Annual captures, apparent survival and sex ratios in Eurasian Nuthatch (*Sitta europae*a Linnaeus, 1758) in western Hungary

Ročné odchyty, zdanlivá miera prežívania a pomer pohlaví u brhlíka lesného (Sitta europaea *Linnaeus, 1758*) *v západnom Maďarsku*

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Abstract. *Individual survival are important factors affecting the population dynamics of small passerines. Understanding variation in the population dynamics and survival rates is critical for ecological studies and nature conservation. The aim of this study was to investigate the annual capture-recapture, apparent survival, capture probability and sex ratio of the Eurasian Nuthatch* (Sitta europaea *Linnaeus, 1758*) *occurring in western Hungary. Data from 184 juveniles, 66 adults and 239 individuals of unknown age came from a constant-effort ringing scheme, using three ringing periods, spanning 29 years. The annual captures did not show a significant linear trend from 1998 to 2025 and the sex ratio was nearly balanced in the study site for the species, which indicated high habitat quality and a local population that was stable in both abundance and structure. According to the Cormack-Jolly-Seber model, apparent survival and capture probability were age-, sex and year dependent, but the very high mean apparent survival rates and low capture probabilities of the age and gender groups were not significantly different. The apparent survival rate of males showed a significant positive linear trend, while those of females, adults and juveniles showed no significant positive linear trend during 1998-2025. Overall, the Eurasian Nuthatch population tend to remain relatively balanced under stable ecological conditions.*

Key words: *demography, population dynamics, capture-recapture, Cormack-Jolly-Seber model, Tömörd Bird Ringing Station*

Introduction

Many European passerine populations are currently declining rapidly, whereas others are increasing and expanding their range (del Hoyo et al. 2020, BirdLife International 2026). To understand the causes of population increases and declines, detailed demographic data must be collected. In bird populations, survival and dispersal (Thibault & Jenouvrier 2006, Both et al. 2012, Mátrai et al. 2012) are often regarded as among the most important population traits underlying demographic mechanisms (Jankowiak et al. 2016).

Studies that examine both daily survival rates and capture probabilities of small passerines generally rely on in-hand identification of individuals, that is, the capture and recapture of

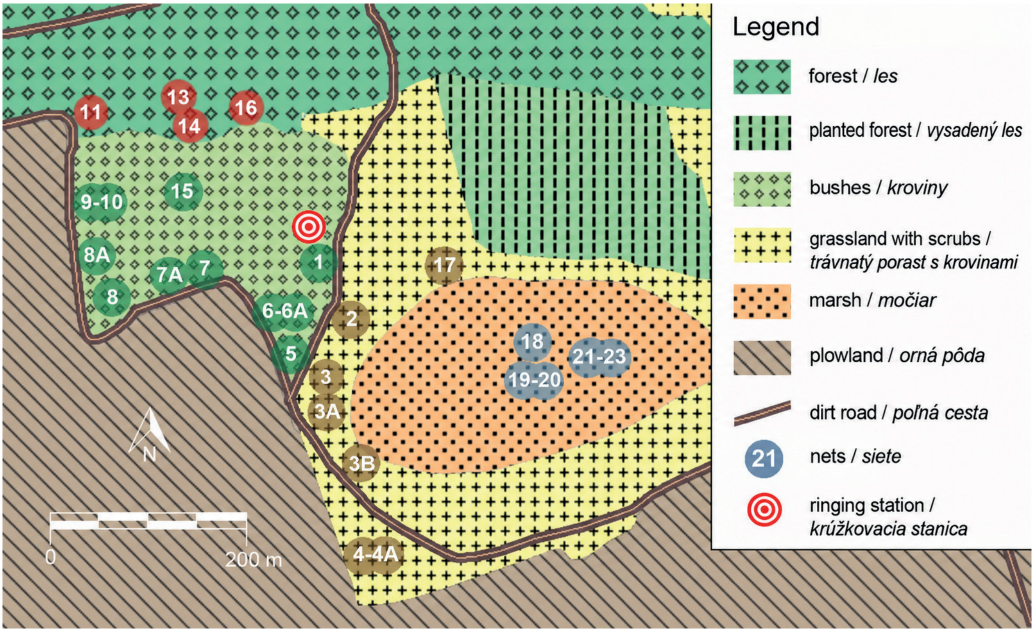

Fig. 1. Habitat map of the study area with locations of mist-nets at Tömörd, W Hungary
Obr. 1. *Mapa biotopov študijnej lokality s umiestnením ornitologických sietí v Tömörde, západné Maďarsko.*

ringed birds using mist nets (Silkey et al. 1999). These methods appear to constitute efficient and effective tools for collecting critical data on demographic parameters such as survival (Nur et al. 2004). In this study, we analysed capture–recapture data from a Eurasian Nuthatch (*Sitta europaea Linnaeus*, 1758) population in western Hungary. The number of captured adult and juvenile females and males provides a reliable proxy for local population size, age and sex ratios (De Feu & McMeeking 2004, Robinson et al. 2009).

The Eurasian Nuthatch is a cavity-nesting, resident passerine species that feeds on invertebrates when available; during winter, it relies primarily on seeds and nuts. Egg incubation is performed exclusively by the female, which also constructs the nest; juveniles typically settle at greater distances from the nesting site than adults (Török 2009, del Hoyo 2013, Haraszthy 2019). The Eurasian Nuthatches exhibit strong territorial behaviour and high site fidelity between successive years (Krištín et al. 2001, Matthysen 2005, Török 2009). Consequently, standardized capture of ringed individuals can be an effective approach for estimating age- and sex-specific apparent survival, defined as the probability that an individual survives and remains within the study area. However, accurate modelling of survival is subject to uncertainty, as capture probability may vary among individuals (Robinson et al. 2009).

Population monitoring and survival studies have predominantly been conducted during the breeding season (Thibault & Jenouvrier 2006, Horak & Lebreton 2008, Bastianelli et al. 2021), despite dispersion and wintering constituting the most hazardous phase of the avian life cycle (Newton 2007). Incorporating individuals captured during pre- and post-breeding periods into survival estimates is therefore also necessary to achieve a more comprehensive understanding of the constraints shaping populations across the annual cycle (Salewski et al. 2013, Ward et al. 2018). We aimed to obtain information about the local population dynamics and estimate to apparent survival and capture probability for individuals ringed as juveniles or adults, taking into account that, in other ringing studies, first-year birds show substantially lower recapture rates in subsequent years than adults (Peach & Bailie 2004, Kiss et al. 2020). First, we predicted that the age and sex groups have similar annual capture-recapture changes due to their similar territoriality and foraging strategies. Secondly, we predicted that juveniles would have lower apparent survival rates and capture probability than the adults, based on their lower dominance ranking status. Finally, based on different gender strategies in mating systems, parental care and dispersal, we predicted sex differences in apparent survival and capture probability. We expect males to have higher apparent survival and capture probabilities than females, owing to the greater dispersal tendency of females or increased female mortality during breeding due to energetic costs.

Material and Methods

Study area and data collection

The study was carried out at the Tömörd Bird Ringing Station in western Hungary (47°21'N 16°40'E, elevation 240 metres) and represents the SE European migration network (SEEN, Busse & Meissner 2015). The study site has a typical continental climate with cold winters and warm summers. The study area has a mean annual temperature ranging from 8.8 to 9.6 °C and a mean annual precipitation of approximately 650 mm. There are four habitat types around the station of Tömörd where the mist-nets were set up (Fig. 1): 1) Bushes: shrubs and herbs make up compact, dense vegetation, which is dissected by small grass patches. Its characteristic plant is the blackthorn (*Prunus spinosa*). 2) Forest: broadleaf trees and bushes form a compact, dense edge, forming an ecotone community with the Turkey oak (*Quercus cerris*) as the characteristic plant. These forests are characterized with regular felling and other forestry activities. Most of the trees in the forest are approximately 80 years old. 3) Grassland with shrubs: this habitat type represents a transition between the wet habitats of the swamp and the steppe communities that used to cover the agricultural land around the marsh. There

Fig. 2. Mist-nets in the bushes (a) in the forest (b), in the grassland with scrubs habitat (c) and in the marsh (d).
Obr 2. *Ornitologické siete umiestnené v krovinách (a), v lesnom poraste (b), v trávnatom poraste s rozptýlenými krovinami (c) a v mokradi (d).*

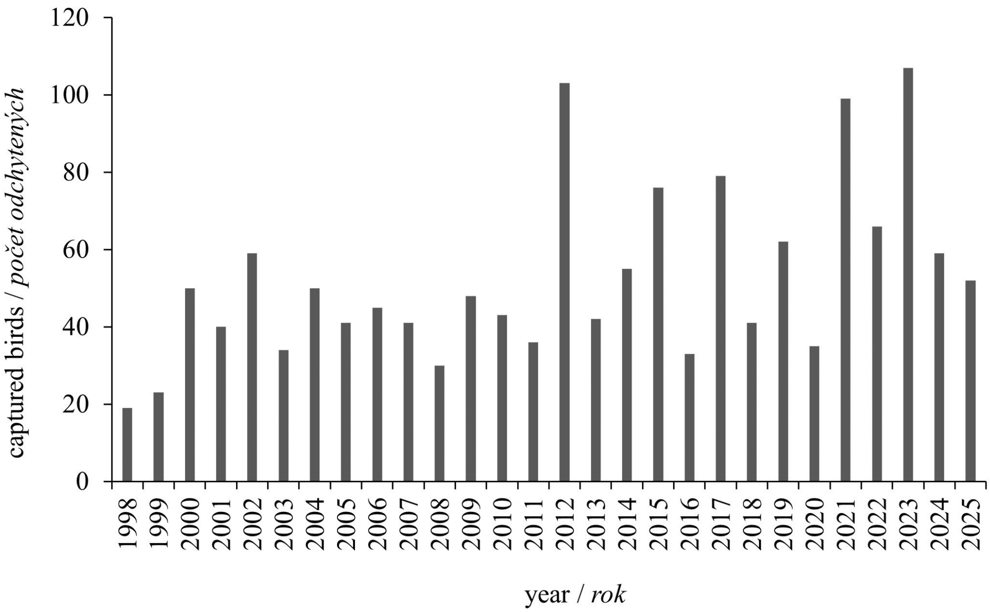

Fig. 3. Total annual captures of the Eurasian Nuthatches at Tömörd, W Hungary during 1998–2025.
Obr. 3. *Celkový ročný počet odchytov brhlíka lesného v lokalite Tömörd, západné Maďarsko, v rokoch 1998 – 2025.*

are a few bushes in the grassland, with two small patches of the dwarf elder (*Sambucus ebulus*). The grassland is not managed. 4) Marsh: a small (6 ha), permanent, and isolated wetland. The characteristic plant is the reedmace (*Typha latifolia*) (Fig. 2).

Bird ringing for this study took place during the spring migration (an Actio Hungarica programme from the last weekend of March to the first weekend of April), the breeding (a Constant Effort Site programme, one sampling day was scheduled within each 10-day interval between 15 April and 15 July) and post-fledging (also an Actio Hungarica programme from the first weekend August to the first weekend November) periods between 1998 and 2025. We used 23 (spring), 13 (breeding) and 28 (autumn), individually numbered Ecotone mist-nets (12 metres long and 2.5 metres high, with 5 shelves and a mesh size of 16 mm) for trapping. Ringing sessions lasted from sunrise to noon (CES) or dusk, except on rainy and stormy days when the nets were closed; numbers, locations, types, and lengths of mist nets were held constant (Gyurácz et al. 2017). No tape-luring was used during bird capture. All birds were ringed, sexed and aged according to Svensson (1992). Flattened maximum wing length and 3rd primary were measured to the nearest millimeter using a graded wing ruler, and birds were weighed to the nearest 0.1 g using a digital balance. Fat and pectoral muscle scores were estimated visually according to the SE European Bird migration network protocol (Busse & Meissner 2015). First-year birds that hatched in the year of ringing were defined as juveniles, while all older birds were defined as adults.

Apparent survival and capture analysis

Due to the lack of dispersion data, we could not distinguish between mortality and emigration. Consequently, we used the apparent survival, which underestimated the true survival (Schaub & Royle 2013).

The survival probabilities of passerines at a particular site are frequently analysed by using capture-recapture models: the Cormack-Jolly-Seber (CJS) formula is used most often (Lebreton et al. 1992, Naef-Daenzer et al. 2001, Williams et al. 2002, Greńo et al. 2008, Jones et al. 2021). In the CJS model, the probability of encounter (p) is explicitly modelled in order to correct possible biases in survival estimates (Jankowiak et al. 2016). In this study, analysis of bird survival and capture probabilities were based on capture-recapture, using the standard CJS model (Barker 1999). The analyses were performed using MARK software v. 11.2 (White & Burnham 1999). We ran 64 models to test for the effect of age, sex and time (year of capture) on survival estimates and capture probability.

The CJS model enables the calculation of apparent survival φ(i) (the probability that an individual survives from year i to year i + 1 and returns to the sampling area) and the probability of encounter p(i) (the probability that an animal in the sampling area at time i is encountered at time i). Differences between age and sex groups were considered significant if there were no overlaps between the 95% CI values of p and φ in each group.

Goodness-of-fit (GOF) test performed in UCARE (Choquet et al. 2009). Model adjustments for less-than-optimal fit were performed by changing the ĉ value (ĉ: variance inflation factor used to estimate and correct for overdispersion. It was calculated based on the result of the GOF bootstrapping test in RMARK v. 3.0.0; 100 randomization cycles). For the CJS model, model selection was performed using the information-theory approach. The Akaike Information Criterion, corrected for small sample size (QAICc), was used to rank the fit of models to the data. The model with the lowest QAICc was considered to be the best fit. If there were multiple most-probable models (QAICc values differed by less than 2 from the best-fit model), model parameters were calculated by model averaging (weighted average using QAICc weights) (White & Burnham 1999).

The multivariate linear model was used to determine trends in the annual capture-recapture rate, apparent survival, and capture probability of age and sex groups. The distribution of capture-recapture rates and recapture index (recapture event/recapture) according to age and sex groups was compared with Fisher's exact test (χ^2). The Past 4.03 computer program was used for the statistical analysis (Hammer et al. 2001).

Results

Capture-recapture, sex ratio

A total of 489 individuals of the Eurasian Nuthatch were ringed: 184 juveniles, 66 adults and 239 unknown ages. The total annual captures did not show a significant linear trend from 1998 to 2025 (*slope* = 0.3218, *SE* = 0.1986; t = 0.3029; P = 0.12; Fig. 3). The ratios of females and males in the total capture was 49.69 – 50.31 percent, which corresponds to a 1:1 sex ratio (χ^2 = 0.01, P = 0.943) (Table 1). The annual sex ratios did not differ significantly from those values (females: χ^2 = 2.84, P = 0.527, males: χ^2 = 35.89, P = 0.117). The same-year recaptures (χ^2 = 2.26, P = 0.322), recapture proportions (χ^2 = 3.69, P = 0.158) and recapture index (χ^2 = 0.31, P = 0.855) distribution of females and males across different age groups showed non-significant differences (Table 1). Individuals recaptured in the year of ringing had significantly higher fat score and shorter 3rd primary than those not-recaptured, but did not differ in wing length, body mass and pectoral muscle score (Table 2).

In the first year following ringing, 18 males and 12 females were recaptured. In the second year, four males and four females were recaptured; in the third year, two males; in the fourth year, one male; and in the fifth year, one male. No individuals were recaptured more than five years after ringing.

Apparent survival, capture probability

Based on the result of the CJS modeling, an age-, sex- and time-dependent (year) model was fitted to the data the best (Table 3), but the average apparent survival rate (φ) and capture probability (p) of the age and gender groups were not significantly different (Table 4). The apparent survival rate of males showed a significant positive linear trend (P = 0.046), while their capture probability showed a significant negative linear trend (P = 0.029) from 1998 to 2025. The survival rates of females, adults and juveniles also showed no significant change during this period (Table 5).

Table 1. Capture-recapture data of the Eurasian Nuthatches at Tömörd, western Hungary during 1998–2025.
***Tabuľka 1.** Údaje z odchytu a spätného odchytu brhlíka lesného v lokalite Tömörd, západné Maďarsko, v rokoch 1998 – 2025.*

Age *Vek*	juvenile *mláďa*		adult *dospelý*		unknown *neznámy*		Total *Celkom*
Sex *Pohlavie*	female *samica*	male *samec*	female *samica*	male *samec*	female *samica*	male *samec*	
Capture *Odchyt*	87	97	30	36	126	113	489
Same-year recapture R *Kontrolný odchyt v rovnakom roku KO*	46	50	12	24	34	44	210
R ratio % *KO podiel (%)*	52.87	51.54	40.00	66.67	26.98	38.93	42.94
R event Re *KO Odchyt* KO_o	263	215	85	161	101	151	976
R index Re/R *KO index* KO_o/KO	5.72	4.30	6.83	6.71	2.97	3.43	4.65

Table 2. Comparison of non-retrap (NR) and retrap (R) biometric data of Eurasian Nuthatches at Tömörd, western Hungary. Explanations: W = Wilcoxon rank sum test with continuity correction. Significant probability values are in bold.
***Tabuľka 2.** Porovnanie neodchytených (NR) a opätovne odchytených (R) jedincov brhlíka lesného v lokalite Tömörd, západné Maďarsko. Vysvetlivky: W = Wilcoxonov test súčtu poradí s korekciou na spojitosť. Štatisticky významné hodnoty pravdepodobnosti sú hrubo vyznačené.*

	NR		R		W *W*	P *P*
N	213		280			
	Mean *Priemer*	SD *SD*	Mean *Priemer*	SD *SD*		
Wing length *Dĺžka krídla* mm	85.82	2.25	85.46	2.38	22698	0.126
3rd primary *3. ručná letka (P3) mm*	65.31	1.81	64.86	2.02	**16748**	**0.034**
Body mass g *hmotnosť g*	21.74	1.31	21.57	1.38	23156	0.155
Fat score *tukové zásoby*	0.47	0.68	0.76	0.82	**25180**	**0.001**
Muscle score *Stupeň osvalenia*	2.39	0.58	2.45	0.67	17098	0.173

Table 3. Cormack–Jolly–Seber models used to estimate apparent survival rate (φ) and capture probability (p) parameters of the Eurasian Nuthatches. AICc = small sample sizes corrected Akaike values; ΔAICc = difference of models' AICc values in relation to the top model; AICc weights = indicating model probabilities; No. Par. = Number of parameters; ĉ = variance inflation factor. Only the top models (ΔAICc<3) are shown. p =0.089, ĉ=1.1
***Tabuľka 3.** Cormack–Jolly–Seber modely použité na odhad parametrov zdanlivej miery prežívania (φ) a pravdepodobnosti odchytu (p) brhlíka lesného. AICc = Akaikeho informačné kritérium korigované pre malé súbory; ΔAICc = rozdiel hodnôt AICc modelov vzhľadom na najlepší model; vážené AICc = indikátor pravdepodobnosti modelov; No. Par. = počet parametrov; ĉ = faktor nadmernej disperzie. Zobrazené sú iba najlepšie modely (ΔAICc<3). p = 0,089, ĉ = 1,1.*

model	no. par *poč. par*	AICc *AICc*	ΔAICc *ΔAICc*	AICc weights *váhy AICc*	Deviance *Odchýlka*
φ (~Age + Year)p(~Age + Year)	8	5540.718	0	0.451	5524.61
φ (~Age + Gender + Year)p(~Age + Year)	9	5542.607	1.888	0.175	5524.47
φ (~Age + Year)p(~Age + Gender + Year)	9	5542.610	1.892	0.175	5524.47

Table 4. Summary of average values of apparent survival rate (φ), capture probability (p) for the Eurasian Nuthatches of different age (1Y – juveniles, +1Y – adults) and sex (M – males, F – females) according to the best models from CJS model. SE = standard error, CI = confidence interval.
Tabuľka 4. *Súhrn priemerných hodnôt zdanlivej miery prežívania (φ) a pravdepodobnosti odchytu (p) pre brhlíky lesné rôzneho veku (1Y – juvenily, +1Y – adulty) a pohlavia (M – samce, F – samice) podľa najlepších CJS (Cormack–Jolly–Seber) modelov. SE = stredná chyba aritmetického priemeru, CI = konfidenčný interval.*

Parameters *Parametre*	Weighted average *Vážený priemer*	SE *SE*	95% CI *95% CI*	
φ 1+	0.995	0.002	0.989	0.997
φ 1+F	0.995	0.003	0.981	0.998
φ 1+M	0.995	0.002	0.987	0.998
φ 1y	0.989	0.002	0.986	0.992
φ 1yF	0.992	0.002	0.987	0.995
φ 1yM	0.987	0.002	0.981	0.991
p1+	0.114	0.010	0.096	0.136
p1+F	0.099	0.016	0.073	0.135
p1+M	0.122	0.013	0.099	0.150
p1y	0.131	0.007	0.117	0.145
p1yF	0.141	0.010	0.123	0.162
p1yM	0.117	0.009	0.099	0.138

Table 5. Results of the multivariate linear model test of the Eurasian Nuthatches at Tömörd, western Hungary, with apparent survival rate (φ) and capture probability (p) as dependent variables and year (covariate) as independent variable. Explanations: 1+ = adults 1y = juveniles, F = females, M = males. Significant probability values are in bold.
Tabuľka 5. *Koeficienty testu viacrozmerným lineárnym modelom pre brhlíka lesného v lokalite Tömörd, západné Maďarsko, so zdanlivou mierou prežívania (φ) a pravdepodobnosťou odchytu (p) ako závislými premennými a rokom (kovariát) ako nezávislou premennou. Vysvetlivky: 1+ = dospelé jedince, 1y = juvenilné jedince, F = samice, M = samce. Štatisticky významné hodnoty sú hrubo vyznačené.*

Variables *Premenné*	Slope *Sklon*	SE *SE*	t *t*	P *P*
φ 1+, F and M	0.0092	0.0076	1.207	0.240
φ 1y, F and M	0.0001	0.0006	0.061	0.952
φ F, 1+ and 1y	0.0004	0.0003	1.210	0.237
φ M 1+ and 1y	0.0004	0.0002	**2.096**	**0.046**
p1+, F and M	-0.0026	0.0022	-1.157	0.259
p1y, F and M	-0.0026	0.0023	-1.148	0.262
pF, 1+ and 1y	-0.0025	0.0018	-1.357	0.187
pM, 1+ and 1y	-0.0041	0.0017	**-2.305**	**0.029**

Discussion

Population dynamics

When interannual variation is inferred from ringing or capture data, part of the observed fluctuation may also reflect differences in capture probability or sampling effort rather than true changes in population size. Therefore, annual variation in capture numbers should be interpreted cautiously, particularly when sample sizes are small. Based on our annual captures-recaptures, the local population of the Eurasian Nuthatch has remained stable over recent decades, consistent with national and European population trends. Stability was characteristic of all age and sex groups within the local population under study. The Pan-European population of the Eurasian Nuthatch has shown generally stable to moderately increasing trends during recent decades, although regional fluctuations have occurred in response to habitat alteration, forest management practices and climate variability (PECBMS 2026). In Hungary, the breeding and wintering population also moderately increased (3.2 ± 0.4 percent, $P <$ 0.01) between 1999 and 2025 (BirdLife Hungary 2026). The past three years, 2023–2025, are the three warmest on record in Europe (C3S/ECMWF & WMO 2026) and since 2000, afforestation efforts have increased the forest cover in Hungary by 172 thousand hectares, corresponding to an expansion of approximately 9.6% (Central Statistics Office, Hungary 2026). Across much of Western and Central Europe, Eurasian Nuthatch populations expanded during the late twentieth century, partly due to the maturation of secondary woodlands, increased forest cover, and milder winter conditions that improved overwinter survival (Nilsson 1987, Kirwan et al. 2025).

Similarly, at least two successional stages are evident in the study site, which may provide favorable conditions for the breeding and foraging of the Eurasian Nuthatches. In older shrub belts, protected by dense vegetation, crab apple (*Malus sylvestris*) and wild pear trees (*Pyrus pyraster*) coexist with emerging Turkey oak, wild cherry (*Prunus avium*), field maple (*Acer campestre*), and common ash trees (*Fraxinus excelsior*). These trees escape browsing by deer and grow undisturbed, forming the early stages of future forest patches. At forest edges, hawthorns persist but struggle to survive under the shaded canopy. In some western areas, succession has advanced to the point where only the dead stumps of former shrubs remain beneath the closed canopy (Németh 2019). The similarly low capture probabilities across both groups, as well as the decline in the capture probability of males during the study period, suggests that the area of wooded habitats favorable for the European Nuthatches increased, thereby expanding the potential home ranges of individuals. In recent decades, winters in Hungary have also become increasingly mild (C3S/ECMWF & WMO 2026), which is likewise favorable for the survival of resident birds and may contribute to the stability of the local Eurasian Nuthatch population. Similar trends have been documented in parts of Northern Europe, where climate warming has reduced winter mortality and facilitated the establishment of breeding populations farther north (Harrison et al. 2003, Hewson & Noble 2009).

Despite these positive continental trends, local declines have occurred in regions experiencing intensive forestry, habitat fragmentation, or the loss of mature deciduous woodland (Matthysen 1998). Because the species depends strongly on tree cavities for nesting, the removal of old-growth trees and deadwood can negatively affect breeding density. In Mediterranean and some Eastern European regions, drought stress and changing forest composition may also reduce habitat suitability (Thévenot et al. 2003, Gyurácz & Csörgő 2022). Consequently, population dynamics vary considerably between landscapes depending on forest age structure, management intensity, and food availability (Bellamy et al. 1998).

Annual fluctuations in European Nuthatch populations are often associated with mast production in deciduous trees such as oak (*Quercus spp.*), beech (*Fagus sylvatica*) and hazelnut (*Corylus avellana*) (Matthysen 1989a, Kirwan et al. 2025). High seed production typically enhances winter survival and increases breeding success during the following season, whereas poor mast years may lead to temporary declines (Wesolowski & Stawarczyk 1991). Severe winters historically caused localized mortality events, although such effects have become less frequent under recent climatic conditions (Kirwan et al. 2025).

Apparent survival and sex ratio

We detected similarly high apparent survival rates and similarly low capture probabilities across all age and sex groups, indicating no evidence of lower competitive ability in juveniles or females (Matthysen 1989b), but not in Enoksson (1988). The stability and increase in apparent survival rates during the study period — particularly among males exhibiting territorial behavior in winter (Matthysen 1998) — further suggests that changes in local vegetation and climatic conditions were favorable for all age and sex groups of the Eurasian Nuthatch.

At our study site, the sex ratio was nearly balanced. Other European studies have reported either a slight to moderate male bias or similarly balanced sex ratios (Krištin et al. 2001, Zang & Kunze 2009). Our results, similarly to those reported in other studies, indicate that adult sex ratios in stable populations are usually close to parity, meaning that the numbers of males and females are relatively balanced (Matejka et al. 2024). This suggests that habitat quality may influence sex composition. Less suitable habitats are probably occupied by juveniles, unpaired males, whereas higher-quality habitats, where winter territories are defended by pairs, exhibit a more balanced sex ratio (Matthysen 1990, Matejka et al. 2024). In addition, differences in the dispersal strategies of juvenile birds may also explain the higher proportion of males in lower quality habitats, such as urban parks Matthysen & Schmidt 1987, Matejka et al. 2024). Furthermore, females could be displaced from territories by unpaired males before and after the breeding season (Glutz von Blotzheim & Bauer 1993), though paired individuals do not typically attack non-paired females (Matthysen 1990, Glutz & Bauer 1993).

In addition to the balanced sex ratio, the high local apparent survival rate, over 98% and recapture rate, over 42% observed across all age and sex classes also indicate that the study area represents a high-quality habitat for Eurasian Nuthatches. Their territory size typically ranging from 1 to 10 hectares depending on habitat quality (Matthysen 1998). The territories are smallest in optimal habitats, i.e. oak or mixed broad-leaved woodland. The significantly better condition of the recaptured birds suggests that they are more successful in competition for local territories. In Great Britain in the 1970s, the survival of adults was 85% between 1 April and 1 November but only 54% in winter (Nilsson 1987). The annual apparent survival rate of male Corsican Nuthatches (*Sitta whiteheadi*) was 61.6% between 1998 and 2005 (Thiabult & Jenouvrier 2006). However, one important factor possibly affect sex-specific population dynamics is differential survival. Males with established territories often exhibit relatively high survival rates. Females, in contrast, may experience slightly greater mortality due to the energetic costs of egg production, incubation, and brood care (Matthysen 1990, Kašová et al. 2014). Harsh winters or food shortages can therefore disproportionately reduce female survival in some populations (Nilsson et al. 1993). However, mean winter survival of the adult birds is not correlated with the beech mast supply in the preceding autumn (Enoksson & Nilsson 1983, Källander 1993). Survival in autumn was markedly higher in years with beech mast, particularly in juveniles: 48 % and 65% survived in two autumns without beech mast, vs. 77% and 80% in two mast years. These differences were found only in territories containing beech trees Matthysen (1998).

The dispersal pattern likely does not cause different fluctuations in the numbers of males and females. The number of nestlings successfully leaving their natal area must be estimated at about 83% (Matthysen et al. 1995). The Eurasian Nuthatch is generally considered a long-term socially monogamous species and mate switching is uncommon and generally occurs only following the loss of a partner (Cramp 1998, Kirwan et al. 2025). Like many monogamous passerines, dispersal is thought to be female-biased: females tending to disperse farther than males, but research could not find robust species-specific male vs female distance estimates for Eurasian Nuthatch. The absence of a sexual bias in dispersal distance is explained by the symmetry in territorial behavior of the sexes (Matthysen & Schmidt 1987). Similar dispersion between the sexes can temporarily create local balances in population structure.

Overall, the numbers of adults and juveniles, females and males in Eurasian Nuthatch populations tend to remain relatively balanced under stable ecological conditions, but local and annual deviations can occur due to differences in survival, dispersal, reproductive costs, and habitat quality. The availability of tree seeds, particularly those of beech and oak, is a key determinant of overwinter survival because

Eurasian Nuthatches rely extensively on cached food reserves. Consequently, mast years are often followed by higher survival rates and increased breeding success, whereas poor seed crops may lead to reduced survival and lower population sizes in the subsequent breeding season (Nilsson 1987). Breeding success is further affected by spring weather, the abundance of invertebrate prey during the nestling period, and nest predation. In addition, the species exhibits strong territorial behaviour throughout the year, and the availability of suitable nesting cavities and territories limits local breeding density, thereby constraining population growth even under favourable environmental conditions (Matthysen 1998). Local abundance may also vary because of post-fledging dispersal of juveniles, although the Eurasian Nuthatch is largely sedentary and does not undertake regular long-distance migration (Cramp 1998, Kirwan et al. 2025). Understanding these age- and sex- and habitat-specific demographic processes is important for interpreting broader population dynamics and assessing the long-term viability of woodland bird populations.

Conclusions

The annual capture data provided a reliable indication of the yearly population size of the local bird population. Which appeared to remain stable throughout the study period, because the annual captures did not show a significant linear trend from 1998 to 2025 and the sex ratio was nearly balanced in the study site for the species. The apparent survival and capture probability were age-, sex and year dependent, but the very high mean apparent survival rates and low capture probabilities of the age and gender groups were not significantly different. The apparent survival rate of males showed a significant positive linear trend, while those of females, adults and juveniles showed no significant positive linear trend during 1998-2025. Our results are in coincidence with current conservation assessments classify the Eurasian Nuthatch as a species of "Least Concern" in Europe due to its large range and generally stable demographic trajectory. Nevertheless, continued monitoring remains important because long-term environmental changes, including climate change and habitat degradation, may alter future population trends. Conservation measures that preserve mature woodland habitats and maintain structural diversity within forests are considered essential for sustaining stable populations across Europe.

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Súhrn

Individuálne prežívanie patrí medzi kľúčové faktory ovplyvňujúce populačnú dynamiku drobných spevavcov. Pochopenie demografie vo vzťahu k populačnej dynamike je zásadné pre ekologický výskum aj ochranu prírody. Cieľom tejto štúdie bolo analyzovať ročné odchyty v režime odchyt/spätný odchyt (capture-recapture), zdanlivú mieru prežívania, pravdepodobnosť odchytu a pomer pohlaví u brhlíka lesného (*Sitta europaea*) vyskytujúceho sa v západnom Maďarsku. Údaje pochádzali od 184 juvenilných jedincov, 66 dospelých jedincov a 239 jedincov s neznámym vekom, získaných v rámci schémy odchytu s konštantným úsilím, v troch odchytových obdobiach, pokrývajúcich 29 rokov. Ročné odchyty nevykazovali v období 1998 – 2025 štatisticky významný lineárny trend a pomer pohlaví bol na študijnom území takmer vyrovnaný, čo poukazuje na kvalitu biotopu a stabilnú miestnu populáciu z hľadiska početnosti aj štruktúry. Podľa štandardného Cormack–Jolly–Seberovho modelu boli zdanlivá miera prežívania aj pravdepodobnosť odchytu závislé od veku, pohlavia a roku, avšak veľmi vysoké priemerné hodnoty zdanlivej

miery prežívania a nízke pravdepodobnosti odchytu v jednotlivých vekových a pohlavných kategóriách sa štatisticky významne nelíšili. Zdanlivá miera prežívania samcov vykazovala štatisticky významný pozitívny lineárny trend, zatiaľ čo u samíc, dospelých jedincov a juvenilov sa medzi rokmi 1998 a 2025 nepreukázal významný pozitívny lineárny trend. Celkovo počty dospelých a juvenilných jedincov, samíc a samcov v populáciách brhlíka lesného za stabilných ekologických podmienok zvyknú byť relatívne vyrovnané.

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