Changes in breeding birds in the Monte Fenera Natural Park shaped by 30 years of forest encroachment

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Abstract - Changes in composition and abundance of breeding birds have been studied in the Monte Fenera Natural Park (north-west Italy, Piedmont), a foothill area at the margins of the Alps that has seen landscape upheaval over the last 40 years, from traditional mountain management to a substantial abandonment. This area symbolizes the impact of forest encroachment on the fringes of the Alps, as the current land use is predominantly characterized by young dense forests that have replaced hay meadows and crops. In this area, breeding birds have been investigated exhaustively since the 1990s. This study aims to show the changes related to breeding bird species over the last 30 years, comparing surveys from 1997, 2007, and 2023. The results show a significant turnover, with 24 species lost. The decrease in species diversity concerns above all shrublands and open habitat species. On the other hand, 9 species of forest birds are increasing between 20% to 267%. Of particular interest are two emblematic species: *Columba oenas*, which has been confirmed as a breeding species after 45 years of absence, and *Dryocopus martius*, which has increased from one to at least six pairs in the area. In conclusion, breeding birds in the Monte Fenera Natural Park are showing strong spatial and temporal dynamics because of changes in land use. Finally, a checklist of the 121 species of birds ever observed in the area is provided, with an updated status for the protected area for the year 2023.

Key words: Alps, biodiversity, birds, Fenera, landscape, park.

Riassunto - La risposta dell'avifauna nidificante del Parco Naturale del Monte Fenera dopo trent'anni di espansione forestale.

L'avifauna nidificante del Parco Naturale del Monte Fenera è stata recentemente oggetto di studio e confrontata con i dati disponibili relativi ai decenni più recenti. L'area di studio si trova in un contesto collinare ai margini delle Alpi (Italia nord-occidentale), che negli ultimi 40 anni ha subito profonde trasformazioni paesaggistiche, passando da una gestione montana tradizionale a un progressivo e sostanziale abbandono. Quest'area rappresenta un caso emblematico dell'attuale avanzata del bosco nelle aree alpine e prealpine, dove l'uso del suolo è oggi dominato da giovani formazioni forestali che negli ultimi anni hanno progressivamente sostituito prati da sfalcio, coltivi e altre tipologie di ambienti aperti o semiaperti. In quanto area protetta, il Parco è stato oggetto di indagini faunistiche approfondite a partire dagli anni '90, che hanno fornito una prima fotografia dettagliata dell'abbondanza e della distribuzione delle specie di uccelli nidificanti. Grazie al presente studio, è stato possibile analizzare come la comunità ornitica si sia modificata nel corso degli ultimi trent'anni, attraverso il confronto tra i dati raccolti nel 1997, 2007 e quelli più recenti del 2023. I risultati evidenziano un marcato ricambio nella composizione delle specie, in particolare: 24 specie nidificanti non risultano più presenti come tali, in particolare quelle legate ad ambienti aperti o arbustivi. Parallelamente, si è registrato un aumento significativo di 9 specie forestali, con incrementi che variano dal 20% al 267%. Di particolare rilievo sono i casi di Columba oenas, nuovamente confermata come nidificante dopo 45 anni di assenza, e di Dryocopus martius, la cui popolazione è passata da una sola coppia a almeno sei coppie nidificanti (con territori riproduttivi che ricadono almeno in parte entro i confini dell'area protetta). Le variazioni osservate nella composizione e nella distribuzione delle specie vengono contestualizzate alla luce dei cambiamenti recenti nell'uso del suolo. Infine, viene presentata una checklist aggiornata al 2023 delle 121 specie osservate nel territorio del Parco, con indicazioni puntuali sullo status attuale di ciascuna.

Parole chiave: Alpi, uccelli, cambiamenti, clima, gestione, foreste.

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INTRODUCTION

In recent decades, climate change (Walther *et al.,* 2002) has driven biodiversity toward strong spatial and temporal dynamics. This phenomenon is particularly concerning in mountainous areas, where climate change is compounded by changes in land use (Pătru-Stupariu *et al.*, 2020; Amezтegui *et al*., 2021). The abandonment of less profitable agricultural areas and rising temperatures are reshaping landscapes in rural areas (Tasser *et al*. 2023), resulting in a notable decline in bird communities in terms of both richness and abundance (Pearce-Higgins *et al*., 2016; Scridel *et al*., 2018; Allen *et al.*, 2019). In northern Italy, climate change is manifesting in rising temperatures and decreasing precipitation (Fratianni & Acquaotta, 2017), while land use is showing mainly reforestation (Falcucci *et al.,* 2007).

To safeguard biodiversity, mountain-protected areas play a crucial role (Kollmair *et al*., 2005), and also smaller ones can contribute significantly to preserving species and habitats at the local scale, particularly in addressing habitat loss from anthropization, land use, or natural resource exploitation. However, their limited extension may have limited effectiveness in counteracting the ongoing long-term trends from the recent climate changes, as has been observed in larger areas as well (Holsinger *et al.,* 2019). Management activities targeted at conserving habitats or species demand a thorough understanding of the biological communities within their jurisdiction. It is also essential to remain vigilant on their evolution in response to any changes. To achieve this knowledge, it is often necessary to

use easily collected taxon-based bioindicators, which can serve as proxies for poorly known taxonomic groups and require fewer resources (Lindenmayer *et al*., 2015; Yong *et al*., 2018). Indicator species are defined as species closely tied to a particular habitat type and sensitive to changes in environmental conditions (Simamora *et al.,* 2021). The use of birds as bioindicators has been widely applied in mountain areas (Scridel *et al*., 2018), and the validity of birds as bioindicators for other taxa has been proven worldwide (Eglington *et al.,* 2012; Anderle *et al*., 2024). Birds are a well-known and easily counted group, occupying most habitat types and different ecological niches; furthermore, they provide important ecosystem services, like as seed dispersal (Garcia *et al*., 2010), pest control, and recreational interest (Sekercioglu *et al.,* 2016).

The Monte Fenera Natural Park (MFNP) serves as a perfect example of the forest encroachment process in the Alps. The abandonment of family-run traditional management practices and, in some cases, the depopulation of many rural areas are inducing changes in land use and within various faunal communities. The process is evident and likely accelerated at the margins of the Alps, possibly exacerbated by rising temperatures, leading to a reduction in the extent of semi-natural areas that once covered the mountain slopes, now gradually being replaced by forests. The term "forest" must mean a "dynamic complex of plant, animals and micro-organism communities and their abiotic environment interacting as a functional unit, where trees are a key component of the system" (Chazdon *et al*., 2016). This study highlights the impact of forest encroachment on breeding birds in the pre-Alpine belt of northwestern Italy. Additionally, the results aim to offer an updated tool delineating the current breeding bird community, facilitating the efficient allocation of resources and efforts for the conservation of habitats and/or species within the protected area and surroundings.

MATERIALS AND METHODS

Study area

The MFNP is located in north-west Italy, in Piedmont, within the alpine biogeographical area, at the interface with the continental one. Designated as a Regional protected area in 1987 and recognized as a Site of European Interest in 1995 as part of the "Natura 2000" Network (code IT1120003), it was granted "Special Protection Area" status in 2017 (European "Habitat" Directive 92/43/CEE).

The protected area covers 3348 ha, characterized by a rugged topography with an altitudinal range from 300 m to the summit of "Monte Fenera", which stands at 899 m.

Currently the area is almost entirely covered by dense forests (92%) (Mosini *et al*., 2024), mainly of *Castanea sativa* woods (Directive 92/43/CEE, Annex I, habitat code: 9260; extent: 55%), but also with presence of Sub-Atlantic and medio-European oak-hornbeam forests (9160; 12%), *Robinia pseudacacia* woods (10%), *Quercus sp*. thermophilic woods (5%), Luzulo-Fagetum beech forests (9110; 3%), Tilio-Acerion forests of slopes (9180*; 3%; * = priority for the Directive 92/43/CEE) and Alluvial forests with *Alnus* and *Fraxinus* (91E0*; <1%). Scattered coniferous forests are also present, but mainly as a result of past forestry management, featuring the exotic *Pinus nigra* (<1%). Open areas cover 6% of the total, encompassing a few hectares of habitats of conservation interest, such as European dry heaths (4030), lowland hay meadows (6510), and calcareous rocky slopes and inland cliffs (8210), contributing to total coverage of approximately 3%. The remaining portion pertains to rural areas, including vineyards (2%), orchards, and vegetable gardens. Finally, less than 2% of the entire area is inhabited.

The MFNP is also famous for its caves not open to the public (8310), making the area interesting from an archaeological and paleontological point of view. Particularly noteworthy is the karst cave known as "Grotta del Laghetto", with a small entrance located in the middle of the broadest rock patch, at 15 m high from the ground and extending 55 m deep (Cave n°PI2547; AGSP, 2024). From this cave, more than 5000 remains of faunal bones were unearthed in a paleo-soil dating back 3000 years. These findings mainly include birds (30%) and small mammals (Strobino & Janvier, 1971). More recent studies from the nearby cave "Ciota Ciara", with a ground-level wider entrance, dated other faunistic remains back to 35,000-100,000 years ago (Arzarello *et al*., 2012; Berto *et al*., 2016). Among the bird remains, typical alpine taxa were present, such as *Lyrurus* sp. and *Lagopus* sp.*,* along with taxa likely from the post-glacial open-steppe period, including *Perdix* sp., *Pica pica*, and *Tyto alba.* Additionally, some species were more reminiscent of the current community and more associated with forested habitats, such as *Corvus corone*, *Coccothraustes* sp., *Columba palumbus,* and *Streptopelia turtur*. The best guess is that all these findings constitute predation remains of birds of prey, and maybe small carnivores, from the past, which used the cave for breeding or roosting over the last millennia. The outcome of this scenario is a fairly representative collection of the fauna present in the area since the last glaciation (Holocene). Furthermore, the pollen discovered in the paleo-soils, dating back 2000 to 3000 years, indicates an abundance of *Fagus sylvatica* and coniferous plants, with very low frequencies of *Quercus sp*. (Strobino & Janvier, 1971), suggesting quite colder temperatures from a humid temperate domain. All this historical information sheds light on changes over the past millennia, both in the landscape and bird communities.

Field surveys

To compare the breeding bird community of the MFNP over the last 30 years, it was necessary to plan the surveys from the year 2023 (3rd survey) to ensure comparability with previous ones, conducted during 1992-1997 (1st survey) and 2002-2007 (2nd survey) (Bordignon, 1999; 2008). To do this, it was necessary to refer all data to a spatial grid with square meshes of 500 m on each side (0.25 km^2). The necessity to conduct investigations only during the 2023 breeding season prevented comprehensive surveys for all 145 resulting squares. Exhaustive investigations were instead conducted previously in the 1st and 2nd surveys, requiring a 5-year-long sampling effort. Detailed results from the 2nd survey are reported only for the species that increased or decreased in frequencies over 30%, and the trend for all the other ones was considered "stable" (Bordignon, 2008), while from 1st survey results are reported detailing the distributions of each species for each mesh (0.25 km^2) of the grid of the whole study area (Bordignon, 1999). Thus, in 2023, to achieve

comprehensive and comparative monitoring, 27 sample squares were meticulously selected to ensure that: i) they represented all the main habitats; ii) they were evenly distributed across the area; and iii) they encompassed all the breeding species recorded in the first two surveys. Next, frequencies were compared by filtering the previous datasets to include only the 27 squares common to all three periods. This comparison also involved assessing the number of breeding pairs when present, or simply considering the breeding presence for some species (as in the case of some raptors). Because the study area is almost entirely covered by forests, the 27 sampling squares covered the most representative, and almost all, non-forested habitats. By doing so, species that breed in open habitats, for which an underestimation could be occurring, could only fall within one of the 27 selected cells.

Birds were surveyed in all 27 selected squares using a 10-minute point-count method (Bibby *et al.,* 2000; Klingbeil & Willig, 2015). Each point-count was at least 400 m apart from another, and all of them were visited three times during the breeding season, from mid-March to mid-June. Surveys were conducted within the first 5 hours following dawn, without the limitation to a 100-m radius. Point counts were distributed across the three more representative habitats: 9 in forests; 9 in open rural areas (countryside, vineyards, etc.); 8 in natural open habitats and ecotones (hilltops, clearings, edges of rocky outcrops), while only 1 site was located in the suburban village of "Arlezze" (Fig. 1). This last site is the only one outside the MFNP, but 500 m apart from the boundaries. It was selected to investigate potential changes from the nearest suburban area and assess anthropophilic species, benefiting from comparable data from the two past investigations. To avoid biases that arise from potential breeding observations by individuals far from their actual nesting site, only certain breeding observations were considered for the genera *Apus, Delichon, Corvus, Hirundo*, and *Ptyonoprogne.*

Not all species could be surveyed properly using point counts, leading to the integration of the investigation with *ad-hoc* samplings to confirm the breeding presence of these other taxa in the MFNP, either inside or outside the 27 selected squares. Nocturnal birds (Strigiformes and Caprimulgidae) were surveyed following the recommendations of Zuberogoitia & Campos (1998), using 20-minute nocturnal point counts conducted within the first 2 hours after sunset, and for these, we return only reproductive confirmation in the area with no more details. The nocturnal point counts comprised 10 minutes of passive listening to calls, followed, if appropriate, by playback recording of territorial songs/calls for the genera *Asio, Athena, Caprimulgus, Otus*, and *Strix*. Playbacks were broadcast based on the size of the owls, from the smallest to

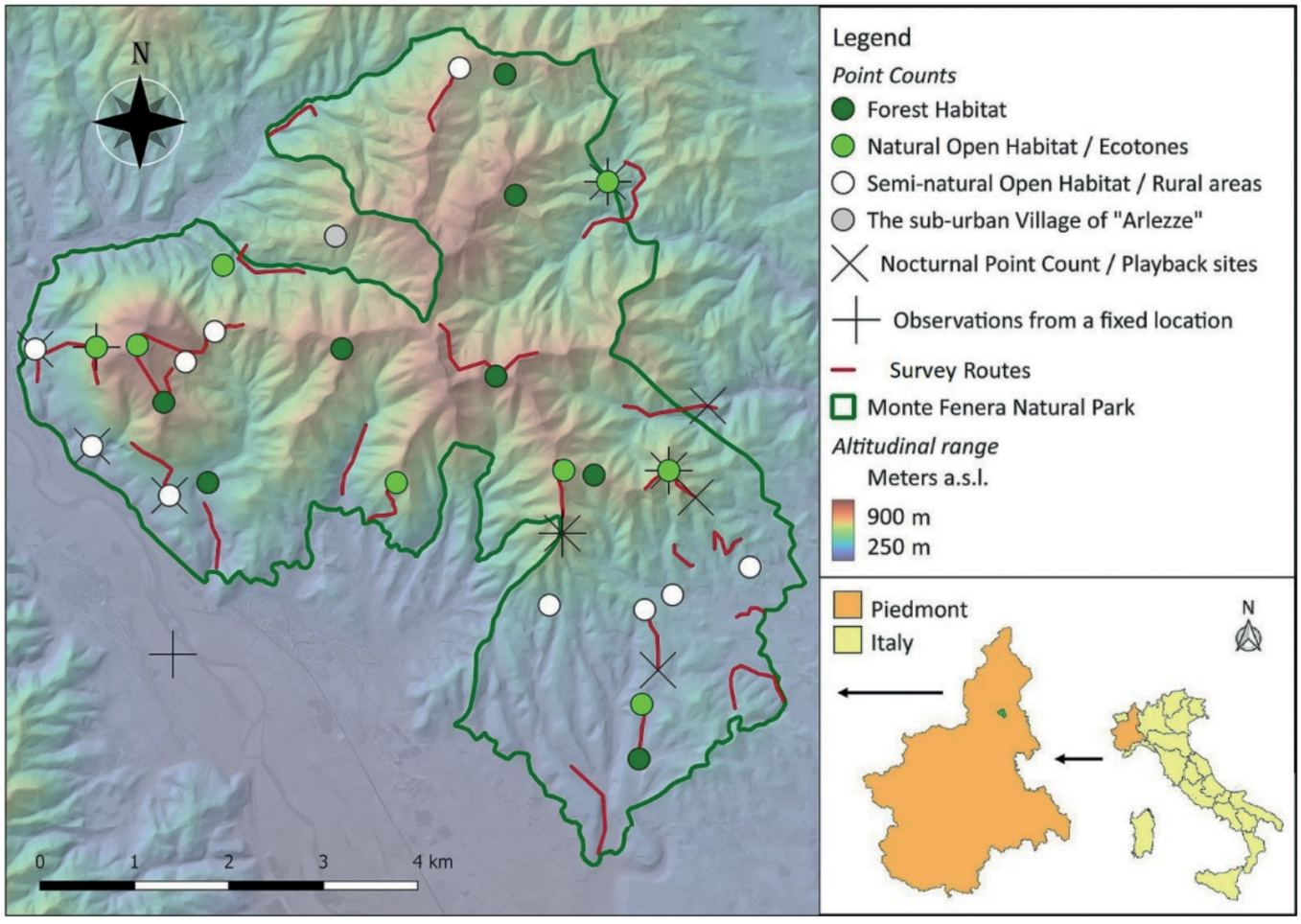

Fig. 1 – Map of the study area and administrative details at the regional and national scale. / Mappa dell'area di studio e dettagli amministrativi a scala regionale e nazionale.

the largest, starting with *Caprimulgus*. Playback referring to *Bubo bubo* has never been played, and it was sometimes stimulated with the playback of *Strix aluco.* Nocturnal surveys were conducted at 9 sites, sometimes repeated twice between November 2022 and June 2023 (depending on the target species), resulting in a total of 17 nights of surveys. For *Caprimulgus europaeus* and *Strix aluco,* all singing territorial males were censused from a sample area of about 400 ha and located between the localities "Motto della Capretta" and "La Pelosa", in the south-eastern part of the study area.

Specific surveys were also conducted for raptors, *Ciconia* sp., and *Corvus corax,* following the recommendations of Andersen (2007). Observations by fixed location were conducted, supplemented by additional data collection during car/on-foot transfers in the study area. The counts at fixed locations spanned 5 days between mid-March and mid-May, including one day with simultaneous counts from three sites (on March 21st).

Furthermore, specific survey routes were conducted at least once during the breeding season to search for elusive or low-density species, such as *Cinclus cinclus, Motacilla cinerea*, *Phylloscopus bonelli*, and *P. sibilatrix*, whose breeding presence might have been overlooked within the 27 selected squares. Additionally, these routes improved breeding observations for all species, especially by integrating data from other methods to confirm the absence of breeding individuals.

Checklists details

The checklists of breeding birds reported in the results include detailed information, provided as follows.

1. The classification, taxonomy, and common names are based on the CISO-COI Checklist (Baccetti & Fracasso, 2021).
2. Breeding evidence is represented by categorized observations to determine whether the species is a possible, probable, or confirmed breeder. Recording information about the likelihood that a bird species breeds in the area is essential to distinguish actual breeding birds from those using the area during post-breeding dispersal, migration, or wintertime. The breeding codes used in this work follow those of the last breeding bird atlas in Italy (Lardelli *et al*., 2022), which have become the basis for many Italian atlases in the last decades. The highest code for all the breeding species from the year 2023 is reported, and the descriptions of the only used codes are provided as follows: i) possible: ***cod. 3*** "singing bird in suitable nesting habitat"; ii) probable: ***cod. 4*** "pair observed in suitable nesting habitat"; ***cod. 5*** "singing male present at the same location on at least two times 10 or more days apart"; ***cod. 6*** "repeated visits to a probable nest site by the pair"; ***cod. 7*** "courtship behavior with male and female"; ***cod. 8*** "agitated behavior or anxiety calls from adults indicating a nest site or young in the vicinity"; ***cod. 10*** "adult carrying nesting material or nest-building"; iii) confirmed: ***cod. 13*** "recently fledged or downy young still dependent upon adults and incapable of extended flights"; ***cod. 14*** "occupied nest indicated by adult entering nest site and remaining"; ***cod. 16*** "adult carrying food for young"; ***cod. 19*** "nest with eggs or young seen or heard".
3. The trend of the breeding species is reported as frequency, resulting in comparing the number of occupied squares (among the 27 selected squares) since the first survey in 1997, and the two subsequent investigations, updated to 2007 (Bordignon, 2008) and 2023 (present study).

RESULTS

In total, 2126 data were collected in the entire area from November 2022 to October 2023. Of these, 873 were obtained from point counts, 17 from night surveys, 18 from fixed points, and the remaining 1218 were derived from survey routes and occasional observations. In 2023, 48 breeding species of birds were confirmed, and frequencies (Tab. 1) or the number of breeding pairs (Tab. 2) were compared with the two previous surveys.

Tab. 1 – Breeding bird frequencies for the study area and their trends over the last 30 years are reported. / Sono riportate le frequenze degli uccelli nidificanti nell'area di studio e le loro tendenze negli ultimi 30 anni.

Scientific name	Frequencies in the study area (%)			Additional info		
	1° survey (1992-1997)	2° survey (2002-2007)	3° survey (2023)	2023 – higher breeding code	Trend 1°-2°surveys (Bordignon, 2008)	Trend 1°-3° surveys (present work)
Colinus virginianus	7	0	0	-	Dis.	Dis.
Coturnix coturnix	0	-	4	3	-	(?)
Phasianus colchicus	15	-	7	3	Dis.	(?)
Columba oenas	0	-	11	5	-	New
Columba palumbus	33	-	74	13	s	>>
Streptopelia turtur	15	-	0	-	s	Dis.
Streptopelia decaocto	4	-	0	-	s	Dis.
Tachymarptis melba	11	-	0	-	s	Dis.
Apus apus	19	-	22	14	s	>

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Scientific name	Frequencies in the study area (%)			Additional info		
	1° survey (1992-1997)	2° survey (2002-2007)	3° survey (2023)	2023 – higher breeding code	Trend 1°-2°surveys (Bordignon, 2008)	Trend 1°-3° surveys (present work)
Cuculus canorus	63	-	67	5	s	s
Jynx torquilla	4	0	0	-	Dis.	Dis.
Picus viridis	52	-	63	16	s	>
Dryocopus martius	11	52	56	13	>>	>>
Dryobates minor	44	63	33	5	>	<
Dendrocopos major	78	-	85	13	s	s
Lanius collurio	19	0	0	-	Dis.	Dis.
Garrulus glandarius	89	-	70	13	s	<
Pica pica	0	0	4	16	-	New
Corvur corone cornix	52	-	19	13	s	<<
Periparus ater	26	-	7	5	s	<<
Lophophanes cristatus	0	4	0	-	New	Dis.
Poecile palustris	56	-	52	13	s	s
Cyanistes caeruleus	63	-	74	16	s	>
Parus major	56	-	96	16	s	>
Lullula arborea	0	0	4	3	-	(?)
Hippolais polyglotta	11	7	0	-	<<	Dis.
Delichon urbicum	4	-	0	-	s	Dis.
Hirundo rustica	15	7	0	-	<<	Dis.
Phylloscopus bonelli	33	22	0	3	<	<<
Phylloscopus sibilatrix	4	0	0	-	<<	Dis.
Phylloscopus collybita	56	-	74	5	s	>
Aegithalos caudatus	74	-	81	16	s	s
Sylvia atricapilla	81	-	96	5	s	>
Certhia brachydactila	22	-	4	5	s	s
Sitta europea	67	-	96	13	s	>
Troglodites troglodites	74	-	59	5	<	<
Sturnus vulgaris	11	0	11	13	Dis.	s
Turdus philomelos	30	-	70	5	s	>>
Turdus merula	78	-	100	16	s	>
Muscicapa striata	67	-	30	5	s	<<
Erithacus rubecola	89	-	85	8	s	s
Luscinia megarhynchos	22	11	0	-	<<	Dis.
Phoenichurus ochrurus	11	19	41	16	>>	>>
Phoenichurus phoenichurus	22	-	15	5	s	<
Regulus ignicapillus	7	11	22	5	>	>>
Passer italiae	30	22	7	19	<	<<
Passer montanus	19	11	0	-	<	Dis.
Motacilla cinerea	15	-	7	5	s	<
Fringilla coelebs	89	-	96	10	s	s
Coccothraustes coccothraustes	7	-	7	5	<	s
Pyrrhula pyrrhula	30	7	0	-	<<	Dis.
Chloris chloris	63	-	59	-	s	Dis.
Carduelis carduelis	26	15	4	13	<	<<
Serinus serinus	15	-	15	5	s	s
Emberiza cia	11	-	0	-	s	Dis.
Emberiza cirlus	15	19	15	5	>	s

<<, strong decline (<55%); <, decline (-20% <-50%); s, stable (±10%); >, increase (15% <75%); >>, strong increase (>120%); conf., species confirmed to breed in the area with at least one pair; dis., species disappeared as breeding species; new, new breeding species; (?), uncertain data; -, not available data.

Out of these, 38 species were confirmed through point counts, while all raptors, *Caprimulgus europaeus, Cinclus cinclus,* and *Corvus corax*, were verified through *ad-hoc* surveys, with at least one breeding pair in the study area. For these ten last species, quantitative data for comparison were not collected. The checklist of the 121 total species of birds ever observed in the study area is provided in *Tab. S1*.

The results revealed the absence of 24 breeding species, referring to previous data. Four species were lost before the year 1993 (*Athene noctua*, *Bubo bubo, Jynx torquilla*, *Perdix perdix*), two more were lost before 2005 (*Colinus virginianus, Falco tinnunculus*), other 14 species were lost in the years leading up to 2023 (*Apus apus, Chloris chloris, Delichon urbicum, Emberiza cia, Falco subbuteo, Hippolais polyglotta, Luscinia megarhynchos, Milvus migrans, Passer montanus, Pyrrhula pyrrhula, Ptyonoprogne rupestris, Streptopelia decaocto, S. turtur, Tachymarptis melba*), while three species are considered irregular breeders due to their appearance and subsequent disappearance in a relatively short time (*Ciconia nigra, Lophophanes cristatus*, *Philloscopus sibilatrix)*.

In summary, the results revealed 6 species with a strong decline, 5 species in decline, and 3 species considered dubious due to their popularity in hunting (*Colinus virginianus*, *Coturnix coturnix, Phasianus colchicus*), whose presence could be related to hunting purposes. Additionally, 1 species (*Sturnus vulgaris*) resumed breeding after 2007, 10 species show stable trends, 8 species increased, and 5

Tab. 2 – Breeding birds in the Monte Fenera Natural Park verified through *ad-hoc* monitoring with reported numbers of nesting pairs (values marked with an asterisk "*" come from a 400-ha sampled area). The year of the last observation or the census is reported. / Uccelli nidificanti nel Parco Naturale del Monte Fenera verificati attraverso un monitoraggio *ad hoc* con il numero di coppie nidificanti riportato (i valori contrassegnati dall'asterisco "*" provengono da un'area campionata di 400 ettari). È riportato l'anno dell'ultima osservazione o del censimento.

Scientific name	Last confirmations before the year 1992	1° survey (1992-1997)	Notes 1° survey	2° survey (2002-2007)	Notes 2° survey	3° survey (2023)	2023 - higher breeding code
Perdix perdix	1960	0		0		0	-
Columba oenas	1976	0		0		3	5
Streptopelia turtur	-	9	1995	-		0	-
Streptopelia decaocto	-	3		-		0	-
Caprimulgus europaeus	-	8*	1992	-		10*	7
Tachymarptis melba	-	8	since 1996	-		0	-
Ciconia nigra	-	1	1994-1996	0		0	-
Athene noctua	1970	0		0		0	-
Strix aluco	-	27	1992	-		5*	8
Bubo bubo	1985	0		0		0	-
Pernis apivorus	-	6	1994	7	2006	≥1	7
Circus gallicus	-	1		-		1	7
Accipiter nisus	-	5	1994	-		≥1	19
Accipiter gentilis	-	1		3		≥1	4
Milvus migrans	-	1		-		0	-
Buteo buteo	-	11	1993	-		≥1	13
Jynx torquilla	-	2	since 1992	0		0	-
Dryocopus martius	-	1		4		6	13
Falco tinnunculus	-	1		0	from 2005	0	-
Falco subbuteo	-	1		-		0	-
Falco peregrinus	-	1		1		1	6
Lanius collurio	-	8		0	from 2001	0	-
Pica pica	-	0		0		1	16
Corvus corax	-	2		3		≥1	13
Hippolais polyglotta	-	7	1996	3	2007	0	-
Hirundo rustica	-	15	1992	5	2007	0	-
Ptyonoprogne rupestris	-	1		0		0	-
Phylloscopus bonelli	-	29	1996	18	2006	1	3
Cinclus cinclus	-	4		-		≥1	13
Luscinia megarhynchos	-	29	1994	14	2007	0	-
Passer montanus	-	65-75	1994	32-34	2006	0	-
Pyrrhula pyrrhula	-	≥10		3-4		0	-

species strongly increased. Notably, *Pica pica* nested for the first time in the area, and *Columba oenas* nested for the first time in thirty years, with no observations from 1976.

DISCUSSION AND CONCLUSIONS

General considerations about forest encroachment in the Monte Fenera Natural Park

In the MFNP, landscape re-shaping is still ongoing. Although some natural open habitats, such as the edges of rocky outcrops and arid summits, may persist in the medium term, the situation for open areas still actively exploited by humans is different. Without an inversion of the trend concerning reforestation, more breeding species could be lost soon. The three species with the highest risk of ceasing breeding in the area are *Carduelis carduelis, Corvus cornix*, and *Phylloscopus bonelli*, all observed exhibiting breeding behavior from only one location each, in 2023.

The overall breeding bird community of the study area seems to be transitioning into a distinctive forest reference community. Species richness increased in mature woodland contexts over time, while open areas experienced a noticeable decline in species. The phenomenon is mainly attributed to the abandonment of mostly family-run traditional management, which previously maintained a more heterogeneous semi-natural landscape than the climax of this area suggests.

The species richness observed in each of the 27 selected squares ranges from a minimum of 7 breeding species to a maximum of 27 species. These extreme values correspond to the identical squares identified in previous surveys as the least and the richest, with the counts respectively of 3 and 32 species in 1997, and 4 and 32 species in 2007. Upon closer examination of these two areas, we observe that the least square is primarily characterized by a young chestnut forest and is located in a warm hilltop area. Conversely, the richest square is situated within a semi-natural environment that is still managed, featuring diverse habitats, such as mature broad-leaved forests, clearings with pioneer vegetation, rocky outcrop edges, vegetable gardens, small orchards, and scattered houses in the hilltop village named "La Colma". Additionally, the point count in this square is situated in the backyard of the 16th-century Church of St. Antonio Abate. Historically, this old building hosted several breeding species on its bell tower, including *Falco tinnunculus* and *Tachymarptis melba*, both absent in 2023. The significant variation in species richness is further exemplified by the pronounced positive trend observed in indicator birds specific to forest habitats, including *Dryocopus martius* (increased by 400%; from 1 to 6 breeding pairs), *Regulus ignicapillus* (+200%), *Turdus philomelos* (+137%), and *Columba palumbus* (+122%). This is further supported by the positive trend of *Cyanistes caeruleus, Phylloscopus collybita, Picus viridis, Sitta europaea*, and *Sylvia atricapilla*, which have shown increased frequencies ranging from 17% to 75%. The response of the breeding bird community to forest encroachment is further exemplified by the absence in the year 2023 of species indicative of open habitats, such as *Hippolais polyglotta, Lanius collurio, Passer montanus*, and *Streptopelia turtur*. The declines of *Carduelis carduelis* (-87%) and *Phylloscopus bonelli* (-89%) are equally significant. Another significant decline is noticeable among more anthropophilic species, like *Delichon urbicum, Hirundo rustica*, and *Streptopelia decaocto*, absent as breeding species in 2023. This pattern is similarly observed in *Passer italiae* (-75%), *Corvus cornix* (-64%), and *Muscicapa striata* (-55%), in decline across the entire area. The sole exception is the remarkable 266% increase in *Phoenicurus ochruros*, accompanied by the appearance of *Pica pica* and the return of *Sturnus vulgaris* as a breeding species. For the latter species, insights from the Italian population trends (Rete Rurale Nazionale & Lipu, 2023) may explain their countertrend despite the decline in human presence in the area. This is particularly plausible for *P. pica* and *P. ochruros*, which thrive in urban areas with high population densities (Kopij, 2017).

The overall trend of the bird community remains consistent when comparing data over intervals of 10 or 25 years, a coherence that aligns with the observed landscape evolution in other mountainous regions across Europe (Guilherme *et al*., 2013; Ameztegui *et al*., 2021). This trend is similarly observed in semi-natural landscapes that may not be strictly classified as mountainous, featuring expansive open areas, such as the heathlands of Northwestern Italy (Cattaneo, 2000; Battisti & Bordignon, 2014), as well as upland regions in northern Europe (Douglas *et al*., 2020; Corkery *et al.,* 2020).

Given that the abandonment of rural management is the primary cause of forest encroachment, particularly at medium to lower altitudes along the Alps and latitudes across Europe, this recent landscape transformation could be deemed "natural", as it tends to progress towards the climax state. In this perspective, the question arises: what are the true benefits of investing resources to preserve habitats and/or species whose presence was influenced by human traditional management rather than occurring naturally? This consideration becomes even more relevant for small, protected areas with limited effectiveness in counteracting the ongoing long-term trends both from the recent climate changes and the decline of family-run management in mountain areas, which are reflecting future environmental and socioeconomic uncertainties (Schirpke *et al*., 2023). However, given that we are currently experiencing the ongoing sixth mass extinction caused by human activities (Ceballos *et al*., 2015), it is concerning to keep in mind that these open areas harbor a high number of species of conservation concern (Allen *et al*., 2019; Corkery *et al.,* 2020). In conclusion, conservation efforts for small, protected areas should aim for the best possible compromise. In many pre-alpine regions, conserving semi-natural habitats shaped by family-run management and their resident species may require substantial efforts due to trends of depopulation and migration, which are encouraged by the proximity of developed plains and towns. Alternatively, a more effective approach could prioritize the conservation of more stable endemic habitats. Looking specifically at MFNP, the conservation of semi-natural open habitats may not be economically sustainable in the long term, given the ongoing demographic decline in five out of the six municipalities within the protected area (Mosini *et al.,* 2023). At this local scale, prioritizing forest management to benefit protected species like *Dryocopus martius, Columba oenas*, and *Caprimulgus europaeus*, or facilitating the return

of *Ciconia nigra*, would likely have a greater impact on bird conservation than attempting to reintroduce traditional land exploitation practices to enhance open habitats or promote bird richness.

Comments for selected taxa strictly related to the Monte Fenera Natural Park

The high number of species that have disappeared as breeding birds might leave some doubts about the results derived from the comparison made during a single breeding season (the year 2023), as it might not be sufficient to draw definitive conclusions about the permanent absence of certain species. Species that might exhibit irregular breeding or have been absent in 2023 due to exceptional circumstances, such as the drought in 2022 (Montanari *et al*., 2023), or otherwise. For example, *Phasianus colchicus*, *Ptyonoprogne rupestris*, and *Sturnus vulgaris* were locally declared extinct as breeders in 2007, while they have been observed exhibiting reproductive behaviors in the subsequent years. For this reason, species that have been absent as breeders after 1997 are referred to in this work as "disappeared", without categorizing them as "locally extinct". In some cases, it is possible that these species may resume breeding, and such a possibility cannot be discounted. To gain a clearer insight into the observed trends for some species, a detailed account of the breeding history spanning the past 50 years is provided. This includes all species absent as breeders in 2023, species protected at the European level (Annex I, Birds Directive 2009/147/EC), and other species of particular interest at the local scale. All historical data, unless stated otherwise, are sourced from Bordignon (2008).

Comments on 34 species follow (alphabetical order)

Athene noctua

This species was present until 1960 around the village of "Ara", and until 1970 in the vineyards around the Sanctuary of Boca. Since 1991, the species has never been observed, except for one recently fledged young observed in the summer of 1996, but 300 m outside the boundary of the protected area in the direction of the village of "Boca" (Bordignon, 1999). This last observation is in line with the only one pair observed during transfers around the study area in 2023, and it was 1 km away from the boundaries of the MFNP.

Bubo bubo (protected)

This species was present until 1985 along the cliffs of the Monte Fenera, with one breeding pair. Since 1986, the species has not been encountered, except on a single occasion in February 2006 when a singing male was heard multiple times throughout the month, but without further confirmation in the following months. This species was actively searched for in winter 2022-23, with nocturnal point count close to the locations "Fenera S. Giulio", "F. Annunziata", and "Ara". Among the hypothesized causes of abandonment in the '90s were the disturbances that occurred in 1985 due to excavation operations near the diurnal roost of the pair, and the ongoing rodent control activities. Anyway, the absence of breeding for this species over the past 30 years could be attributed to a combination of factors, including heightened disturbance along nesting sites. Sport climbing became popular at this site in the late '80s and was later prohibited in the mid-'90s to protect the new pair of *Falco peregrinus* that started breeding on site. As a result, a new climbing crag was established above the village of "Ara", impacting another small cliff potentially used as a roost or maybe also as a nesting site. In comparison, archaeological and speleological activities have been conducted near the cliffs since the '50s, including the construction of the Archaeological and Speleological Group of Borgosesia (GASB) refuge, which sometimes involved the use of explosives, but also despite this, the pair of *B. bubo* was still present in the early '80s. In conclusion, forest encroachment may have contributed to reduced environmental suitability for *B. bubo,* favoring *F. peregrinus* instead, as already observed elsewhere in the Alps (Penteriani *et al*., 2002; Brambilla *et al*., 2010). Indeed, *F. peregrinus* began nesting along the cliff right in 1992. Anyway, irregular reproductive attempts of *B. bubo* cannot be ruled out today, especially since the surrounding alpine population is in good health, and juvenile dispersal movements are far from limited (Aebischer *et al*., 2010).

Caprimulgus europaeus (protected)

The species breeds along the drier slopes of the area, amidst heathland patches and ecotones with forested areas. In 2023, at least 13 different territorial males were observed in approximately 500 ha in the southeastern sector, with 10 of them inside the boundaries of the MFNP (400 ha).

Chloris chloris

The species was confirmed to nest until 2007 in rural areas and vineyards, with no substantial changes in distribution between 1997 and 2007. Its absence as a breeding species in the following years confirms the regression observed in Italy (Lardelli *et al*., 2022; Rete Rurale Nazionale & Lipu, 2023). In 2023, only one individual was observed close to the village of "Ara" (March 17th), but without confirmation of breeding behavior.

Ciconia nigra (protected)

The MFNP was the first breeding site discovered in Italy (Bordignon, 1995). However, successful nesting only occurred from 1994 to 1996, with the fledging of 9 young birds in three years. In 1997, the pair only frequented the area, and from 1998, it was no longer observed. The abandonment of the nesting site was presumably caused by disturbance from a few photographers (L. Bordignon, pers. com.). Anyway, this species has begun nesting also in other nearby areas with similar environmental conditions, within a radius of 10 to 80 km. The 2-3 breeding pairs occurring in the surroundings have shown reasonable breeding success over the last 20 years (Fraissinet *et al*., 2018), indicating that the MFNP may still serve as a suitable breeding area (Fontaneto *et al*., 2006). The species' absence can be attributed to the absence of large areas devoid of human disturbance. The area used by the pair in the '90s is now affected by hiking trails and mountain bike routes, as well as an off-road racetrack 3 km away from the past nesting site. It is a protected species, which is why, if it were to nest again, it would be advisable to take greater precautions to ensure successful breeding.

Circaetus gallicus (protected)

The species currently nests, as it did in the past, with at least one breeding pair in the southern part of the area.

Columba palumbus

Forest species which has shown a significant increase in the study area, as well as the species with the highest

continuity and intensity of growth in Italy (Campedelli *et al*., 2012; Lardelli *et al*., 2022; Rete Rurale Nazionale & Lipu, 2023) and Piedmont (Boano *et al*., 2023) over the last decades.

Columba oenas

This species was known to breed in the past in Valsesia (Giglioli, 1889), with confirmation until 1976 in larger fruit chestnut trees near the village of "La Colma" (G. Berlassini, pers. com; Bordignon, 2008). A singing male was also recorded at this location in April 1993, but there was no further confirmation. In 2023, at least 3 territorial males were confirmed between March and June in the areas of "La Colma", "Bertagnina", and "Montalbano", suggesting a potential return of the species. This trend aligns with observations from Piedmont (Boano *et al*., 2023) but contrasts with those reported for the rest of Italy (Lardelli *et al*., 2022).

Delichon urbicum

This species bred until 1993 exclusively in the village "La Colma", with 3-5 pairs. Subsequently, the gradual abandonment of small settlements and the forest encroachment near the houses likely contributed to the abandonment of breeding sites.

Dryocopus martius (protected)

The species bred for the first time in 1996, in the middle of the study area. Subsequently, it rapidly expanded, forming 4 breeding pairs in 2007 and at least 6 in 2023 (enlarged to 8 pairs considering the surroundings of the MFNP), with an increase of 400% in the last 30 years. This trend is consistent with observations in Italy (Lardelli *et al*., 2022), particularly with those from the foothill belt of Piedmont (Boano *et al*., 2023).

Emberiza cia

The species bred with 6 confirmed pairs in 1993, along the slopes of the Monte Fenera and ridges with sparse vegetation between the locations "Sasso Bianco", "Croce del Teso", and "La Pelosa". No significant changes in distribution were reported between 1997 and 2007. Its absence as a breeding species in the following years confirms the decline observed in pre-alpine areas in Italy due to forest encroachment (Boano *et al*., 2023).

Emberiza cirlus

A breeding species in the southern part of the area, with 21 territorial males recorded in 1995. After the year 2000, the species significantly increased, with 32 males recorded in 2007, also at hilltop locations and in the heart of the area. However, in 2023, only 4 territorial males were confirmed in the remaining vineyards, confirming the overall fluctuating trend observed in Italy (Lardelli *et al*., 2022) and especially in Piedmont (Boano *et al*., 2023).

Falco peregrinus (protected)

This species has nested in the broadest rock wall below the Monte Fenera for the first time in 1992, with one or two young fledged each year from 1993 onward for the following 5 years (Bordignon, 1999). Since then, no further monitoring has been done, but the species appears to have continued breeding, with observations of fledging young between 2015 and 2022 by archaeologists active at the site (M. Arzarello, pers. com.). On the 3rd of March 2023, one of the adults was found dead a few meters away from the nest, under a service cable suspended near the cliff, likely resulting in death from impact. From March 21st to the end of June, another individual started to frequent the nesting site, along with the remaining adult, without being mobbed away, thus suggesting the formation of a new pair. However, given the age of the new individual (first cycle, juvenile plumage) or the lateness of the breeding season, no breeding occurred in 2023. An update from June 2024 reported two chicks observed in the nest (MFNP Surveillance Corp, pers. comm.). Since it is a protected species, it is crucial to emphasize the need for careful management of maintenance and service activities at the GASB refuge.

Falco tinnunculus

Breeding species with two known pairs until 1990, one along the cliffs of Monte Fenera and one along the wall of the Sanctuary of Boca. In the year 2004, the last pair at the Sanctuary ceased breeding. In 2023, the situation seems unchanged from 2007, with only two immature individuals (first cycle, juvenile plumage) observed, one at each of the two known sites. The establishment of the *F. peregrinus* pair may have led to the abandonment of the rock breeding site by *F. tinnunculus*. Anyway, since the Italian population of the species is stable (Lardelli *et al*., 2022), its disappearance as a breeding species is probably due to forest encroachment.

Hippolais polyglotta

The species mainly bred in the vineyards surrounding the Sanctuary of Boca, with 7 pairs recorded in 1997 and 4 pairs in 2007, indicating a decline that continued until its disappearance in 2023.

Jynx torquilla

This species was common in the past during breeding time and was also described as "numerous in fruit chestnut orchards". The last two territorial males were observed in 1992, in the countryside near the villages "Ara" and "Baraggiotta". The species was already in decline in Italy in the '90s and after (Campedelli *et al*., 2012; Rete Rurale Nazionale & Lipu, 2023), and this trend continues today. Although favorable habitat still existed in some vineyards within the MFNP until 2007, there have been no confirmed or probable breeding observations since 1992, except for a few possible unconfirmed breeding instances until 1997. In this regard, artificial nest boxes could compensate for the lack of natural cavities and potentially lead to some nesting of the species again (Assandri *et al*., 2018).

Hirundo rustica

The breeding population consisted of around 15 pairs in the early '90s. It was an abundant species, particularly around the village of "Ara", and nesting was also reported at "La Colma", in 1992. Bordignon warned of the risk of local extinction as early as 1997, and in the year 2007, only 3 pairs were nesting around "Ara", disappearing definitively shortly after.

Lanius collurio (protected)

The species nested in rural areas and vineyards, mainly in the southern part of the study area. Breeding pairs decreased from 8 to 3 between 1992 and 1997, and they have been absent since 2000, with the presence of a single male without breeding confirmation. The effectiveness of conservation efforts for this protected species can only be considered if there is a new positive trend in expanding crop

and vineyard areas. In this scenario, promoting heterogeneity and traditional hedgerow use is advisable (Casale & Brambilla, 2009).

Luscinia megarhynchos

The species mainly bred in the vineyards surrounding the Sanctuary of Boca, with 29 pairs recorded in 1994 and 14 pairs in 2007, indicating a decline that continued until its absence in 2023.

Passer montanus

In the past, this species was common and bred in rural areas and near houses, with 65-75 pairs recorded in 1994. However, by 2006, this number had decreased to 32-34 pairs, indicating an ongoing decline. In 2023, only one pair nested in "Bertolotto", but 200 m outside the MFNP. This observation underscores the significant decline observed in Europe and Italy over the last 20 years (Lardelli *et al*., 2022; Rete Rurale Nazionale & Lipu, 2023), despite suitable habitats still being present. While forest encroachment and land-use changes are likely contributing factors to this decline, recent studies suggest that the impact of heavy metals (Zhang *et al.*, 2023) and light pollution (Jiang *et al*., 2020) may also play a role.

Perdix perdix (protected)

Another species that was commonly observed breeding until the '50s, with confirmed reproduction in several localities, including "Arlezze", "Rasco", "Cantone", and the vineyards surrounding the Sanctuary of Boca. However, it disappeared from these areas between 1955 and 1965, with the last flock observed in 1968 near the locality "Motto della Capretta". Only one individual was seen in 1983 at "Fenera S. Giulio", likely released for hunting purposes. Despite being a game species in the past, there may have been a truly wild population descended from the one present in the area over the last millennia, as suggested by paleontological findings (Strobino & Janvier, 1971).

Pernis apivorus (protected)

The species currently nests, as it did in the past, with 6-7 pairs, with at least three breeding pairs in the southern part of the area in 2023. However, no specific censuses were conducted in 2023.

Philloscopus bonelli

The species mainly nested in the southern forested slopes, with 29 territorial males recorded in 1996. A significant decline occurred afterward, with only 18 territorial males in 2006, mostly found at higher altitudes. Despite a slight overall increase in Italy, this local decline confirms the one observed in Piedmont (Boano *et al*., 2023), particularly along the foothill belt. In 2023, only one male was heard singing on a single occasion (May 3rd), suggesting no breeding. Due to the habitat potential, the species still falls among the 38 breeding species, but it is likely to disappear in the coming years, possibly due to rising average temperatures rather than habitat availability (Lardelli *et al*., 2022).

Phylloscopus sibilatrix

The species exhibited irregular breeding until 1997, with a maximum of two territorial males observed simultaneously in 1995, within mixed forests predominantly consisting of *Fagus sylvatica*. In 2023, efforts were made to locate this species primarily along routes covering all previously known sites, but without success. However, since the year 2000, the species has not been recorded, confirming the decline observed in Italy along the Alps and the foothill belt (Lardelli *et al*., 2022; Boano *et al*., 2023).

Pyrrhula pyrrhula

In the past, this species was common, with around 20 breeding pairs in rural areas. However, by 2007, this number had halved, with breeding mainly limited to the northernmost sector of the area, indicating a continued decline until its disappearance in 2023. The most plausible cause of its decline across the Italian pre-alpine area appears to be a negative correlation with the annual mean temperature (Lardelli *et al*., 2022).

Pica pica

The species bred for the first time in 2023, with one pair successfully fledging three young near the Sanctuary of Boca. This species seems to be closely associated with food remnants from tourists visiting the sanctuary.

Ptyonoprogne rupestris

This species has been breeding on the cliffs of Monte Fenera since the '70s, with around 2 – 3 pairs in the late 1980s. However, the last breeding confirmation was in 1993 (Bordignon, 1999). In 2023, the species was only seen overwintering, with observations close to the village named "La Colma". Despite specific surveys at known nesting sites, no individuals were spotted in the area between March and June. Despite this, at least one breeding attempt is known in 2017 by archaeologists active at the site, with a pair at the entrance of the cave "Ciota Ciara", but the nest was destroyed by a storm (M. Arzarello, pers. com.), due to water runoff on the rock. In July 2023, a small group persisted around the GASB Refuge (G. Vaudano, pers. com), but since the species was absent at the end of June, it was probably a post-breeding flock. Therefore, it is possible that the species sporadically nests in the area, although likely with low breeding success.

Streptopelia decaocto

The species bred for the first time in 1993, with 3 breeding pairs in 1997 in the village of "Ara". Despite the increase in Italy (Lardelli *et al*., 2022), there were no significant changes as of 2007, and it was absent in 2023.

S. turtur

The species was present mainly in the vineyards surrounding the Sanctuary of Boca, with 9 breeding pairs in 1995. Despite the increase in Italy, there were no significant changes as of 2007, and it was absent in 2023.

Tachymarptis melba

The species was known to breed with at least 8 pairs from three different colonies in the '90s, including the cliffs of Monte Fenera, the bell tower of the church in the village "La Colma", and the walls of the Sanctuary of Boca. However, it disappeared from the latter location in 1997, and in the subsequent years, it vanished throughout the MFNP. In 2023, only *Apus apus* was observed at the three known colonies.

Species whose reproduction in the area is still doubtful

Lullula arborea (protected)

This species was never confirmed as a probable or certain breeder. Only two records of singing males (April 11th, 2007, and May 5th, 2023) suggest possible breeding

attempts in vineyard areas, but without confirmation. Since it has never been confirmed as a breeding species, it is not included among the 38 breeding species. However, given the slight increase in Piedmont (Boano *et al*., 2023), irregular breeding attempts cannot be ruled out. It is a protected species, and any potential expansion of vineyards could encourage breeding attempts.

Colinus virginianus, Coturnix coturnix, and Phasianus colchicus

These game species may be subject to releases for hunting purposes, although they are present in Italy with wild and/or naturalized populations (Lardelli *et al.*, 2022). This situation could explain the irregularity of possible breeding behavior, also in unsuitable habitats, as observed for a male of *C. coturnix* singing from a small intensive vineyard surrounded by woods on the 3rd of June 2023.

AN UPDATED CHECKLIST

The consequences of land use and rising temperatures are not evident only upon breeding species; they also impact the regularity of winter and migratory occurrences (Princé & Zuckerberg, 2015). Although specific investigations about wintering or migratory species have not been conducted since 2007, an overall view across taxa reveals that after the year 1998, some typically alpine species have not been observed anymore (*Tab. S1*). These include *Acanthis flammea cabaret, Carduelis citrinella, Loxia curvirostra, Nucifraga caryocatactes*, as well as species from North Europe, such as *Bombycilla garrulus* or *Corvus fragileus*. These last species, in particular, were still considered regular migratory and wintering species in 1997 (Bordignon, 2008).

The checklist should not be considered exhaustive for the study area. This is evident from the absence of post-breeding dispersal of common species from surrounding areas, such as *Anas platyrhynchos, Columba livia*, and *Corvus corone,* as well as regular migratory or wintering species that are common but less detectable, like *Asio otus*. Despite this, the checklist of all bird species recorded within the MFNP is provided, along with suggestions regarding the updated status of each species at the local scale. This update aims to provide an informative tool for management and conservation considerations that should be closely related to the study area and surroundings.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online for this article.

Tab. S1 – The complete checklist of all bird species observed in the Monte Fenera Natural Park.

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