Short Communication

Multi-year autumn activity (2001-2025) of the Torre Flavia ringing station (central Italy): a significant abrupt decrease of Penduline Tit (*Remiz pendulinus*) and further remarks on species of conservation concern

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Abstract - We reported data from the ringing station located in the Torre Flavia wetland (SPA IT6030020; 147/2009/CE Bird Directive; Tyrrhenian central Italy) for the 2001-2025 autumn period (with some interruptions), using a comparable research effort. We grouped data in four sub-periods. A total of 13,052 birds (58 species) were ringed during the period of study with *Remiz pendulinus, Phylloscopus collybita, Emberiza schoeniclus, Erithacus rubecula* and *Acrocephalus melanopogon* the most captured. Comparing sub-periods, total number of captures and species did not show significant changes. At species level, *Remiz pendulinus* is the only species showing a significant decrease in the captured individuals in the last sub-period (2021-2025), probably linked to dynamism at continental scale. Differently, we showed a significant increase of *Cettia cetti* captures between the first two sub-periods (2001-2005 vs. 2006-2010) probably linked to increase in reedbed extent with ageing and colonization of shrubs making more suitable the area for this species, perhaps also due to lower winter mortality. Sample rarefaction curve among all the years does not show cumulation, also due to the high number of poor abundant (Chao1) or occurring (Chao2) species that increased the richness estimators (S_{Chao1} =73.13; S_{Chao2}=72.4). Among the species of conservation concern, Torre Flavia appears to be of particular importance for the passage of *Alcedo atthis*, *Cyanecula svecica* and *Acrocephalus melanopogon,* species in the EU 'Birds' Directive Annex I.

Keywords: *Remiz pendulinus, Cettia cetti, Phylloscopus collybita*, richness, diversity, Chao estimators, rarefaction curve.

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Riassunto - Attività pluriennale autunnale (2001-2025) della stazione di inanellamento di Torre Flavia (Italia centrale): un calo improvviso e significativo della popolazione di pendolino europeo (*Remiz pendulinus*) e ulteriori osservazioni sulle specie di interesse conservazionistico.

Abbiamo riportato i dati della stazione di inanellamento situata nella Palude di Torre Flavia (ZPS IT6030020; Direttiva Uccelli 147/2009/CE; Italia centrale tirrenica) per il periodo autunnale 2001-2025 (con alcune interruzioni), utilizzando uno sforzo di ricerca comparabile. Abbiamo raggruppato i dati in quattro sottoperiodi. Un totale di 13.052 uccelli (58 specie) sono stati inanellati durante il periodo di studio, con *Remiz pendulinus, Phylloscopus collybita, Emberiza schoeniclus, Erithacus rubecula* e *Acrocephalus melanopogon* le specie più catturate. Confrontando i sottoperiodi, il numero totale di individui e specie non ha mostrato variazioni significative. A livello di specie, *Remiz pendulinus* è l'unica che ha mostrato una diminuzione significativa degli individui catturati nell'ultimo sottoperiodo (2021-2025), probabilmente legata a dinamiche di areale a scala continentale. Diversamente, abbiamo evidenziato un aumento significativo delle catture di *Cettia cetti* tra i primi due sottoperiodi (2001-2005 vs. 2006-2010), probabilmente legato all'aumento dell'estensione e all'invecchiamento del canneto e la conseguente colonizzazione di arbusti che hanno reso ecologicamente più idonea l'area per questa specie, forse anche per una minore mortalità invernale. La curva di rarefazione sull'intero periodo di studio non mostra una cumulazione, a causa dell'alto numero di specie rare, sia considerando il numero di catture (Chao1; S_{Chao1} =73,13 specie) che le presenze/assenze (Chao2; S_{Chao2} =72,4). Tra le specie di interesse conservazionistico, l'area sembra essere di particolare impor-

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tanza come sito di sosta e transito per *Alcedo atthis, Cyanecula svecica* e *Acrocephalus melanopogon*, inserite nell'Allegato I della Direttiva EU 'Uccelli'.

Parole chiave: *Cettia cetti*, curva di rarefazione, diversità, estimatori Chao, *Phylloscopus collybita*, *Remiz pendulinus*, ricchezza di specie.

To Flavia

Ringing is an effective tool to monitor bird species (Spina, 1999; Sutherland *et al*., 2004). Along Italy a large number of ringing stations are active: their activity allows us to investigate migratory flows, phenologies and obtain data on the biometrics of species, as well as on their presence in specific sites of conservation concern, with implications on the protection of these biotopes (Messineo *et al*., 2001; Spina & Volponi, 2008; La Gioia & Scebba, 2009). In this work, we reported data on the autumn activity carried out at the ringing station of Torre Flavia wetland, along a longtime range (2001-2025, with some interruptions), grouping them in sub-periods to detect differences both in averaged number, either of individuals (at species level), and in species richness (absolute and normalized) and diversity (community level). This work represents an updating step when compared to previous papers for the same study area (Sorace *et al*., 2001, 2003, 2006, 2015; Iavicoli *et al*., 2022).

Ringing activities were carried out in the 'Palude di Torre Flavia' natural Monument (41°58'N; 12°03'E; central Italy; EUAP code 1071, Special Protection Area code IT6030020; 147/2009/CE "Bird" Directive), a remnant fragment of wetland embedded inside an agricultural and urbanized landscape mosaic. At local scale, it shows a semi-natural heterogeneity with *Phragmites australis* reed-beds, channels, flooded meadows with *Carex hirta, Juncus acutus* and Cyperaceae corresponding to Juncetalia maritimi habitat type (EC "Habitat" Directive 92/43/EC), dune and back dune areas. Climate is Mediterranean (Tomaselli *et al*., 1973; Blasi & Michetti, 2005). The water in the wetland is mainly of meteoric and sea storm origin, and flow from surrounding areas is scarce. During the study period (2001-2025) the local environment changed: particularly, reedbeds of *Phragmites australis* showed a progressively ageing with colonization of shrubs (*Sambucus nigra, Rhamnus alaternus, Tamarix* sp.; Aglitti *et al*., 2006; Battisti *et al*., 2020; Giordano *et al*., 2024). However, some sectors of reedbeds were managed any year in the late summer by mowing: a measure to allow suitable surfaces for heliophilous plant species (see, e.g., Brusa *et al*., 2019). Water levels in channels showed periodical (seasonal) oscillations that affected many water-related species (Battisti *et al.*, 2004; Causarano & Battisti, 2009; Redolfi De Zan *et al.*, 2010; Zacchei *et al.*, 2011; Battisti *et al.,* 2023).

We analyzed the data collected from 15 October to 7 November throughout the whole study period (2001-2025, excluding 2015-2020 and 2022 years). Mist-nets were opened at sunrise and maintained open for a period of six hours. A total of 10 mist-nets (12 m x 2.4 m with four pockets and 16 x 16 mm mesh) placed along a 120-m transect in a *Phragmites australis* reed-bed (about 10 ha-wide) were used. All captured individuals were ringed with ISPRA rings. We used the diagnostic keys reported in Svensson (2023). For systematic we followed Baccetti *et al.* (2021). For the analysis, in each year only the first capture of an individual (i.e., either not yet ringed or ringed in previous years) was considered in the total number of captured ones.

After we subdivided the 2001-2025 period in four multiyear sub-periods where ringing activities were carried out: 2001-2005, 2006-2010, 2011-2014 and 2021-2025 (excluding 2022). For each sub-period, we obtained the: (i) number of ringed individuals (at single species level, n, and total, N), (ii) relative frequency at single species level (fr); (iii) total number of species (S). Only for dominant (fr>0.05) and sub-dominant species (fr ranging between >0.02 and 0.05), we obtained the mean values (and standard deviation, s.d.). We also calculated the mean values of number of species, the normalized richness (Margalef index, as Dm = S-1/lnN; Margalef, 1958) and the Shannon-Wiener diversity index as $H' = -\Sigma\, fr_i \cdot \ln[fr_i]$ (Spellerberg & Fedor, 2003; review of univariate metrics of diversity in Magurran, 2013).

In order to predict the species richness, two non-parametric richness estimators were used, either considering species occurrence (i.e., presence/absence) and species abundance (number of individuals): respectively, (i) Chao 1 (individual-based estimator) as $S_{Chao1} = S_{obs} + F_1^2/2F_2$, where S_{obs} is the total number of ringed species, F_1 is the number of species represented by a single individual (singletons), and F_2 is number of species represented by two individuals (doubletons), and (ii) Chao 2 (sample-based indicator) as $S_{Chao2} = S_{obs} + Q_1^2/2Q_2$, where Q_1, the number of species ringed in only one year (independently by the number of individuals), Q_2, the number of species ringed in two years. Differences between the two estimators is that Chao 1 requires abundance data (number of individuals), differently Chao 2 requires presence/absence (i.e., occurrences) ones (into the last case, taking in account the distribution of the species amongst samples and not their individual abundance; Chao, 1987; Magurran, 2013). Using all the data set, we obtained a sample rarefaction curve (Mao's Tau) using PAST 4.01 (Hammer *et al.*, 2001).

Finally, we compared the averaged values among all the sub-periods using the Kruskall-Wallis test and, when necessary, between paired years using the Mann-Whitney U paired test with alpha level set at 0.05 (Dytham, 2011).

As species of conservation concern, we considered those birds included in the: (i) Annex I of EC Directive 2009/147/CE on wild bird conservation; (ii) the threat category at global scale (IUCN, 2021), (iii) the European population trends (BirdLife International, 2021), (iv) and national threat category of Red List of breeding population (Gustin *et al*., 2021). We considered *Phylloscopus* (*collybita*) *tristis* as a species (see Doniol-Valcroze, 2024).

On the whole, during the period of study, 13,052 individuals from 58 different species were captured (Margalef normalized richness: 6.02, Shannon-Wiener diversity index: 2.25; Tab. 1). The dominant species

most caught (frequency > 0.05) were: *Remis pendulinus, Phylloscopus collybita, Emberiza schoeniclus, Erithacus rubecula, Acrocephalus melanopogon*; sub-dominant (fr. ranging from 0.02 to 0.05) were: *Cettia cetti, Saxicola torquatus, Acrocephalus scirpaceus*. Non passerine species were represented by 11 species (19%), more rarely occurring, except for *Alcedo atthis*, regularly captured throughout the study period (Tab. 1; Supplementary informations 1 and 2).

Trends among sub-periods did not result statistically significant for the averaged values in species number, total number of captured individuals, normalized richness and Shannon-Wiener diversity index (Tab. 1; Fig. 1). At single species level, the only species showing an abrupt significant reduction comparing the last sub-periods was the *Remiz pendulinus* both in number of captures (p=0.019) and in relative frequency (p=0.03; Mann-Whitney U test; Fig. 2, Tab. 2, Supplementary informations 1 and 2). *Cettia cetti* showed a marked increase in number of captures comparing the first two sub-periods (2001-2005 vs. 2006 vs. 2010; p=0.012; Mann-Whitney U test). *Phylloscopus collbyita* showed a significant increase in the last sub-periods, but only comparing total frequencies (p=0.019; Mann-Whitney U test; Table 2 and Fig. 2).

Sample rarefaction curve among all the years does not show cumulation (Fig. 3), also due to the high number of poor abundant (Chao1; individual-based) or rarely occurring (Chao2; sample-based) species that increased the richness estimators (S_{Chao1}=73.13; S_{Chao2}=72.4).

Among the captured species, several were of conservation concern: *Alcedo atthis, Cyanecula svecica, Acrocephalus melanopogon* are included in Annex I - Dir. 2009/147/ CE; in the threat categories of Italian breeding population Red List 2021 (Gustin *et al*., 2021) two species are Critically endangered (*Emberiza schoeniclus, Acrocephalus schoenobaenus*), six are Endangered

Tab. 1 - Mean number di ringed individuals (N), species (S), Shannon-Wiener diversity index (H'), Margalef normalized richness (Dm) (with ±standard deviation among brackets) for the four study sub-periods: 2001-2005 (n=5); 2006-2010 (n=5); 2011-2014 (=4); 2021-2025, excluding 2022 (n=4) at Torre Flavia wetland. / Numero medio di individui inanellati (N), specie (S), indice di diversità di Shannon-Wiener (H'), ricchezza normalizzata di Margalef (Dm) (con ± deviazione standard tra parentesi) per i quattro sotto-periodi di studio: 2001-2005 (n=5); 2006-2010 (n=5); 2011-2014 (=4); 2021-2025, escluso il 2022 (n=4) nella zona umida di Torre Flavia.

	2001-2005	2006-2010	2011-2014	2021-2025	H value	p
N mean (sd)	822.2 (278.7)	607.6 (35.15)	870.25 (178.07)	605.5 (251.87)	4.66	0.198
S mean	26.8 (2.17)	27 (3.39)	28.75 (3.10)	27.25 (5.19)	0.741	0.861
H' mean	2.11 (0.17)	2.14 (0.13)	2.10 (0.06)	2.19 (0.16)	1.063	0.786
Dm mean	3.87 (0.19)	4.06 (0.52)	4.10 (0.36)	4.12 (0.59)	1.437	0.697

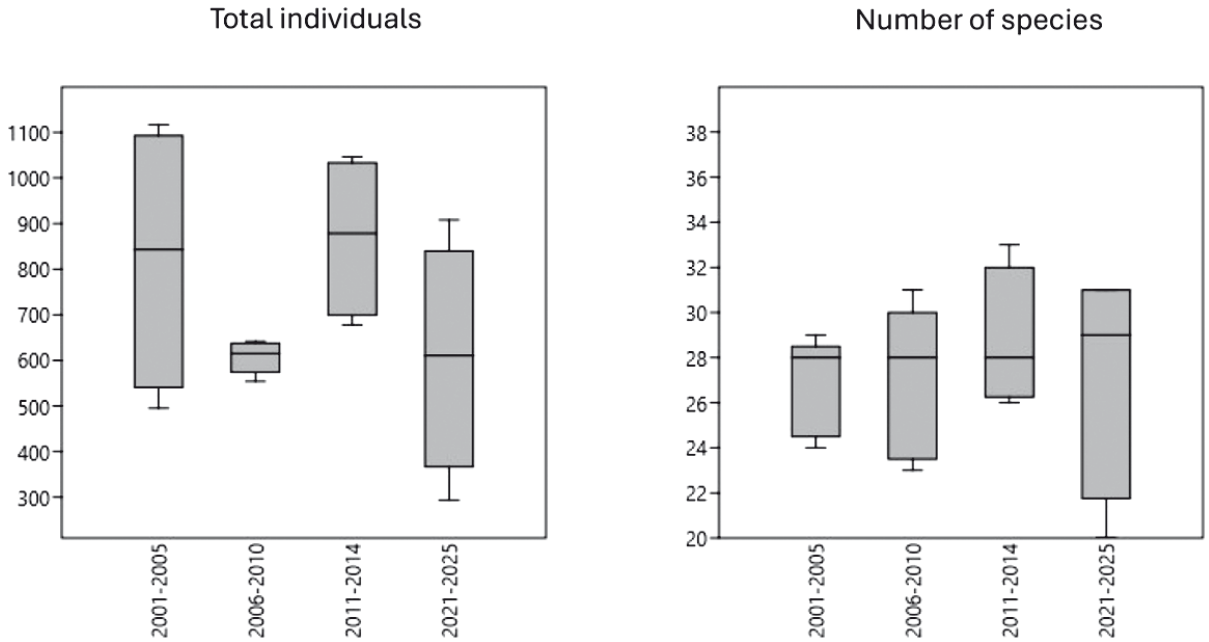

Fig. 1 - Averaged total number of individuals (left) and total number of species (right) ringed in the study period in the Torre Flavia station. / Numero totale medio di individui (a sinistra) e numero totale di specie (a destra) inanellati nel periodo di studio presso la stazione di Torre Flavia.

(*Acrocephalus melanopogon, Saxicola torquatus, Sylvia borin, Panurus biarmicus, Locustella luscinioides, Jynx torquilla*), 5 species are Vulnerable (*Remiz pendulinus, Passer italiae, Chloris chloris, Botaurus minutus, Saxicola rubetra*) and 7 Near Treatened (*Alcedo atthis, Prunella modularis, Acrocephalus arundinaceus, Passer montanus, Hirundo rustica, Carduelis carduelis, Motacilla flava*).

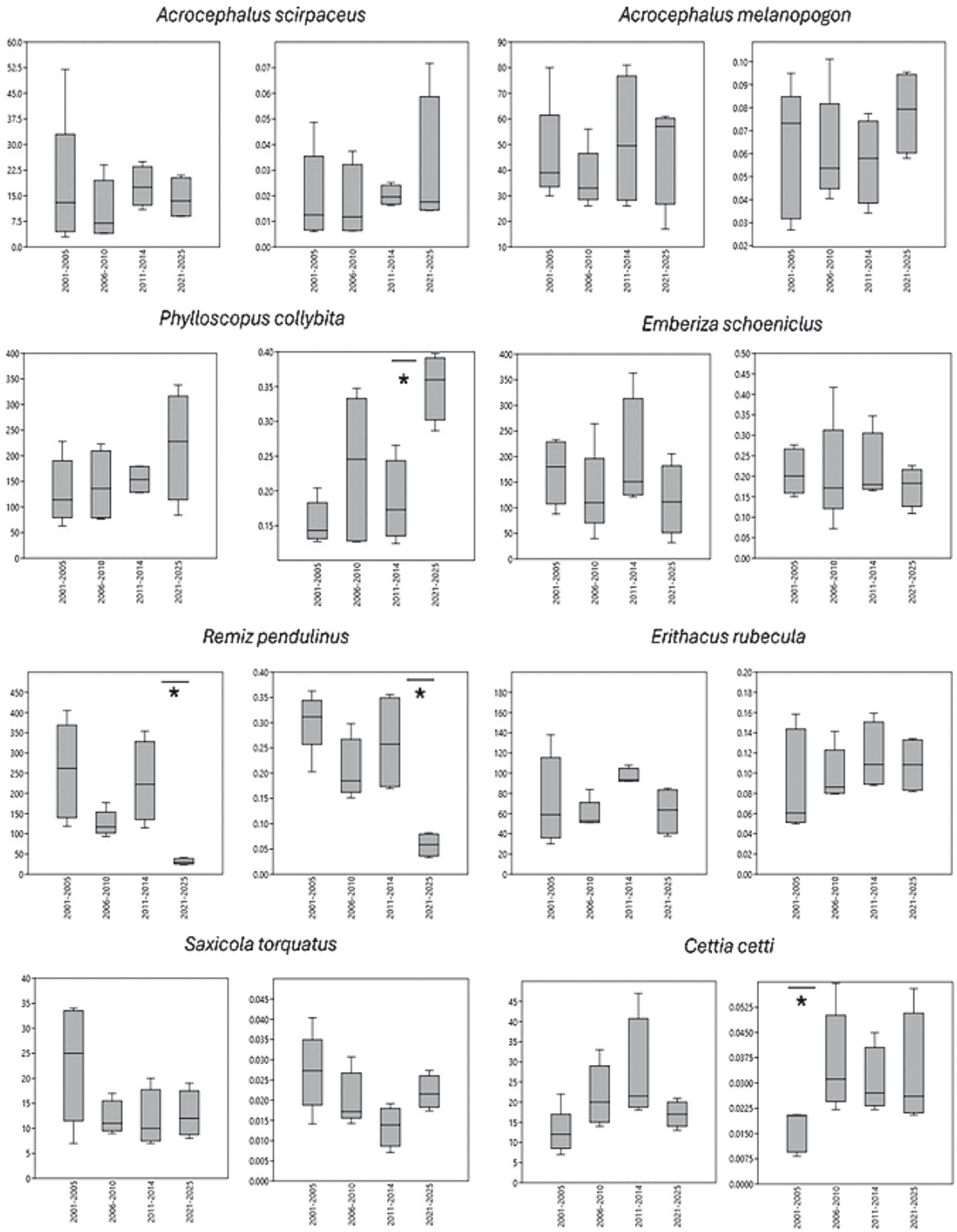

Fig. 2 - Averaged total number of ringed individuals and relative frequencies in the study period (Torre Flavia station; only dominant and sub-dominant species). / Numero totale medio di individui inanellati e frequenze relative nel periodo di studio (stazione di Torre Flavia; solo specie dominanti e subdominanti).

Autumn migration at the Palude di Torre Flavia, recorded during the period 2001-2025, was characterized by the dominance of species (e.g. *Remiz pendulinus*, *Emberiza schoeniclus*) that, in the October-November period, were among the most frequently captured, as reported for other ringing stations of similar habitat type (reed beds) in central Italy (Gustin *et al.*, 2001; Muzzatti *et al.*, 2010, Sorace *et al.*, 2010).

At the single species level, *Remiz pendulinus*, a local migrant and wintering in Torre Flavia (Battisti & Sorace, 2006; Battisti *et al.,* 2021), with picks of captures in October (e.g., Pedrini *et al*., 2021), showed an abrupt decrease in captures in the last sub-periods when compared to the previous ones. The Italian population has shown a contraction in its range and a decrease in the breeding population of 50-70% since the 1980s (Brichetti & Grattini, 2010; Brichetti & Fracasso, 2020; Galimberti, 2022), especially in Northern Italy (e.g., Pavesi *et al*., 2023), and this trend is part of a phenomenon that began several decades ago (e.g., Campedelli *et al*., 2012; Muzzatti *et al*., 2010). However, this species has been characterized by high demographic and geographical range dynamisms (with contractions and expansions at the regional level). For example, at continental level, range borders have been highly dynamic in the past decades (Valera *et al*., 1990; Glutz von Blotzheim & Bauer, 1993; Flade, 2020). In Europe *Remiz pendulinus* is encreasing and has least concern status (BirdLife International, 2021). Locally, in our study area, we observed a decrease in captures even a few years ago (Iavicoli *et al*., 2022); in the first sub-period were recovered nine birds ringed in Italy or in another European Country (Sorace *et al*., 2006), none in the last one. Since in the last years reedbeds in Torre Flavia increased significantly, making more suitable this wetland for the species (reedbeds provide nesting materials and food resources in the post-fledging periods and during the migration; Glutz von Blotzheim & Bauer, 1993; Štastný & Riegert, 2021), we think that this significant decrease in number of captures may be due to factors at regional/continental scale, not to local ones. *Remiz pendulinus* is a poorly studied species in Italy (Sarà, 2023), and these results may be useful for deepening their migratory trends.

We also observed a significant increase in *Cettia cetti* captures comparing the first two sub-periods (2001-2005 vs. 2006-2010). This trend can probably be explained by an improvement in the ecological suitability of the site for this passerine (see Araújo *et al.,* 2016): in the early 2000s, the reed beds were

Tab. 2 - Mean number di ringed individuals (only dominant and sub-dominant species) and their relative frequency (with ±standard deviation among brackets) for the four study (sub-periods: 2001-2005 (n=5); 2006-2010 (n=5); 2011-2014 (=4); 2021-2025, excluding 2022 (n=4)) at Torre Flavia wetland. H and p-values (Kruskall-Wallis test) have been reported. / Numero medio di individui inanellati (solo specie dominanti e subdominanti) e loro frequenza relativa (con ± deviazione standard tra parentesi) per i quattro periodi di studio (sottoperiodi: 2001-2005 (n=5); 2006-2010 (n=5); 2011-2014 (=4); 2021-2025, escluso il 2022 (n=4)) nella zona umida di Torre Flavia. Sono stati riportati i valori H e p (test di Kruskal-Wallis).

	ringed individuals					
Species	**2001-2005**	**2006-2010**	**2011-2014**	**2021-2025**	**H**	**p**
Remiz pendulinus	256 (118.28)	125.8 (31.70)	228.5 (100.55)	31.25 (7.63)	11.9	0.008**
Phylloscopus collybita	130.6 (63.45)	142.4 (66.30)	153.75 (28.62)	219.5 (105.99)	2.819	0.42
Emberiza schoeniclus	170.4 (62.36)	128.6 (82.60)	196.5 (112.40)	115 (70.75)	3.104	0.375
Erithacus rubecula	72.4 (43.67)	59.4 (14.05)	96.75 (7.63)	62.5 (23.01)	5.912	0.115
Acrocephalus melanopogon	45.8 (19.69)	36.6 (11.55)	51.5 (25.49)	48 (20.77)	1.692	0.638
Cettia cetti	12.6 (5.64)	21.6 (7.64)	27 (13.44)	17 (3.27)	6.998	0.071
Saxicola torquatus	23 (11.51)	12.2 (3.27)	11.75 (5.74)	12.75 (4.65)	2.993	0.39
Acrocephalus scirpaceus	17.6 (19.78)	10.8 (8.64)	17.75 (5.85)	14.25 (6.18)	2.547	0.466
Species	**relative frequency**				**H**	**p**
Remiz pendulinus	0.30 (0.06)	0.21 (0.06)	0.26 (0.1)	0.06 (0.02)	11.45	0.009**
Phylloscopus collybita	0.15 (0.03)	0.23 (0.10)	0.18 (0.06)	0.35 (0.05)	8.418	0.038*
Emberiza schoeniclus	0.21 (0.05)	0.21 (0.13)	0.22 (0.09)	0.18 (0.05)	0.244	0.970
Erithacus rubecula	0.09 (0.05)	0.10 (0.03)	0.12 (0.03)	0.11 (0.03)	2.351	0.503
Acrocephalus melanopogon	0.06 (0.03)	0.06 (0.02)	0.06 (0.02)	0.08 (0.02)	1.984	0.576
Cettia cetti	0.02 (0.01)	0.04 (0.01)	0.03 (0.01)	0.03 (0.01)	10.11	0.018*
Saxicola torquatus	0.03 (0.01)	0.02 (0.01)	0.01 (0.005)	0.02 (0.004)	6.111	0.106
Acrocephalus scirpaceus	0.02 (0.02)	0.02 (0.01)	0.02 (0.003)	0.03 (0.03)	1.339	0.72

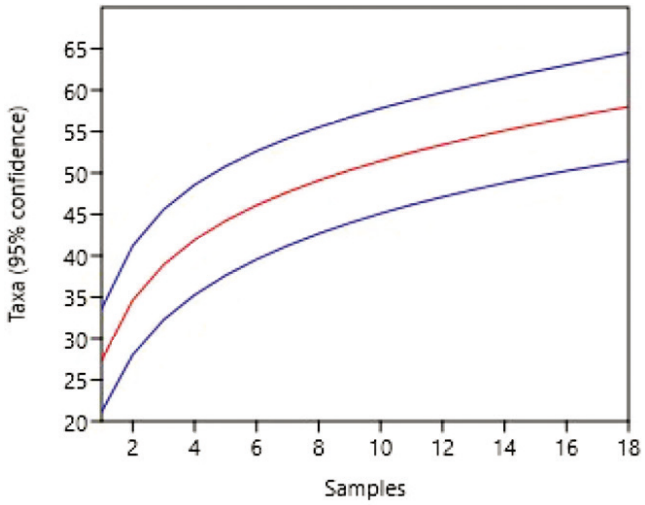

Fig. 3 - Sample rarefaction curve (Mao's Tau) for the total number of species ringed in the study period in the Torre Flavia ringing station. / Esempio di curva di rarefazione (Tau di Mao) relativa al numero totale di specie inanellate nel periodo di studio presso la stazione di inanellamento di Torre Flavia.

small and in juvenile stage; in the following years, with the abandonment of the practice of fish farming that periodically mowed and burned these environments, we witnessed an increase in extension and a progressive ageing (with the presence of shrubs, in the core of reedbeds), inducing a clear increase in breeding pairs of this species (Causarano *et al*., 2009; Battisti *et al*., 2020; Giordano *et al*., 2024).

About the increase in averaged frequency of captures in the last sub-period of *Phylloscopus collybita*, it may be linked to a moderate increase in Europe (Pan-European Common Bird Monitoring Scheme, 2022+). Italian range of the species resulted stable (Boscain, 2022).

Among species of conservation concern, *Alcedo atthis*, is now considered Least Concern (it was Vulnerable in 2015; BirdLife International, 2021), and locally, a constant (although seasonally oscillating; Battisti *et al*., 2006) water presence might have promoted the settlement of a more stable community of prey available for this species, allowing its occurrence and concentration in the study area. Moreover, since the "Torre Flavia" Natura2000 - Standard Data Form lacks of information on the population ("concentration" and "wintering" type) of the species, our data can represent a useful tool for its conservation at a local scale.

Our results may improve the evidence about local patterns of migrant species, particularly on *Remiz pendulinus*. Long-term investigations of migratory birds using ringing techniques are particularly necessary to define conservation strategies (Spina, 1999; Baillie, 2001; Anderson & Green, 2009; Cuti & Canale, 2014; Dalui & Mondal., 2023). Nevertheless, there are still few papers on autumn migration of passerines in Italian wetlands, based on long time spans (e.g., Muzzatti *et al*., 2010; Leo & Bertoli, 2015; Bandini *et al*., 2023; Battaglia *et al*., 2025; Fasano *et al*., 2025).

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SUPPLEMENTARY INFORMATION / INFORMAZIONI SUPPLEMENTARI

Additional Supplementary Information may be found online for this article.

SI: Tab. 1 - Number di ringed individuals of each species at Torre Flavia wetland. / Numero di individui inanellati nella zona umida di Torre Flavia.

SI: Tab. 2 - Level of conservation concern for the ringed species in the Torre Flavia station. / Livello di preoccupazione per la conservazione delle specie anellate nella stazione di Torre Flavia.