two extremes (the lowest-effort year 1987 and the highest-effort year 2002; Fig. 1). After eliminating those

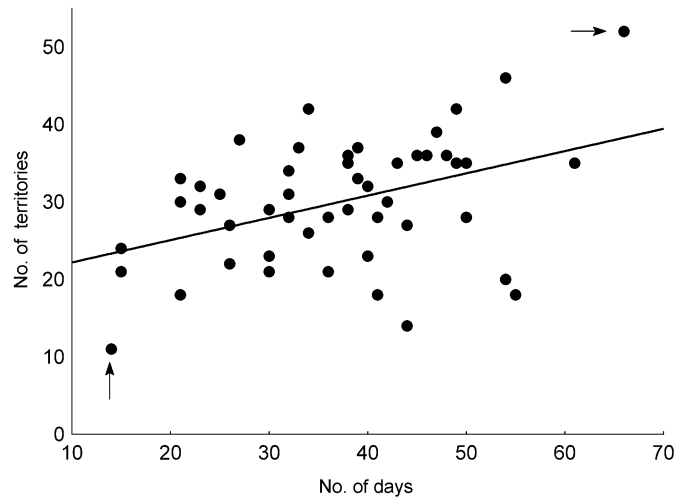


Fig. 1. Relationship between annual survey effort and the total number of raptor nesting territories detected. Two outliers (years 1987 and 2002), which were eliminated in some analyses, are indicated with arrows.

years, the relationship became merely suggestive ($r = 0.25$, $n = 50$, $P = 0.084$) and only explained 4% of the variation (cf. 16% in the case of the full set of years). Thus, we eliminated those two years from the analyses of population trends, and the year 1987 (the worst under-estimation) from the calculations of population densities.

For establishing trends, the census results were averaged by five-year periods to reduce the effects of random fluctuations and temporal pseudoreplication. Species diversity was calculated as Shannon index: $H' = -\sum(p_i \ln p_i)$, where p_i is the proportion of the i th species of the total number of raptor nesting territories. According to the frequency distributions observed, the trends of summary statistics (pooled densities of species, species richness, Shannon diversity) were analysed using Pearson correlation, while Spearman rank correlation was used for individual species. For analysing subsets of the assemblage, we distinguished two size categories (small-sized vs medium-sized or large species) and four main types of habitat use among the species (those primarily inhabiting rural, open, mosaic, or forested landscapes; Table 2). The types of habitat use were based on various sources but most notably the Estonian data on raptor foraging habitats by Lõhmus (2001).

To illustrate assemblage changes, we used non-metric multidimensional scaling with Sørensen distance as the measure of dissimilarity in PC-ORD 5 software (McCune & Mefford, 2006). The data matrix included five-year average abundances by species (all species included). The analyses were run for one- to three-dimensional solutions (90 runs with real and 100 with randomized data).

Table 2. Abundance of raptors nesting in the Saue study area, 1961–2010

Species ^a or variable	Nesting territories per 100 km ² land area and years										Mean ± std	Trend ^c
	1961–1965	1966–1970	1971–1975	1976–1980	1981–1985	1986–1990 ^b	1991–1995	1996–2000	2001–2005	2006–2010		
<i>Pernis apivorus</i> (F)	1.3	1.7	1.3	2.3	0.7	0.8	2.0	1.7	2.3	0.3	1.45±0.69	
<i>Circus aeruginosus</i> (O)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	0.23±0.63	
<i>C. cyaneus</i> (O)	2.3	2.0	1.3	0.7	1.0	1.3	1.3	1.0	2.0	1.0	1.39±0.54	
<i>C. pygargus</i> (O)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.7	0.3	0.20±0.36	0.75
<i>Accipiter gentilis</i> (F)	3.3	2.3	4.0	4.0	3.7	4.2	4.3	5.0	2.7	2.7	3.62±0.85	
<i>A. nisus</i> (f)	4.0	3.7	4.7	3.3	2.7	3.8	5.0	4.3	6.3	5.7	4.34±1.11	
<i>Buteo buteo</i> (M)	11.0	11.0	10.0	15.0	10.3	12.1	15.3	16.0	19.0	15.7	13.54±3.05	0.80*
<i>Aquila pomarina</i> (M)	1.0	1.0	1.0	1.3	0.3	1.3	1.0	1.7	0.7	1.7	1.09±0.41	
<i>Falco tinnunculus</i> (r)	13.3	10.0	6.3	7.0	3.0	0.4	1.3	4.0	5.0	5.3	5.58±3.89	
<i>F. columbarius</i> (m)	1.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30±0.55	-0.81*
<i>F. subbuteo</i> (m)	4.7	5.7	3.7	4.0	1.3	0.4	0.3	3.0	3.0	2.3	2.84±1.77	-0.65
<i>Bubo bubo</i> (F)	2.7	1.7	1.0	1.3	1.3	0.4	1.0	0.3	0.0	0.0	0.98±0.83	-0.92*
<i>Glaucidium passerinum</i> (f)	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.04±0.13	
<i>Strix aluco</i> (R)	4.3	3.7	4.3	7.7	6.3	5.8	5.3	5.7	3.7	0.7	4.75±1.91	
<i>S. uralensis</i> (F)	1.0	1.7	1.3	2.3	4.0	3.3	3.7	4.3	4.7	4.3	3.07±1.37	0.93*
<i>Asio otus</i> (R)	2.7	3.7	3.0	6.3	5.7	3.3	4.7	5.3	10.3	9.7	5.47±2.68	0.75
<i>A. flammeus</i> (O)	0.7	1.0	1.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.33±0.42	-0.63
<i>Aegolius funereus</i> (f)	0.7	2.0	1.0	2.0	1.3	2.1	1.0	0.7	1.0	0.0	1.18±0.68	
Total, all species	54.7	51.7	44.7	57.3	42.0	39.6	46.3	54.0	62.0	51.7	50.39±7.10	
incl. rural species	20.3	17.3	13.7	21.0	15.0	9.6	11.3	15.0	19.0	15.7	15.79±3.72	
open-land species	3.0	3.0	2.3	0.7	1.3	1.3	1.3	2.0	3.3	3.3	2.16±0.98	
land-mosaic species	18.3	18.3	15.3	20.3	12.0	13.8	16.7	20.7	22.7	19.7	17.78±3.33	
forest species	13.0	13.0	13.3	15.3	13.7	15.0	17.0	16.3	17.0	13.0	14.67±1.68	
Total, small species	24.3	22.0	16.3	16.3	8.3	7.1	7.7	12.0	15.3	13.3	14.28±5.84	-0.65
Total, medium-sized species	30.3	29.7	28.3	41.0	33.7	32.5	38.7	42.0	46.7	38.3	36.12±6.11	0.75
% small species	45	43	37	28	20	18	17	22	25	26	27.9±10.0	-0.79*
Annual species richness	12.40	12.60	11.40	11.80	10.00	10.00	10.00	11.20	11.20	10.20	11.08±1.00	-0.72
Diversity (Shannon index)	2.32	2.39	2.39	2.26	2.26	2.17	2.13	2.25	2.20	2.09	2.25±0.10	-0.83*

^a Typical habitat in brackets: O – open land; R – rural areas near human habitation; M – mosaics of agricultural land and forest; F – forest. The letters are in lowercase for species considered 'small'.

^b The lowest-effort year (1987) has been omitted.

^c Correlation coefficients based on the means of the 10 periods (Pearson correlation for summary statistics; Spearman rank correlation for individual species); only significant coefficients ($P < 0.05$) are shown, * $P < 0.01$. Years 1987 and 2002 have been omitted (cf. Fig. 1).

Stress reduction was determined after 200 iterations using Monte Carlo tests. The final two-dimensional stress value was acceptable (4.9; $P = 0.02$).

RESULTS

Altogether, 11 species of diurnal raptors and 7 species of owls were found nesting over the 50-year period (Table 2). While the total density stayed remarkably stable, the annual species richness decreased from about 12 to 10 species, and an even more pronounced decrease was found for species diversity (Shannon index; Table 2).

Ordination analysis confirmed the existence of a pronounced long-term trend in species composition (Axis 1 in Fig. 2); additionally, distinct communities were recorded in the 1980s and early 1990s (positive values of Axis 2 in Fig. 2). The main contributors to Axis 1 (cf. with the trends in Table 2) were the three species that disappeared (*Falco columbarius*, *Bubo bubo*, *Asio flammeus*; $r > 0.7$ for each) and the common species that increased (*Strix uralensis*: $r = -0.91$; *Asio otus*: $r = -0.86$; *Buteo buteo*: $r = -0.81$). *Falco tinnunculus* and *F. subbuteo* contributed both to Axis 1 ($r = 0.64$ and $r = 0.58$, respectively, indicating decrease) and Axis 2 ($r = -0.78$ and $r = -0.80$, respectively; indicating dramatic decreases during the 1980s). In turn, *Accipiter gentilis* and *Strix aluco* had their highest abundance in the middle of the study period, as indicated by positive correlations with Axis 2 ($r = 0.61$ and $r = 0.58$, respectively).

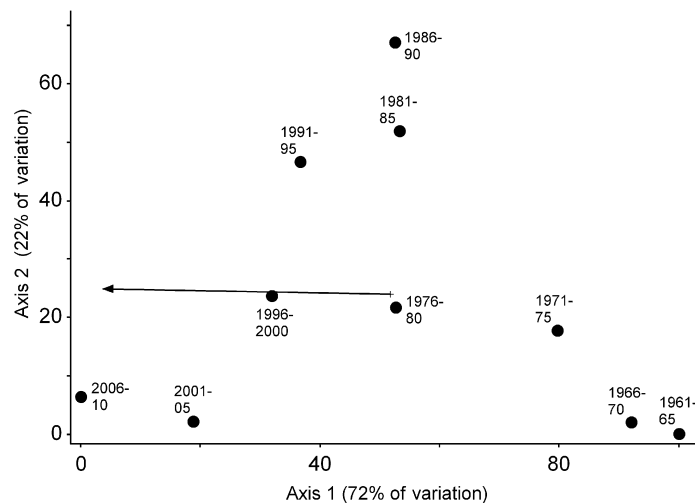


Fig. 2. Ordination graph of the nesting raptor assemblage near Saue during 10 five-year periods, 1961–2010. Non-metric multidimensional scaling has been used; the axis values represent % of maximum; the arrow indicates the correlation with year ($r = -0.98$ with Axis 1). Years 1987 and 2002 have been omitted (cf. Fig. 1).

These otherwise clear trends were not consistent among species with broadly similar habitat requirements and therefore were not significant for such ecological groups (Table 2). For example, the typical rural species *F. tinnunculus*, *S. aluco*, and *A. otus* had very contrasting trends. At the same time, there was a striking difference between the generally decreasing trends of small-sized species and the increasing trends of medium-sized species, which was particularly clear when expressed as a decrease in the share of small-sized species in the assemblage (Table 2).

DISCUSSION

This study highlighted long-term shifts in the composition of a raptor assemblage at the landscape scale. Those shifts took place at a stable total density, which indicates that the general abundance of nesting raptors is not a suitable measure for detecting assemblage change. A stable density as such is, however, also interesting for two reasons. First, it complements the well-known fact that nesting populations of particular raptor species are rather stable, which can be attributed to the long life-spans of individuals and the buffering effect of the typically large and less stable population of non-territorial ‘floaters’ (Newton, 1998). Given that analogue, a stable total density might indicate that raptor assemblages are partly regulated by interspecific interactions (including the participation of ‘floaters’ of many species), which are ultimately related to the supply of food and nest sites.

A role of species interactions was further indicated by the general trend that small-sized species decreased and medium-sized species increased in the study area. Habitat change is unlikely to cause such trend: the expansion of agricultural lands and urbanization of the area can be expected to reduce the food supply of large rather than small raptors (e.g. Pavez et al., 2010). Instead, the most plausible explanation appears to be that increasing populations of more aggressive medium-sized species have been affecting smaller species by predation risk (Sergio & Hiraldo, 2008). High raptor densities may have contributed to the importance of such interactions: for example, in the early 2000s, there were on average 62 nesting territories per 100 km² in this study area, compared to the average 41 nesting territories in Estonia (Lõhmus, 2004). Predator avoidance has been suspected as a general factor in structuring also the adjacent South-Finnish raptor assemblages (Solonen, 1993). It is more difficult to explain the increase in larger-bodied species, but that may be a combination of a delayed effect of historical persecution (Bijleveld, 1974) and the loss of top intraguild predators (notably *Bubo bubo*) from this urbanizing area.

The distinct period of raptor species composition in the 1980s and early 1990s showed two interesting features: it reversed (Fig. 2), and it comprised low population levels of a few species. Notably, low numbers were observed in three partly (*F. subbuteo*, *F. tinnunculus*) or mostly (*Pernis apivorus*) insect-eating species (Table 2). Thus, this period may stand out for an intensive use of chemicals

(notably insecticides) in agriculture, which culminated in the 1980s in Estonia and decreased dramatically in the early 1990s for socioeconomic reasons (Müür, 1996; Oras, 2005), while raptor populations responded to those changes with a delay. This hypothesis corresponds both to a general understanding of bird-community sensitivity to chemical use in agricultural lands (Billeter et al., 2008) and the observations of rapid temporal change in the use of such lands by raptors after changed agricultural intensity (e.g. Laussmann & Plachter, 1998). Alternatively (or additionally), adverse conditions on migration routes or in wintering areas may have played a role, because *P. apivorus* and *F. subbuteo* were also the longest-distance migrants in this assemblage. However, we also acknowledge that, due to the small size of the study area, territory shifts of individual pairs at the borders of the study area may introduce random noise to the data set. In long-lived species, such as *P. apivorus*, such effects can be prolonged and, thus, this particular evidence of reversed 'decline' requires confirmation from other study areas.

Unexpectedly, no general trends in the raptor assemblage could be directly attributed to landscape change – the dynamics among species having broadly similar habitat requirements were inconsistent and, therefore, did not translate to a significant general trend for any ecological group. This concurs with the results of raptor trend analyses in Scotland (Thompson et al., 2003) and in another Estonian study area (Lõhmus, 2001). We therefore conclude that, at the assemblage level, raptors are relatively resilient to landscape change in temperate Europe. We acknowledge that the situation may differ regionally and may depend on raptor species or the particular landscape change under question (e.g. Mulsow, 1980; Child et al., 2009). For example, urban areas in general are often of superior quality to raptors (Chace & Walsh, 2006); yet, Berry et al. (1998) found a critical landscape threshold at about 5–7% urbanization for sensitive grassland species. Such level has been only recently reached in the Saue area and one should also not forget the slow, but consistent, general decline in the raptor diversity observed (see Pavez et al., 2010, for similar effects of an advanced urbanization process). However, we recommend that, if raptor-based indicators of landscape change are used, these should be explicitly justified and better based on particular species rather than assemblages (see also Sergio et al., 2008). Also, one should remain cautious when translating the results from chronosequence studies on raptors to temporal predictions.

ACKNOWLEDGEMENTS

We thank Aivar Leito and Tapio Solonen for commenting on the manuscript. Since 1997, the fieldwork has been supported by the State Environmental Monitoring Scheme through the Estonian Ornithological Society. While compiling the study, A. L. was supported by the Estonian Science Foundation (grant 7402), the Estonian Ministry of Education and Research (target-funding project 0180012s09), and the European Regional Development Fund (Centre of Excellence FIBIR).

REFERENCES

- Angelstam, P., Roberge, J.-M., Löhmus, A., Bergmanis, M., Brazaitis, G., Dönz-Breuss, M., Edenius, L., Kosinski, Z., Kurlavičius, P., Larmanis, V., Lukins, M., Mikusinski, G., Račinskis, E., Stradz, M. & Tryjanowski, P. 2004. Habitat modelling as a tool for landscape-scale conservation – a review of parameters for focal forest birds. *Ecol. Bull.*, **51**, 427–453.
- Berry, M. E., Bock, C. E. & Haire, S. L. 1998. Abundance of diurnal raptors on open space grasslands in an urbanized landscape. *Condor*, **100**, 601–608.
- Bijleveld, M. 1974. *Birds of Prey in Europe*. MacMillan Press.
- Billetter, R., Liira, J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R., Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekötter, T., Dietz, H., Dirksen, J., Dormann, C., Durka, W., Frenzel, M., Hamersky, R., Hendrickx, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D., Maelfait, J. P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O., Smulders, M. J. M., Speelmans, M., Simova, P., Verboom, J., van Wingerden, W. K. R. E., Zobel, M. & Edwards, P. J. 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. *J. Appl. Ecol.*, **45**, 141–150.
- Bosakowski, T. & Smith, D. G. 1997. Distribution and species richness of a forest raptor community in relation to urbanization. *J. Raptor Res.*, **31**, 26–33.
- Burfield, I. J. 2008. The conservation status and trends of raptors and owls in Europe. *Ambio*, **37**, 401–407.
- Chace, J. F. & Walsh, J. J. 2006. Urban effects on native avifauna: a review. *Landscape Urban Plan.*, **74**, 46–69.
- Child, M. F., Cumming, G. S. & Amano, T. 2009. Assessing the broad-scale impact of agriculturally transformed and protected area landscapes on avian taxonomic and functional richness. *Biol. Conserv.*, **142**, 2593–2601.
- Gregory, R. D., Van Strien, A., Vorisek, P., Meyling, A. W. G., Noble, D. G., Foppen, R. P. B. & Gibbons, D. W. 2005. Developing indicators for European birds. *Philos. T. Roy. Soc. B*, **360**, 269–288.
- Kana, S., Kull, T. & Otsus, M. 2008. Change in agriculturally used land and related habitat loss: a case study in eastern Estonia over 50 years. *Est. J. Ecol.*, **57**, 119–132.
- Kovács, A., Mammen, U. C. C. & Wernham, C. V. 2008. European monitoring for raptors and owls: state of the art and future needs. *Ambio*, **37**, 408–412.
- Laussmann, H. & Plachter, H. 1998. Der Einfluß der Umstrukturierung eines Landwirtschaftsbetriebes auf die Vogelfauna: Ein Fallbeispiel aus Süddeutschland. *Vogelwelt*, **119**, 7–19.
- Lelov, E. 1991. Breeding raptors and owls at Halinga, SW Estonia, in 1978–1989. *Ornis Fenn.*, **68**, 119–122.
- Löhmus, A. 1994. Kulliliste ja kakuliste seire tänapäev Eestis [Monitoring of raptors and owls in Estonia]. *Hirundo*, **2/1994**, 31–45 (in Estonian with English summary).
- Löhmus, A. 1999. Röövlinnuprojekt aastail 1994–1998 [Monitoring of raptors and owls in Estonia, 1994–1998]. *Hirundo*, **12**, 19–35 (in Estonian with English summary).
- Löhmus, A. 2001. Toitumisbiotoobi valikust Loode-Tartumaa röövlindudel [Selection of foraging habitats by birds of prey in north-western Tartumaa]. *Hirundo*, **14**, 27–42 (in Estonian with English summary).
- Löhmus, A. 2004. Röövlinnuseire 1999–2003: kanakulli kadu ja hiiretsükli kellaäär [Monitoring of raptors and owls in Estonia, 1999–2003: decline of the Goshawk and the clockwork of vole-cycles]. *Hirundo*, **17**, 3–18 (in Estonian with English summary).
- Löhmus, A. 2011. Three-year periodicity in historical raptor-persecution data: an indication of vole cycles? *Est. J. Ecol.*, **60**, 155–164.
- McCune, B. & Mefford, M. J. 2006. *PC-ORD. Multivariate Analysis of Ecological Data. Version 5.10*. MjM Software, Gleneden Beach, Oregon.
- Mulsow, R. 1980. Untersuchungen zur Rolle der Vögel als Bioindikatoren – am Beispiel ausgewählter Vogelgemeinschaften im Raum Hamburg. *Hamb. Avifaun. Beitr.*, **17**.

- Müür, J. 1996. Taimekaitsevahendite kasutamine Eestis [Use of pesticides in Estonia]. In *Keskkond 1995* (Meikas, E., ed.), pp. 66–68. Information and Technology Center of Ministry of the Environment, Tallinn (in Estonian).
- Newton, I. 1979. *Population Ecology of Raptors*. Poyser, Berkhamsted.
- Newton, I. 1998. *Population Limitation in Birds*. Academic Press, London.
- Oras, K. (ed.) 2005. *Environment 2004*. Statistical Office of Estonia, Tallinn.
- Palang, H., Mander, Ü. & Luud, A. 1998. Landscape diversity changes in Estonia. *Landscape Urban Plan.*, **41**, 163–169.
- Pavez, E. F., Lobos, G. A. & Jaksic, F. M. 2010. Cambios de largo plazo en el paisaje y los ensambles de micromamíferos y rapaces en Chile central. *Rev. Chil. Hist. Nat.*, **83**, 99–111.
- Randla, T. 1976. *Eesti röövlinnud* [Estonian Birds of Prey]. Valgus, Tallinn (in Estonian with English summary).
- Sanchez-Zapata, J. A. & Calvo, J. F. 1999. Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats. *J. Appl. Ecol.*, **36**, 254–262.
- Saurola, P. 2008. Monitoring birds of prey in Finland: a summary of methods, trends, and statistical power. *Ambio*, **37**, 413–419.
- Sergio, F. & Hiraldo, F. 2008. Intraguild predation in raptor assemblages: a review. *Ibis*, **150** (Suppl. 1), 132–145.
- Sergio, F., Caro, T., Brown, D., Clucas, B., Hunter, J., Ketchum, J., McHugh, K. & Hiraldo, F. 2008. Top predators as conservation tools: ecological rationale, assumptions and efficacy. *Annu. Rev. Ecol. Evol. Syst.*, **39**, 1–19.
- Solonen, T. 1993. Spacing of birds of prey in southern Finland. *Ornis Fenn.*, **70**, 129–143.
- Steenhof, K. 1987. Assessing raptor reproductive success and productivity. In *Raptor Management Techniques Manual* (Pendleton, B. A. G., Millsap, B. A., Cline, K. W. & Bird, D. M., eds), pp. 157–170. Natl. Wildl. Fed., Washington, D.C.
- Thompson, D. B. A., Shaw, P., Riley, H. T., Shewry, M. C., Mackey, E. C., Robertson, P. & Morton, K. 2003. An overview of land use change and implications for raptors. In *Birds of Prey in a Changing Environment* (Thompson, D. B. A., Redpath, S. M., Fielding, A. H., Marquiss, M. & Galbraith, C. A., eds), pp. 307–321. Scottish Natural Heritage, Edinburgh.
- Tuule, E., Tuule, A. & Lõhmus, A. 2001. Röövlindude arvukusest Saue ümbruses 1961.–2000. a. [Numbers of raptors and owls in the surroundings of Saue, 1961–2000]. *Hirundo*, **14**, 97–108 (in Estonian with English summary).
- Tuule, E., Tuule, A. & Lõhmus, A. 2007. Röövlindude pesitsusökoloogiast Saue ümbruses 1959.–2006. a. [Nesting ecology of birds of prey and owls near Saue during 1959–2006]. *Hirundo*, **20**, 14–36 (in Estonian with English summary).

Röövlinnukoosluse dünaamika Saue viiekümne aasta jooksul

Eet Tuule, Aarne Tuule ja Asko Lõhmus

Röövlindude seire on populaarne kogu maailmas, ent röövlinnukoosluste pikaajalise muutumise kohta on andmeid vähe. Uurimuses on kokku võetud 50 aasta (1961–2010) loendustulemused 60 km² suuruselt alalt Põhja-Eestis Saue ümbruses. Kokku leiti pesitsemas 11 liiki kullilisi ja 7 liiki kakulisi. Nende üldasustustihedus püsis kogu uurimisperioodi jooksul enam-vähem stabiilne, samas kui koosluse liigirikkus ja mitmekesisus (Shannoni indeks) vähenesid ning liigilises koosseisus toimus kindlasuunaline muutus. Silmatorkav oli väikeste röövlindude

vähenevamine samaaegselt suuremate liikide arvukuse suurenemisega, mis viitab liikidevaheliste suhete olulisusele koosluse kujunemisel ja tõenäoliselt ka röövlindude ajalooliste tapmiskampaaniate pikaajalisele järelmõjule. 1980. aastatel täheleandati röövlindude suhteliselt väikest arvukust, mis avaldus eriti putukatoidulistel liikidel ja võis seega põhjustatud olla pestitsiidide ulatuslikust kasutamisest tol perioodil. Vastupidiselt eeldatule ei leitud üheseid seoseid röövlinnukoosluse muutumise ja maastiku muutumise vahel – sarnase elupaiganõudlusega liikide arvukuse muutused erinesid ega väljendunud ökoloogiliste rühmade üldtrendidena. Sellest järeldati, et vähemalt koosluse tasemel ei ole röövlinnud kuigi tundlikud maastiku muutuste indikaatorid.