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Bird vocalizations during spring migration on a small Mediterranean island (Ventotene, Italy)

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Abstract Ventotene Island, a small Mediterranean island off the Latium coast (Central Italy), is an important stopover site for several migratory bird species. The migration pathways of these species have been largely studied with classical approaches, such as bird ringing activities, bio-logging, isotope studies, and radar networks. The latest methodological approaches involve bioacoustics analyses (i.e. sonogram analyses), making advantage of the availability of new low-cost ARUs (Autonomous Recording Units) technology. However, although bird species are known to emit breeding and non-breeding vocalizations during migrations, scientific knowledge on these vocalizations is still scarce, particularly in insular stop-over areas. In this study, 54 field surveys were carried out on Ventotene Island during the early spring migration season (April 2024), following a recording protocol of 10-min per sample-point on different day-hours. Three surveys were carried out for each sample-point, resulting in a total of 540 minutes (9 hours) of audio-recording. The vocalizations of the bird species were identified through acoustic and visual sonogram analyses and categorized by their structural similarity. A total of 19 bird species were identified from the audio-recordings. Among them, Eurasian Collared Dove *(Streptopelia decaocto)*, European Serin *(Serinus serinus)*, Sardinian Warbler *(Curruca melanocephala)*, Collared Flycatcher *(Ficedula albicollis)* were the most frequently contacted. The majority of bird vocalizations consisted of alarm and social calls, while reproductive songs were recorded for nine species: Eurasian Collared Dove, Common Cuckoo *(Cuculus canorus)*, Eurasian Blackbird *(Turdus merula)*, Common Nightingale *(Luscinia megarhynchos)*, Great Reed Warbler *(Acrocephalus arundinaceus)*, Common Whitethroat *(C. communis)*, Sardinian Warbler, European Serin, Western Yellow Wagtail *(Motacilla flava)*. The results of this study highlight the potential of bioacoustics as a promising and non-invasive tool for detecting the presence of both migratory and sedentary bird species during spring migration. However, future research should aim to refine recording protocols and field survey techniques, as well as compare the effectiveness of bioacoustics monitoring with other established methods.

Keywords: Ventotene Island, stopover areas, bioacoustics, bird vocalizations, bird migration

Összefoglalás Ventotene-sziget, egy kis mediterrán sziget a Lazio-partvidék közelében (Közép-Olaszország), fontos megállóhely számos vonuló madárfaj számára. Ezeknek a fajoknak a vonulási útvonalait hagyományos módszerekkel – például madárgyűrűzéssel, nyomkövető technológiákkal, izotópos vizsgálatokkal és radarrendszerek segítségével – tanulmányozták eddig. Az újabb módszertani megközelítések között egyre nagyobb teret nyer a bioakusztikai elemzés (szonogramok vizsgálata), amit az olcsóbb, automatikus hangrögzítő egységek elérhetősége is elősegít. Bár ismert, hogy a madárfajok a vonulás során is adnak ki különféle hangokat, ezek akusztikai jellemzőiről különösen a szigeti megállóhelyeken még kevés tudományos adat áll rendelkezésre. A jelen tanulmányban 54 terepi felmérést végeztek Ventotene-szigetén 2024 áprilisában, a tavaszi vonulási időszak elején. A hangrögzítés mintavételi pontonként 10 percig tartott, különböző napszakokban. Minden mintapontot háromszor mértek fel, így összesen 540 perc (9 óra) hangfelvétel keletkezett. A madárfajok hangjait akusztikai és vizuális szonogram-elemzéssel azonosították, majd a hangok szerkezeti hasonlósága alapján kategorizálták. Összesen

19 madárfajt sikerült azonosítani a hangfelvételek alapján. Közülük a kucsmás poszáta *(Curruca melanocephala)*, az örvös légykapó *(Ficedula albicollis)*, a csicsörke *(Serinus serinus)* és a balkáni gerle *(Streptopelia decaocto)* voltak a leggyakrabban észleltek. A felvételeken túlnyomórészt riasztó- és társas hívóhangok szerepeltek, de kilenc fajnál udvarló énekeket is rögzítettek: nádirigó *(Acrocephalus arundinaceus)*, kakukk *(Cuculus canorus)*, mezei poszáta *(C. communis)*, kucsmás poszáta, fülemüle *(Luscinia megarhynchos)*, sárga billegető *(Motacilla flava)*, csicsörke, balkáni gerle és fekete rigó *(Turdus merula)*. Az eredmények rámutatnak arra, hogy a bioakusztikai módszerek ígéretes és nem invazív megoldást jelenthetnek mind a vonuló, mind az állandó madárfajok jelenlétének kimutatására a tavaszi vonulás idején. Ugyanakkor a jövőbeli kutatásoknak célszerű lenne a hangrögzítési protokollok és a terepi felmérési módszerek finomítására törekedni, valamint a bioakusztikai monitorozás hatékonyságát összevetni más bevett megfigyelési eljárásokkal.

Kulcsszavak: Ventotene-sziget, vonulási megállóhely, bioakusztika, madárhang, madárvonulás

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Introduction

The Palearctic-African migration system involves an enormous number of birds traveling between Africa and Europe every year (Hahn *et al.* 2009). During migration, birds often aim to minimize flight duration and energy investment, primarily when crossing large ecological barriers such as deserts and open seas (e.g. Mediterranean Sea; Maggini et al. 2020). Given their strategic position, Mediterranean islands are crucial stopover sites for birds, providing them rest and possibility to refuel before continuing their migration routes (Cecere *et al.* 2011, Barboutis *et al.* 2022). These islands are often the first available lands that birds encounter during the migration towards breeding and wintering areas (Barboutis *et al.* 2022). In this context, the small Mediterranean island of Ventotene, located in the Pontine Archipelago (Central Italy), represents an important bird stopover site, particularly during the spring migration season (Goymann *et al.* 2010, Tenan & Spina 2010). For example, during spring migration from 2014 to 2016, Maggini *et al.* (2020) reported the capture of more than 40,000 individuals representing 12 species on Ponza Island, another island within the Pontine Archipelago complex. Most of these species arrive on these islands after non-stop flights from across Africa (Spina *et al*. 1993), where they find essential resources, primarily water and food, which play a critical role in supporting their migration towards European breeding areas (Spina *et al.* 1993, Tenan & Spina 2010). The nectar consumption and feeding behavior of *Sylvia* species on Ventotene Island are particularly important in sustaining their migration (Schwilch *et al.* 2001, Cecere *et al.* 2011). Understanding the different patterns of migration is crucial for the conservation and monitoring of migratory birds and is often achieved through various methodologies that provide a comprehensive view of the phenomenon (Higuchi 2012). Traditional methods consist of long-term observations at migration hotspots (e.g. Panuccio *et al.* 2017), radar networks, ringing activities, isotope analysis, and tracking devices. The choice of the right methodology is strictly linked to the biology of the bird species and the spatial scale of the study (Flack *et al.* 2022).

Since the first study of bird migrations, classical methods have provided valuable data, and several databases (e.g. EURING Migration Mapping Tool, https://euring.org/research/migration-mapping) are easily accessible with exhaustive data on bird migration routes and phenology (Flack *et al.* 2022). Traditional methods were recently complemented by new approaches, such as the use of Autonomous Recording Units (ARUs) (Manzano-Rubio *et al.* 2022). Through bird vocalizations and their respective sonograms, bioacoustics analyses provide a powerful tool for monitoring species presence/absence and population densities (e.g. Bardeli *et al.* 2010, Frommolt & Tauchert 2014, Pérez-Granados *et al.* 2019), as well as detecting cryptic or rare species (e.g. Leseberg *et al.* 2021).

While most bird species are known to emit reproductive vocalizations within their breeding territories (e.g. Nice 1941), the vocalization types emitted during migration, such as diurnal and nocturnal calls, have been documented for only a limited number of species (e.g. Farnsworth *et al.* 2004, Sanders & Mennill 2014). On Ventotene Island, extensive scientific literature is available on the ecology of migratory species (Montemaggiori & Spina 2002, Goymann *et al.* 2010, Tenan & Spina 2010, Morganti *et al.* 2011), but limited information can be found on the vocalizations of these species while resting on the island, resembling the general lack of bioacoustics data about the whole Palearctic-African migration system.

By using a recording-based methodology and sonogram analyses, this study aims to (i) identify bird species detectable through vocalizations during early spring migration on Ventotene and (ii) classify these vocalizations based on their acoustic and structural similarities.

Materials and Methods

Study area

Ventotene is a small island located approximately 46 km off the Lazio coast in the Tyrrhenian Sea, covering an area of about 135 hectares (Cecere *et al.* 2011, Manica *et al.* 2020, Capizzi *et al.* 2023). This island is part of the Ventotene and Santo Stefano Islands Nature Reserve and is included within the Special Protection Area (SPA code IT6040019, Capizzi *et al.* 2023). The territory of Ventotene Island consists mostly of artificial surfaces, agricultural areas, forests, and semi-natural areas (Capizzi *et al.* 2023). Agricultural areas are characterized mainly by crop fields and cultivations of legumes and fruits, but the progressive abandonment of rural areas is leading to the spread of giant cane *(Arundo donax)* and other pioneer vegetation. The natural and semi-natural areas are dominated by Mediterranean maquis, remnants of Mediterranean scrub vegetation, such as the common myrtle *(Myrtus communis)*, the mastic tree *(Pistacia lentiscus)*, the narrow-leaved mock privet *(Phillyrea angustifolia)*, and non-native vegetation (Pretto *et al.* 2010, Cecere *et al.* 2011, Capizzi *et al.* 2023).

Bird surveys and recording

Bird species were sampled by recording their vocalizations within 18 sample-points (Bibby *et al.* 1992, Gregory *et al.* 2004). Sample-points were selected using QGIS 3.16.0 software

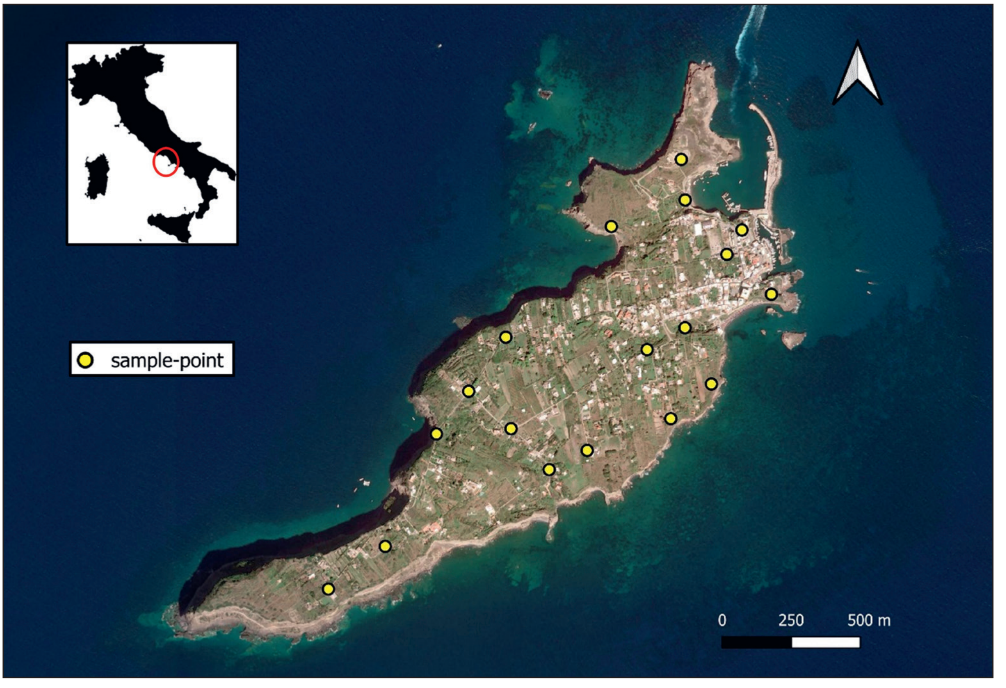

Figure 1. The map of Ventotene Island (QGIS 3.16.0 software). Yellow dots represent the sample-points (18) where bird vocalizations were recorded

1. ábra Ventotene-sziget térképe (QGIS 3.16.0 szoftver). A sárga pontok jelzik azokat a pontokat (18), ahol a madarak hangját rögzítették

(QGIS Geographic Information System 2024) *(Figure 1)* and the latest available online map (Google Earth, April 2022), also considering the wide distribution of inaccessible areas (e.g. private farmlands and cliffs) on the island. The sample-points were selected to ensure comprehensive coverage of the island area and its sub-habitats, with a minimum distance of 50 meters between each point.

The field surveys were carried out during the early spring migration of the bird species, from 9 to 18 April 2024. Each sample-point was surveyed three times: during sunrise hours (6.00–9.00 AM CET), random hours of the day (6.00 AM – 8.00 PM CET) and sunset hours (6.00–9.00 PM CET), with a minimum interval of two days between each survey. In total, 54 surveys were carried out, three for each sample-point.

The different sampling hour strategy was used to cover a higher time frame, due to the different arrival times of the bird species on the island.

To contact the bird species, a standardized protocol of 10-minute sampling per survey was used, avoiding adverse meteorological conditions, collecting a total of 540 minutes (9 hours) of audio-recording. Recording was made with Sennheiser MKE600 directional microphone (https://www.sennheiser.com/en-gb) and Zoom H1N recorder (https://zoomcorp.com/) with a 48 kHz and 24 bit standard protocol. All the recordings were then saved in a WAV format for the following analyses.

Data analysis

Bioacoustics analyses were made with Raven PRO v. 2.0 software (K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology, 2024). To accurately identify bird species, individual vocalizations were processed by amplifying the sound intensity and removing background noises, including wind and human noises.

Bird species were identified through bioacoustics analyses: acoustic identification and visual examination of the structure of each vocalization, visualized in sonograms, conducted by expert ornithologists (J. G. and G. V.). Species identification was based on references from the online wildlife sound database, xeno-canto (https://xeno-canto.org/), and the available scientific literature on individual species (Wroza 2024).

An occurrence binary matrix was built based on the presence/absence (0 = absence and 1 = presence) of the bird species on the audio-recording across the total number of surveys (54). This matrix was used to estimate the total number of bird species identified in all the surveys (N) and the number of species identified within each survey. For each species, the frequency of presence in the surveys was then estimated and calculated as the proportion of surveys in which the species was detected (fr.).

From the binary matrix, the number of bird species detected during surveys conducted at different times of the day was extrapolated (18 per sampling-hour). Specifically, the mean number of species identified during sunrise, random times, and sunset were calculated.

Following species identification, bird vocalizations were categorized and analyzed based on their structural similarity, visualized in sonograms (Raven PRO 2.0). A first distinction was made between "reproductive songs" and "calls" (Spector 1994). Due to the absence of standardized definitions regarding (i) the boundaries between vocalization units and (ii) the distinctions between individual notes and complete sequences (Spector 1994, Rose *et al.* 2022), the analysis focused on descriptive features: phonetic and structural characteristics.

To establish a first preliminary quantitative approach and to determine whether each vocalization type of the species was common or rare within audio-recordings, the ratio between the number of recordings in which each vocalization type was present and the total number of audio-recordings (Nv) was used as a proxy.

Results

Field surveys

A total of 19 species were identified considering all the surveys: Great Reed Warbler *(Acrocephalus arundinaceus)*, Tree Pipit *(Anthus trivialis)*, Hooded Crow *(Corvus cornix)*, Common Cuckoo *(Cuculus canorus)*, Eastern Subalpine Warbler *(Curruca cantillans)*, Common Whitethroat *(C. communis)*, Sardinian Warbler *(C. melanocephala)*, Peregrine Falcon *(Falco peregrinus)*, Collared Flycatcher *(Ficedula albicollis)*, Yellow-legged Gull *(Larus michahellis)*, Common Nightingale *(Luscinia megarhynchos)*, European Bee-eater *(Merops apiaster)*, Western Yellow Wagtail *(Motacilla flava)*, Spotted Flycatcher

(Muscicapa striata), Black Redstart *(Phoenicurus ochruros)*, Common Chiffchaff *(Phylloscopus collybita)*, European Serin *(Serinus serinus)*, Eurasian Collared Dove *(Streptopelia decaocto)*, and Eurasian Blackbird *(Turdus merula)*.

Table 1. List of the contacted species, the n of bird surveys where each species was recorded and the frequency (fr.) of the species considering the total number (54) of surveys

1. táblázat Az érintett fajok, a felmérések száma, amikor észlelték a fajt, és annak a gyakorisága, hogy hány alkalommal észlelték az 54 megfigyelési napból

Species	n of sample-points	Frequency (fr.)
Acrocephalus arundinaceus	1	0.019
Anthus trivialis	5	0.093
Corvus cornix	1	0.019
Cuculus canorus	1	0.019
Curruca cantillans	3	0.056
Curruca communis	2	0.037
Curruca melanocephala	35	0.648
Falco peregrinus	3	0.056
Ficedula albicollis	28	0.519
Larus michahellis	19	0.352
Luscinia megarhynchos	7	0.130
Merops apiaster	4	0.074
Motacilla flava	13	0.241
Muscicapa striata	11	0.204
Phylloscopus collybita	2	0.037
Phoenicurus ochruros	8	0.148
Serinus serinus	46	0.852
Streptopelia decaocto	31	0.574
Turdus merula	19	0.352

The species belonging to the genus *Passer* were detected in the audio-recordings but could not be identified to the species level and were therefore excluded from all analyses. Also, hybrids between Collared Flycatcher and the European Pied Flycatcher may have potentially impacted the accurate identification by vocalization of Collared Flycatcher individuals in this study (Gelter 1987).

The frequency (fr.) of each species was calculated for each sample-point *(Table 1)*. The most contacted species (fr. > 0.5) were the European Serin (fr. = 0.85), Sardinian Warbler (fr. = 0.64), Eurasian Collared Dove (fr. = 0.57), and the Collared Flycatcher (fr. = 0.52). A mean of 4.5±2.2 species per sample-point was identified considering all sampling hours. The mean number of species contacted during sunrise hours was 5.9±2.3, while 4.2±2 and 3.44±1.5 species were detected, respectively, during random and sunset hours *(Figure 2)*.

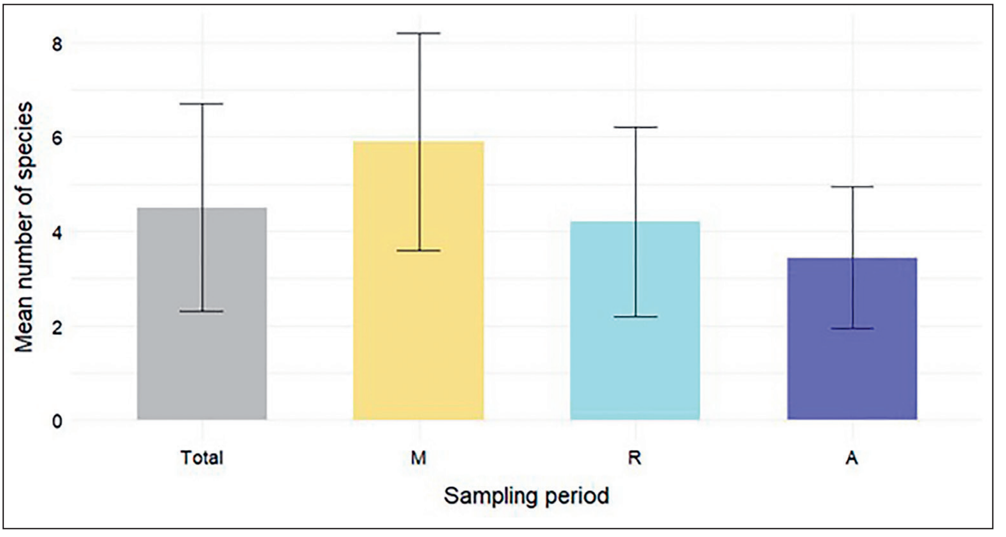

Figure 2. Mean number of species observed in all audio-recordings (Total) and in those obtained during the surveys carried out during sunrise (M), random hours of the day (R), and sunset (A)
2. ábra Az összes hangfelvételen (Total), a napkeltekor (M), a nap véletlenszerű óráiban (R) és napnyugtakor (A) végzett felmérések során rögzített fajok átlagos száma

Type of vocalizations

A total of 30 different bird vocalization types were identified in the audio-recordings. Of these, one reproductive song type was detected for each of the following nine species: Great Reed Warbler, Common Cuckoo, Common Whitethroat, Sardinian Warbler, Common Nightingale, Western Yellow Wagtail, European Serin, Eurasian Collared Dove, and Eurasian Blackbird.

The remaining 21 vocalization types were classified as "calls" and were attributed to 16 species. At least one call type was identified for all species, except for the Common Cuckoo, Great Reed Warbler, and the Eurasian Blackbird, for which no calls were detected. A brief qualitative analysis and description of each vocalization are provided in the following paragraphs.

Black Redstart

The vocalizations of the Black Redstart consisted exclusively of territorial calls, observed in 8 of 54 audio-recordings (Nv = 0.15). These calls were characterized by a short-duration single note and a "*tuk*" similar sound *(Figure 3)*.

Collared Flycatcher

A large number of Collared Flycatcher vocalizations were recorded in 28 audio-recordings (Nv = 0.52). All the vocalizations observed were low-intensity alarm calls, characterized by a single monotone element with a plunging termination, emitted in short time intervals, with a main frequency around 5 kHz *(Figure 4)*.

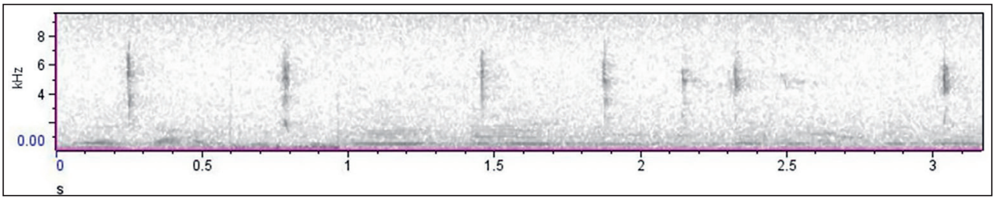

Figure 3. Sonogram of the vocalizations of the Black Redstart *(Ph. ochruros)*
3. ábra A házi rozsdafarkú *(Ph. ochruros)* hangjának szonogramja

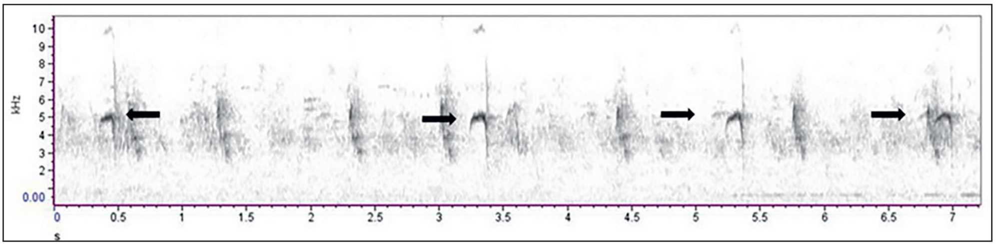

Figure 4. Sonogram of the call of the Collared Flycatcher *(F. albicollis)*. Black arrows indicate the single elements that characterize the low-intensity alarm call
4. ábra Az örvös légykapó *(F. albicollis)* hívóhangjának szonogramja. Fekete nyilak jelzik az alacsony intenzitású riasztás egyes elemeit

Common Chiffchaff

Only a small number of Common Chiffchaff vocalizations were detected, consisting exclusively of the characteristic call ("*huit*"), which was identified in two audio-recordings (Nv = 0.04). The call is characterized by a principal up-slurred and frequency-rising element and few harmonics, reaching a frequency peak at approximately 5–6 kHz *(Figure 5)*.

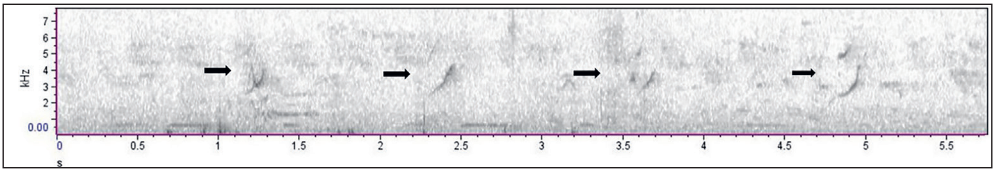

Figure 5. Sonogram of the vocalizations of the Common Chiffchaff *(Ph. collybita)*. Black arrows indicate the up-slurred vocal elements of the call
5. ábra A csilcsalpfüzike *(Ph. collybita)* hangjának szonogramja. Fekete nyilak jelzik a hívóhang felfelé sípoló hangelemeit

Common Cuckoo

The Common Cuckoo vocalizations were identified in one audio-recording. The vocalization type consisted of the classic "*cu-coo*", characterized by two simple elements: the shorter (the "*cu*") and the longer one (the "*coo*"). These two elements are repeated in regular intervals of time (approx. 1.5 seconds) and are characterized by two-five higher-frequency harmonics *(Figure 6)*.

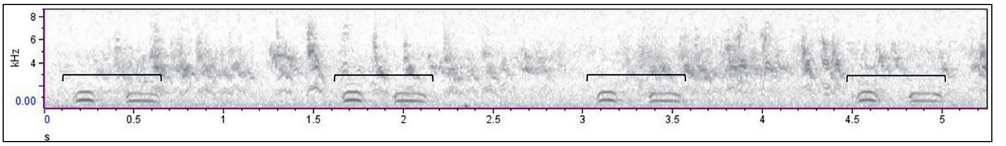

Figure 6. Sonogram of the vocalizations of the Common Cuckoo *(C. canorus)*. The brackets indicate the two elements of the male song: the first shorter *"cu"* and the second longer notes *"coo"*
6. ábra A kakukk *(C. canorus)* hangjának szonogramja. A zárójelek a hím énekének két elemét jelzik: az első rövidebb *„cu"* és a második hosszabb hangok *„coo"*

Common Nightingale

The vocalizations of the Common Nightingale were divided into two different groups: whistle song and calls. The first type was observed in three audio-recordings (Nv = 0.06) and consisted of long, complex, and elaborate vocalizations, with a vocal structure characterized by a wide combination of vocal notes, whistles, and trills. The calls, recorded in six audio-recording (Nv = 0.11), were repetitions of small low-frequency elements and a guttural trill sound *(Figure 7)*.

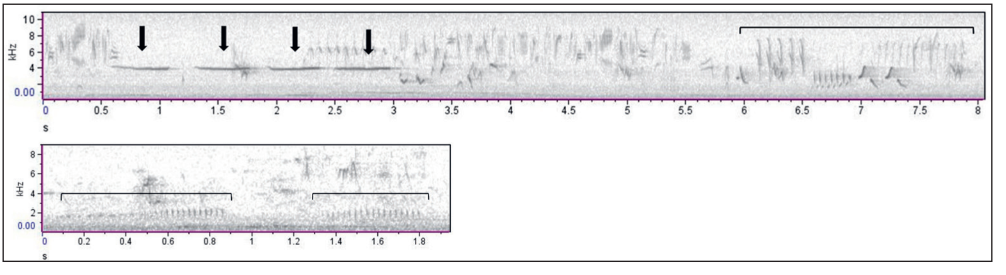

Figure 7. Sonogram of the vocalizations of the Common Nightingale *(L. megarhynchos)*. The whistle songs (top), with the arrows and brackets indicating respectively the single elements and the call (down)
7. ábra A fülemüle *(L. megarhynchos)* hangjának szonogramja. A füttye (fent), a nyilak és a zárójelek az egyes elemeket, illetve a hívást (lent) jelzik

Eastern Subalpine Warbler

The vocalizations of the Eastern Subalpine Warbler consisted exclusively of contact calls, identified in three audio-recordings (Nv = 0.06). The contact calls were characterized by high-frequency peaks, short durations, and a "*check*" similar sound *(Figure 8)*.

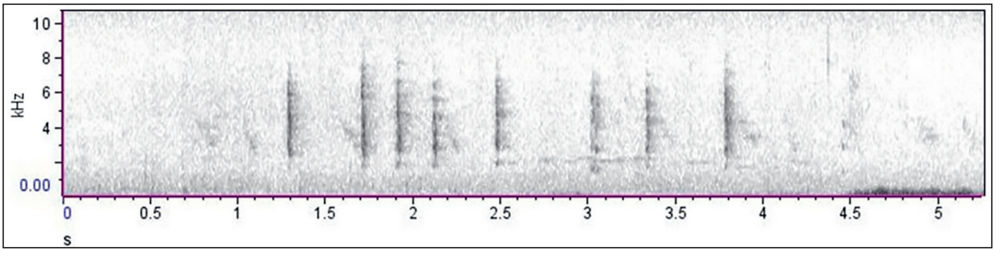

Figure 8. Sonogram of the call of the Eastern Subalpine Warbler *(C. cantillans)*
8. ábra A bajszos poszáta *(C. cantillans)* hívóhangjának szonogramja

Eurasian Blackbird

All the vocalizations of the Eurasian Blackbird were classified as songs, as it was not possible to isolate single calls from these heterogeneous, complex, and long vocal sequences. The songs were characterized by a wide variety of melodious and whistled notes. These vocalizations were observed in 19 audio-recordings (Nv = 0.35), likely to be emitted by several male individuals recorded in the different sample-points *(Figure 9)*.

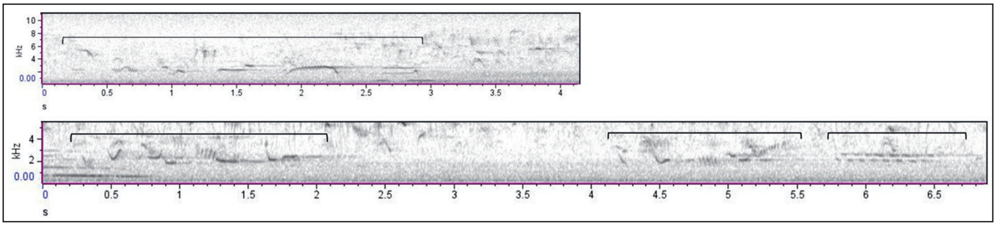

Figure 9. Sonograms of the vocalizations of the Eurasian Blackbird *(T. merula)*. The vocal elements of songs present a high variability in both frequency and duration

9. ábra A fekete rigó *(T. merula)* hangjának szonogramjai. A zárójelek az énekmotívumok hosszát jelzik, a vokális elemek nagyfokú variabilitása mellett

Eurasian Collared Dove

The vocalizations of the Eurasian Collared Dove were classified into two different groups: the coo-vocalizations and alighting call. The coo-vocalizations were identified in 30 audio-recordings (Nv = 0.56) and consisted of a repetition of three small monotone "*coo*", with the first and third ones of similar short duration, while the second by a longer duration ("*hoo-HOO-hoo*"). Alighting calls were detected in nine audio-recordings (Nv = 0.17), characterized by a single frequency-curved element, several relative harmonics and a "*hwaah*" similar sound *(Figure 10)*.

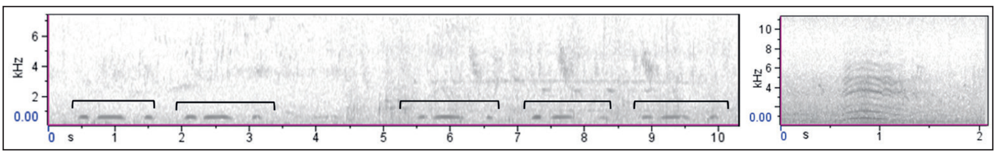

Figure 10. Sonograms of the vocalizations of the Eurasian Collared Dove *(S. decaocto)*. The coo-vocalizations (sx), with the three *"coos"* and the alighting call *(dx)*

10. ábra A balkáni gerle *(S. decaocto)* hangjának szonogramjai

European Bee-eater

The European Bee-eater vocalizations were identified in three different audio-recordings (Nv = 0.06), emitted by different individuals in small migrating flocks. All recorded vocalizations consisted of vocal calls, characterized by repetitions of a similar single element ("*gru*") with an "*M*" shape (slight rises and falls of the notes in the frequency peaks). These calls were emitted at a low frequency, about 2 kHz *(Figure 11)*.

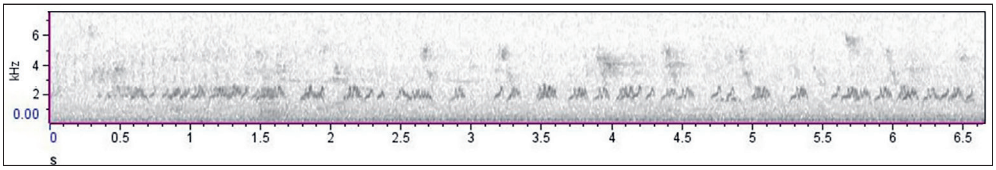

Figure 11. Sonogram of the vocalizations of the European Bee-eater *(M. apiaster)*. Note the overlap between the *"M"* elements emitted by different individuals

11. ábra A gyurgyalag *(M. apiaster)* hangjának szonogramja. Figyeljük meg az átfedést a különböző egyedek által kibocsátott „*M*" elemek között

European Serin

A high number of European Serin vocalizations were identified in the audio recordings. All these vocalizations were classified into three different categories: reproductive songs, trill calls and buzz calls. The songs were observed in 37 out of 54 (Nv = 0.69) audio-recordings, and are characterized by sequences of similar syllables, composed of a wide number of melodious elements that differ in shape and frequency. The trill calls, identified in 39 audio-recordings (Nv = 0.72), consisted of repetitions of similar frequency up-rising notes (mostly from 3 to 10 notes). The last vocalization type, the buzz calls, found in 14 recordings (Nv = 0.26), had a vocal structure characterized by single high frequency rising element and associated harmonics *(Figure 12)*.

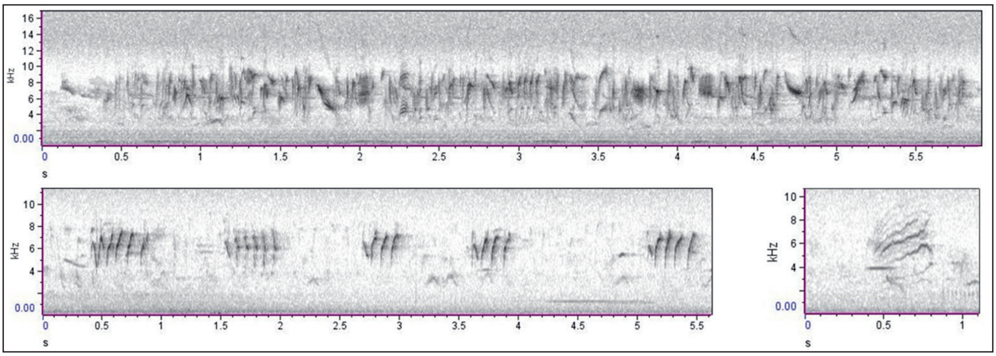

Figure 12. Sonogram of the vocalizations of the European Serin *(S. serinus)*. From top, song of the species, with a complex sequence of shrill notes. The trill call (sx), characterized by trill sequences and the buzz call (dx)

12. ábra A csicsörke *(S. serinus)* hangjának szonogramja. Fentről a faj éneke, a rikító hangok összetett sorozatával. A trillaszekvenciákkal jellemezhető trillahang (sx) és a zümmögő hang (dx)

Great Reed Warbler

The vocalizations of the Great Reed Warbler consisted of a single short song, observed in only one audio-recording (Nv = 0.02). The song was characterized by complex sequences of both guttural ("*krrr-krrr*") and higher-pitched notes, with pauses of 3–10 seconds between motif repetitions *(Figure 13)*.

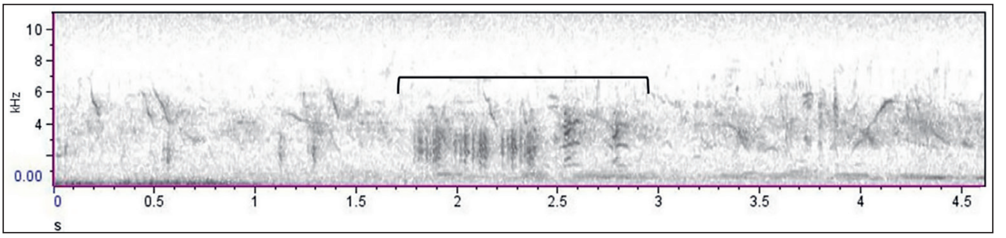

Figure 13. Sonogram of the vocalizations of the Great Reed Warbler (*A. arundinaceus*). The black bracket indicates one of the guttural note sequences that characterize the species song

13. ábra A nádirigó *(A. arundinaceus)* hangjának szonogramja. A fekete zárójel a faj énekét jellemző gutturális hangsorok egyikét jelzi

Common Whitethroat

The Common Whitethroat vocalizations were recorded in two audio-recordings (Nv = 0.04) and consisted of a song-similar vocalization type, with a brief repetition of up-slurred notes with a short duration in time *(Figure 14)*.

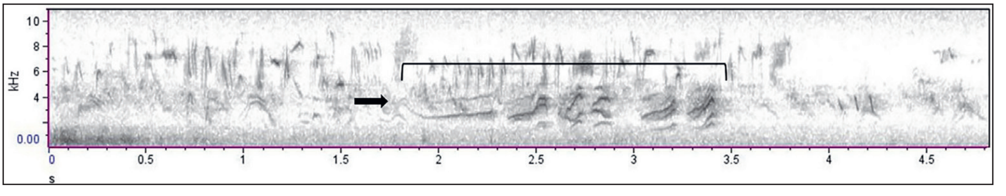

Figure 14. Sonogram of the song type vocalization of the Common Whitethroat *(C. communis)*. The black arrow indicates the start of the song-similar vocalization. Note the overlap with the song of other species *(S. serinus)*

14. ábra A mezei poszáta *(C. communis)* énekének szonogramja. A fekete nyíl jelzi az énekhez hasonló vokalizáció kezdetét. Figyeljük meg az átfedést más fajok *(S. serinus)* énekével

Hooded Crow

Of the total number of field surveys, vocalizations of the Hooded Crow were detected in one audio-recording (Nv = 0.02). The vocalizations observed consisted of the classical "caws" calls, characterized by a single long low-frequency element, with a principal tone around 2 kHz and associated higher harmonics *(Figure 15)*.

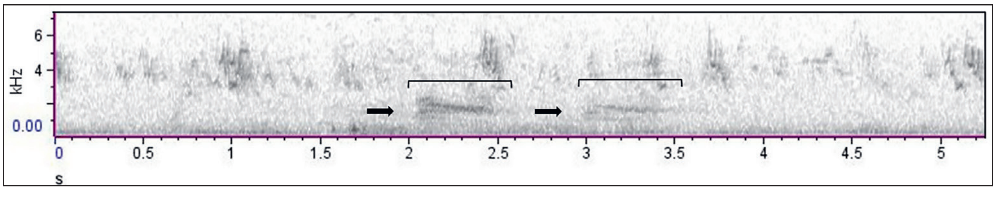

Figure 15. Sonogram of the vocalizations of the Hooded Crow *(C. cornix)*. Black arrows and brackets indicate the single *"caws"* of the species

15. ábra A dolmányos varjú *(C. cornix)* hangjának szonogramja. A fekete nyilak és zárójelek a faj egyes „károgásait" jelzik

Peregrine Falcon
All the vocalizations of the Peregrine Falcon were classified into two distinct call types: the "creaking call" and the "wailing call", identified respectively in one (Nv = 0.02) and two audio-recordings (Nv = 0.04). The "creaking" call is a short call characterized by high frequency peaks (more than 10 kHz), repeated in short intervals of time (approx. 0.25 sec), while the second is a longer and continuous call, marked by more low-frequency notes and harmonics *(Figure 16)*.

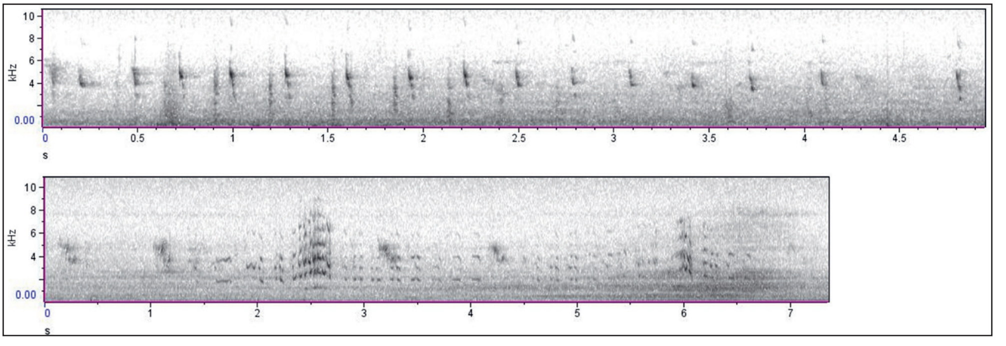

Figure 16. Sonograms of the two vocalizations of the Peregrine Falcon *(F. peregrinus)*: the "*creaking"* call (up), and the wailing call (down)
16. ábra A vándorsólyom *(F. peregrinus)* két hangjának szonogramjai: a „nyikorgó" hang (fent) és a jajveszékelő hang (lent)

Sardinian Warbler
Three vocalization types of the Sardinian Warbler were detected in the audio-recordings: two call types and the reproductive song. The call types were similar in structure, with a main repetition of similar elements, either singularly ("*tr*") or in pairs ("*tr-tr*"), both emitted in a short interval of time and with a trill similar sound. The first type (single element) was identified in 13 audio-recordings (Nv = 0.24), while the second type (two elements) in 10 audio-recordings (Nv = 0.19).

The song was identified in 10 audio-recordings (Nv = 0.19) and consisted of complex combinations of whistles and several "*tr*" notes, which vary in shape, frequency, and duration *(Figure 17)*.

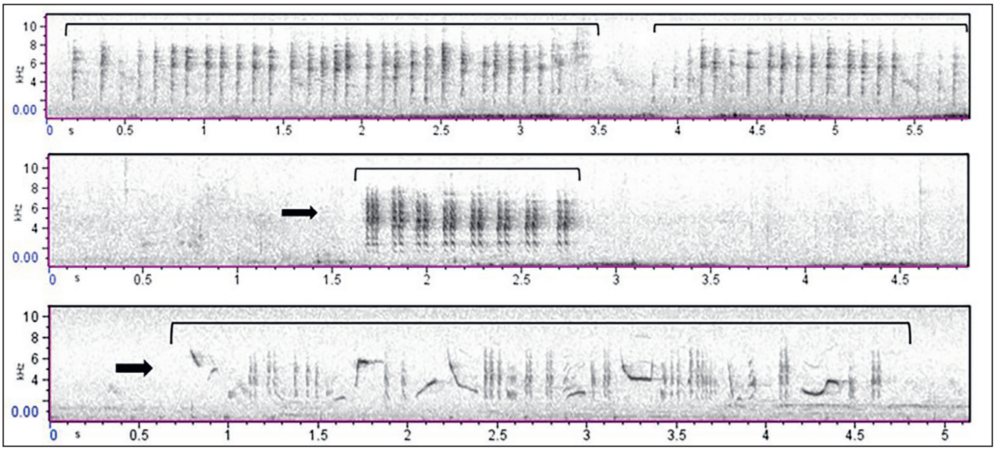

Figure 17. Sonogram of the three vocalization types of the Sardinian Warbler *(C. melanocephala)*. From the top: the call type characterized by repetition of single high-pitched notes, the second call type composed by a bimodal motif and the song of the species, with the complex sequence of notes

17. ábra A kucsmás poszáta *(C. melanocephala)* három hangtípusának szonogramja. Fentről: az egyes magas hangok ismétlődésével jellemezhető hívástípus, a bimodális motívumból álló második hívástípus és a faj éneke, a hangok összetett sorozatával

Spotted Flycatcher

Two types of vocalizations of the Spotted Flycatcher were recorded during field surveys. The first call, identified in eight audio-recordings (Nv = 0.15), is characterized by a repetition of single sharper frequency-descending elements, with a peak around 8 kHz. The second call, detected in three audio-recordings (Nv = 0.06) consisted of a repetition of more vertical notes at a regular intervals of time *(Figure 18)*.

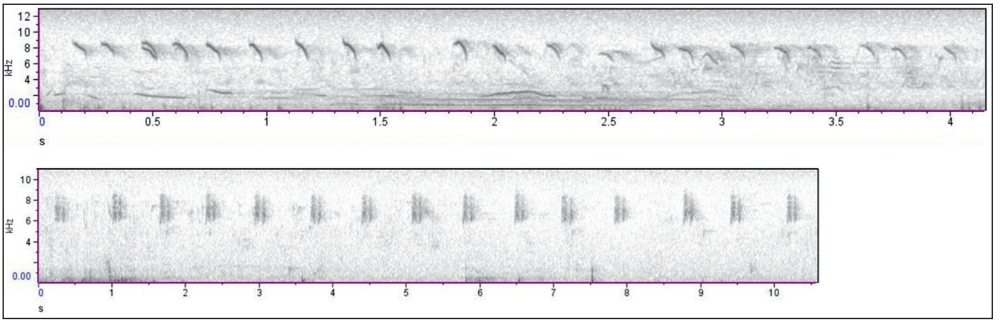

Figure 18. Sonograms of the two distinct vocalization types of the Spotted Flycatcher *(M. striata)*

18. ábra A szürke légykapó *(M. striata)* két különböző hangtípusának szonogramjai

Tree Pipit

Only one type of Tree Pipit vocalization was detected in the audio-recordings: the alarm calls (Nv = 0.02). These calls consisted of single short elements (i.e. notes) with an intensity peak between 5 and 6 kHz. These notes were repeated in regular intervals of time and presented a "*tseep*" or "*seet*" similar sound characterization *(Figure 19)*.

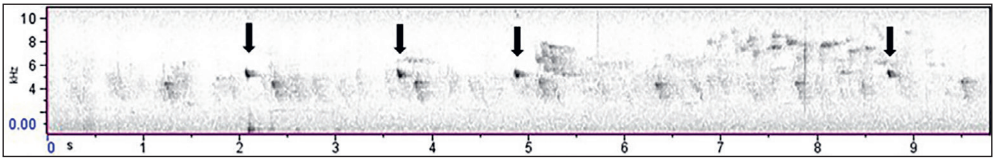

Figure 19. Sonogram of the vocalizations of the Tree Pipit *(A. trivialis)*. Black arrows indicate the single elements that characterize the alarm call of the species

19. ábra Az erdei pityer *(A. trivialis)* hangjának szonogramja. Fekete nyilak jelzik a faj vészhangját jellemző egyes elemeket

Western Yellow Wagtail

The Western Yellow Wagtail was detected in the audio-recordings by the identification of the songs and flight calls. These two types of vocalizations, observed respectively in eight (Nv = 0.15) and five audio-recordings (Nv = 0.09) are similar in sound and structure. Both the vocalizations presented a vocal structure characterized by a first high-peak rising element (up to 6–8 kHz) and a short down-slurred descending element. In the flight calls, this descending element is less pronounced *(Figure 20)*.

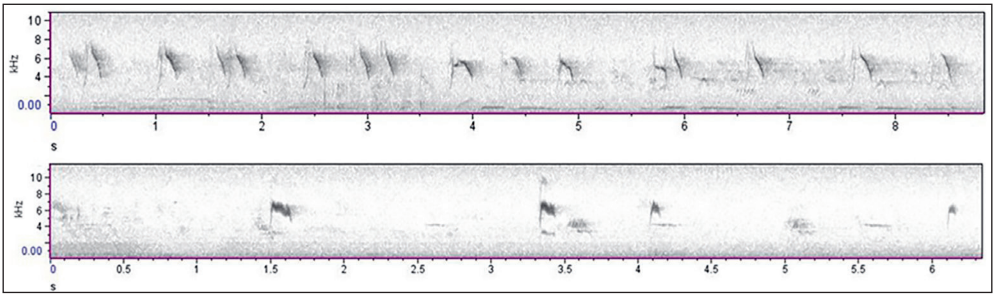

Figure 20. Sonogram of the vocalizations of the Western Yellow Wagtail *(M. flava)*. The song (up) and the flight calls (down) with the charactersitic structure down-slurred shapes

20. ábra A sárga billegető *(M. flava)* hangjának szonogramja. Az ének (fent) és a repülési hívások (lent) a jellegzetes szerkezetű lefelé szaggatott alakzatokkal

Yellow-legged Gull

Two different types of vocalizations of the Yellow-legged Gull were identified in the audio-recordings: the breeding calls and the alarm calls. The breeding calls were observed in six audio-recordings (Nv = 0.11) and consisted of long repetitions of down-slurred horizontal elements and higher-frequency associated harmonics. The alarm calls were identified in 13 (Nv = 0.24) audio-recordings and characterized by single horizontal notes and associated harmonics, emitted at relatively lower frequencies than the breeding calls *(Figure 21)*.

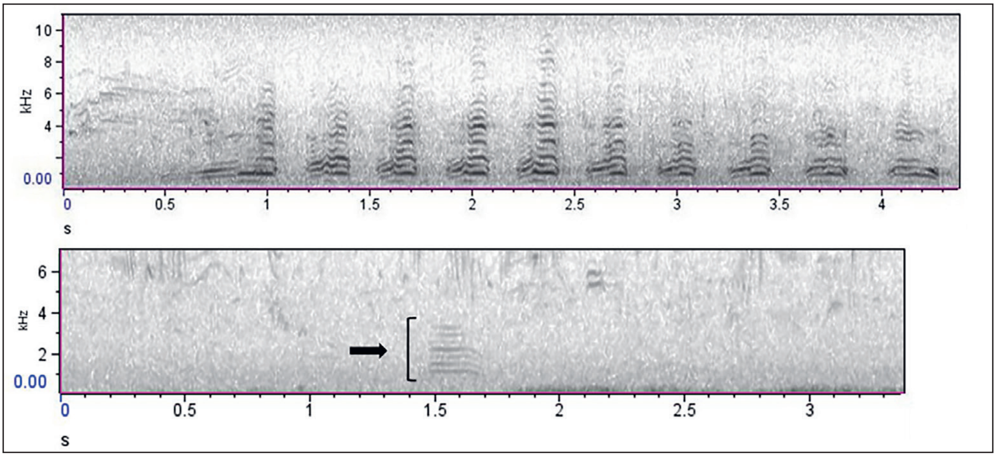

Figure 21. Sonograms of the two vocalizations of the Yellow-legged Gull *(L. michahellis):* the breeding calls (up), and the alarm call (down)

21. ábra A sárgalábú sirály *(L. michahellis)* két hangjának szonogramjai: a költési hangok (fent) és a vészhangok (lent)

Discussion

Bioacoustics monitoring conducted on Ventotene Island during spring migration revealed a high diversity of bird species. Among the detected species, the Common Chiffchaff, Common Cuckoo, Eastern Subalpine Warbler, Eurasian Collared Dove, European Serin, Hooded Crow, Sardinian Warbler, Peregrine Falcon, Spotted Flycatcher, and the Yellow-legged Gull have previously been classified under various breeding categories within the Pontine Islands complex (Brunelli *et al.* 2011).

As expected, several long-distance migrants were recorded, including the Collared Flycatcher, Common Cuckoo, Common Nightingale, Eastern Subalpine Warbler, European Bee-eater, Great Reed Warbler, Common Whitethroat, Tree Pipit, and the Western Yellow Wagtail (for their Italian status and distribution, see Baccetti *et al.* 2021, Lardelli *et al.* 2022). In contrast, most of the remaining detected species are generally considered sedentary in Italy, although both the Eurasian Blackbird and the Sardinian Warbler show highly variable migratory behavior (Fornasari *et al.* 2018, Lardelli *et al.* 2022).

Among all species, the Eurasian Collared Dove, the European Serin, and the Sardinian Warbler were the most frequently recorded and considered to be relatively common at the national scale (Brichetti *et al.* 1986, Calvi *et al.* 2018, Battisti & Zullo 2019).

Detection rates varied by sampling time, with the highest number of species detected during sunrise hours (6–9 AM CET), followed by random hours (6 AM – 8 PM CET) and sunset hours (6–9 PM CET). These results are consistent with the peak of bird vocal activity during early morning hours (e.g. Bruni *et al.* 2014). Species detected only during one sampling window, such as the Great Reed Warbler and the Hooded Crow, were typically those recorded in low numbers, suggesting that the differences observed are probably the result of occasional occurrences rather than systematic temporal patterns.

The results of the bioacoustics analyses indicate that most of the bird vocalizations detected were calls related to social behavior. Alarm calls (Collared Flycatcher, Tree Pipit, and Yellow-legged Gull) and alighting calls (Eurasian Collared Dove) are primarily associated with disturbance and potential dangers during migration (Gelter 1987, Clement *et al.* 2020, Tyler 2020, Romagosa & Mlodinow 2022, Kirwan *et al.* 2024). Other call types, including territorial calls (Black Redstart and Hooded Crow), breeding calls (Western Yellow Wagtail), "coo" vocalizations (Eurasian Collared Dove) and the two specific "creaking" and "wailing" calls (Peregrine Falcon) are strictly related to reproductive functions (Carlier 1995, Wrege & Cade 1997, Ballintijn & Ten Cate 1999, Jensen & Klokker 2006, Jensen *et al.* 2008, Adriaens *et al.* 2020, Collar 2024, Kirwan *et al.* 2024). Contacts and social calls from the Eastern Subalpine Warbler and the European Bee-eater seem to be linked to their social and gregarious behavior (Brambilla & Guidali 2005, Aymí *et al*. 2024, Bastian & Bastian 2024), while the functions of the other calls are still poorly understood.

Elaborate song types were identified in relatively few species. For the European Serin and the Sardinian Warbler*,* the detection of the songs (Luschi 1993, Mota 1999, Mota & Cardoso 2001) supports the ongoing breeding on the island. For other species, such as the Common Cuckoo, Common Nightingale, Great Reed Warbler, and the Common Whitethroat*,* the low number of songs detected may indicate a pre-breeding vocal behavior during migrations. In fact, within their breeding territories, the songs of these species are strictly linked to their territorial defense and mate attraction (Catchpole 1983, Catchpole *et al.* 1986, Naguib *et al*. 2002, Balsby & Dabelsteen 2003, Lei *et al.* 2005, Moskát *et al.* 2017, Xia *et al.* 2019). For the Western Yellow Wagtail, the function of song is still poorly understood, as most studies have focused on taxonomic identification rather than behavioral context (e.g. Bot *et al*. 2014). Finally, although the species has not been previously reported as a breeder, the identification of the Eurasian Blackbird songs (Dabelsteen 1984, Dabelsteen 1988, Collar & Christie 2020) may indicate new nesting attempts of the species on Ventotene Island.

Based on the results, bioacoustics analyses seem to be a promising tool for the passage detection of the non-breeding and migratory Collared Flycatcher and the Western Yellow Wagtail in stopover areas. These species showed a high vocalization presence on the audio-recordings (Nv > 0.15). For other non-breeding species, such as the European Bee-eater, Common Whitethroat, and the Tree Pipit, bioacoustics analyses may reflect an inadequate sampling strategy (e.g. number of surveys) or a non-marked vocalizing behavior during the spring migration. Nevertheless, previous studies highlight the potential of acoustic monitoring for tracking these species during migration (e.g. Moreno-Opo *et al*. 2018, Bota *et al*. 2020, Petrusková *et al*. 2021). Finally, consistently high vocal activity in known breeders (Brunelli *et al*. 2011) further supports their continued nesting on Ventotene Island. Future research may consider bioacoustics to study intra-individual differences in vocalizations and assess geographic microvariations between islands and mainland populations (Baker & Cunningham 1985, Naguib *et al*. 2001, Petrusková *et al*. 2010).

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References

Adriaens, P., Alfrey, P., Gibbins, C. & López-Velasco, D. 2020. Identification of Azores Gull. – Dutch Birding 42: 303–334.

Aymí, R., Gargallo, G., Christie, D. A., Garcia, E., Boesma, P. F. D. & Kirwan, G. M. 2024. Eastern Subalpine Warbler *(Curruca cantillans)*, version 1.1. – In: Kirwan, G. M. (ed.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.easwar1.01.1

Baccetti, N., Fracasso, N. & C.O.I. 2021. CISO-COI Check-list of Italian birds – 2020. – Avocetta 45: 21–85.

Baker, M. C. & Cunningham, M. A. 1985. The Biology of Bird-Song Dialects. – Cambridge University Press

Ballintijn, M. R. & Ten Cate, C. 1999. Variation in number of elements in the perch-coo vocalization of the Collared Dove *(Streptopelia decaocto)* and what it may tell about the sender. – Behaviour 136(7): 847–64.

Balsby, T. J. S. & Dabelsteen, T. 2003. Male singing behaviour and female presence in the territory in Whitethroats *Sylvia communis*. – Acta Ethologica 5: 81–88. DOI: 10.1007/s10211-002-0068-z

Barboutis, C., Navarrete, E., Karris, G., Xirouchakis, S., Fransson, T. & Bounas, A. 2022. Arriving depleted after crossing of the Mediterranean: obligatory stopover patterns underline the importance of Mediterranean islands for migrating birds. – Animal Migration 9(1): 14–23. DOI: 10.1515/ami-2022-0117

Bardeli, R., Wolff, D., Kurth, F., Koch, M., Tauchert, K. H. & Frommolt, K. H. 2010. Detecting bird sounds in a complex acoustic environment and application to bioacoustic monitoring. – Pattern Recognition Letters 31(12): 1524–34. DOI: 10.1016/j.patrec.2009.09.014

Bastian, H. V. & Bastian, A. 2024. European Bee-eater *(Merops apiaster)*, version 3.0. – In: Billerman, S. M. & Keeney, B. K. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.eubeat1.03

Battisti, C. & Zullo, F. 2019. A recent colonizer bird as indicator of human-induced landscape change: Eurasian Collared Dove *(Streptopelia decaocto)* in a small Mediterranean island. – Regional Environmental Change 19(7): 2113–2121. DOI: 10.1007/s10113-019-01547-y

Bibby, C. J., Burgess, N. D. & Hill, D. A. 1992. Bird Census Techniques. – Cambridge University Press

Bot, S., Groenendijk, D. & Van Oosten, H. 2014. Eastern Yellow Wagtails in Europe: identification and vocalisations. – Dutch Birding 36: 295–311.

Bota, G., Traba, J., Sardà-Palomera, F., Giralt, D. & Pérez-Granados, C. 2020. Acoustic monitoring of diurnally migrating European Bee-eaters agrees with data derived from citizen science. – Ardea 108(2): 139–49. DOI: 10.5253/arde.v108i2.a3

Brambilla, M. & Guidali, F. 2005. Quando la voce è tutto: l'identificazione delle sottospecie di sterpazzolina *Sylvia cantillans* [When the voice is everything: the identification of the subspecies of the *Sylvia cantillans*]. – Avocetta 29(2): 154. (in Italian)

Brichetti, P., Saino, N. & Canova, L. 1986. Immigrazione ed espansione della Tortora dal collare orientale *Streptopelia decaocto* in Italia [Immigration and expansion of the Oriental Collared Dove *Streptopelia decaocto* in Italy]. – Avocetta 10: 45–49. (in Italian)

Brunelli, M., Sarrocco, S., Corbi, F., Sorace, A., Boano, A., De Felici, S., Guerrieri, G., Meschini, A. & Roma, S. 2011. Nuovo Atlante degli Uccelli Nidificanti nel Lazio [New Atlas of Nesting Birds in Lazio]. – Edizioni ARP (Agenzia Regionale Parchi) (in Italian)

Bruni, A., Mennill, D. J. & Foote, J. R. 2014. Dawn chorus start time variation in a temperate bird community: relationships with seasonality, weather, and ambient light. – Journal of Ornithology 155(4): 877–890. DOI: 10.1007/s10336-014-1071-7

Calvi, G., Campedelli, T., Florenzano, G. T. & Rossi, P. 2018. Evaluating the benefits of agri-environment schemes on farmland bird communities through a common species monitoring programme. A case study in northern Italy. – Agricultural Systems Elsevier 160: 60–69. DOI: 10.1016/j.agsy.2017.09.002

Capizzi, D., Sposimo, P., Sozio, G., Fratini, S., Zanet, S., Biondo, C., Romano, A., Dell'Agnello, F., Baccetti, N. & Petrassi, F. 2024. For birds and humans: challenges and benefits of rat eradication from an inhabited island (Ventotene, central Italy). – Pest Management Science 80(11): 5510–5518. DOI: 10.1002/ps.7947

Carlier, P. 1995. Vocal communication in Peregrine Falcons *Falco peregrinus* during breeding. – Ibis 137(4): 582–585. DOI: 10.1111/j.1474-919X.1995.tb03269.x

Catchpole, C. K. 1983. Variation in the song of the Great Reed Warbler *Acrocephalus arundinaceus* in relation to mate attraction and territorial defence. – Animal Behaviour 31(4): 1217–1225. DOI: 10.1016/S0003-3472(83)80028-1

Catchpole, C. K. 1986. Song repertoires and reproductive success in the Great Reed Warbler *Acrocephalus arundinaceus*. – Behavioral Ecology and Sociobiology 19(6): 439–445. DOI: 10.1007/BF00300547

Cecere, J., Cornara, L., Spina, F., Imperio, S. & Boitani, L. 2011. Birds outnumber insects in visiting *Brassica* flowers on Ventotene island (central Mediterranean). – Vie et Milieu – Life and Environment 61(3): 145–150.

Clement, P., del Hoyo, J., Collar, N., Kirwan, G. M. & Christie, D. A. 2020. Common Chiffchaff *(Phylloscopus collybita)*, version 1.0. – In: Billerman, S. M., Keeney, B. K., Rodewald, P. G. & Schulenberg, T. S. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.comchi1.01

Collar, N. 2024. Black Redstart *(Phoenicurus ochruros)*, version 1.1. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A., de Juana, E. & Billerman, S. M. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.blared1.01.1

Collar, N. & Christie, D. A. 2020. Eurasian Blackbird *(Turdus merula)*, version 1.0. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.eurbla.01

Dabelsteen, T. 1984. An analysis of the full song of the Blackbird *Turdus merula* with respect to message coding and adaptations for acoustic communication. – Ornis Scandinavica 15(4): 227–239. DOI: 10.2307/3675931

Dabelsteen, T. 1988. The meaning of the full song of the Blackbird *Turdus merula* to untreated and estradiol treated females. – Ornis Scandinavica 19(1): 7–16. DOI: 10.2307/3676520

Farnsworth, A., Gauthreaux, Jr. S. A. & Blaricom, D. V. 2004. A comparison of nocturnal call counts of migrating birds and reflectivity measurements on Doppler radar. – Journal of Avian Biology 35(4): 365–369. DOI: 10.1111/j.0908-8857.2004.03180.x

Flack, A., Aikens, E. O., Kölzsch, A., Nourani, E., Snell, K. R. S., Fiedler, W., Linek, N., Bauer, H.-G., Thorup, K., Partecke, J., Wikelski, M. & Williams, H. J. 2022. New frontiers in bird migration research. – Current Biology 32(20): 1187–1199. DOI: 10.1016/j.cub.2022.08.028

Frommolt, K. H. & Tauchert, K. H. 2014. Applying bioacoustic methods for long-term monitoring of a nocturnal wetland bird. – Ecological Informatics 21: 4–12. DOI: 10.1016/j.ecoinf.2013.12.009

Fornasari, L., Gustin, M., Carini, R. & Maselli, M. 2018. Migration patterns of Blackbird *Turdus merula* in northern Italy: a morphological and capture-recapture approach. – Ringing & Migration 33(2): 68–74. DOI: 10.1080/03078698.2019.1697067

Gelter, H. P. 1987. Song differences between the Pied Flycatcher *Ficedula hypoleuca*, the Collared Flycatcher *F. albicollis*, and their hybrids. – Ornis Scandinavica 18(3): 205–215.

Goymann, W., Spina, F., Ferri, A. & Fusani, L. 2010. Body fat influences departure from stopover sites in migratory birds: evidence from whole-island telemetry. – Biology Letters 6(4): 478–81. DOI: 10.1098/rsbl.2009.1028

Gregory, R. D., Gibbons, D. W. & Donald, P. F. 2004. Bird census and survey techniques. – In: Sutherland, W. J., Newton, I. & Green, R. (eds.) 2004. Bird Ecology and Conservation: A Handbook of Techniques. – Oxford University Press

Hahn, S., Bauer, S. & Liechti, F. 2009. The natural link between Europe and Africa – 2.1 billion birds on migration. – Oikos 118(4): 624–626. DOI: 10.1111/j.1600-0706.2008.17309.x

Higuchi, H. 2012. Bird migration and the conservation of the global environment. – Journal of Ornithology 153(Suppl.1): 3–14. DOI: 10.1007/s10336-011-0768-0

Jensen, K. K. & Klokker, S. 2006. Hearing sensitivity and critical ratios of Hooded Crows *(Corvus corone cornix)*. – The Journal of the Acoustical Society of America 119(2): 1269–1276. DOI: 10.1121/1.2159431

Jensen, K. K., Larsen, O. N. & Attenborough, K. 2008. Measurements and predictions of Hooded Crow *(Corvus corone cornix)* call propagation over open field habitats. – The Journal of the Acoustical Society of America 123(1): 507–518. DOI: 10.1121/1.2817363

K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology 2024. Raven Pro: Interactive Sound Analysis Software (Version 1.6.5). – Ithaca, NY: The Cornell Lab of Ornithology https://www.ravensoundsoftware.com/

Kirwan, G. M., David, T. S., Pyle, P., Sharpe, C. J. & Garcia, E. 2024. Yellow-legged Gull *(Larus michahellis)*, version 1.1. – In: Keeney, B. K. & Kirwan, G. M. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.yelgul1.01.1

Lardelli, R., Bogliani, G., Brichetti, P., Caprio, E., Celada, C., Conca, G., Fraticelli, F., Gustin, M., Janni, O., Pedrini, P., Puglisi, L., Rubolini, D., Ruggieri, L., Spina, F., Tinarelli, R., Calvi, G. & Brambilla, M. 2022. – Atlante degli Uccelli nidificanti in Italia [Atlas of Nesting Birds in Italy]. – Edizioni Belvedere (in Italian)

Lei, F., Zhao, H., Wang, A., Yin, Z. & Payne, R. B. 2005. Vocalizations of the Common Cuckoo *(Cuculus canorus)* in China. – Acta Zoologica Sinica 51(1): 31–37.

Leseberg, N. P., Venables, W. N., Murphy, S. A. & Watson, J. E. M. 2020. Using intrinsic and contextual information associated with automated signal detections to improve call recognizer performance: A case study using the cryptic and critically endangered Night Parrot *Pezoporus occidentalis*. – Methods in Ecology and Evolution 11: 1520–1530. DOI: 10.1111/2041-210X.13475

Luschi, P. 1993. Improvisation of new notes during singing by male Sardinian Warbler *Sylvia melanocephala*. – Bioacoustics 4(4): 235–244. DOI: 10.1080/09524622.1993.10510435

Maggini, I., Trez, M., Cardinale, M. & Fusani, L. 2020. Stopover dynamics of 12 passerine migrant species in a small Mediterranean island during spring migration. – Journal of Ornithology 161(3): 793–802. DOI: 10.1007/s10336-020-01768-7

Manica, M., Riello, S., Scagnolari, C. & Caputo, B. 2020. Spatio-temporal distribution of *Aedes albopictus* and *Culex pipiens* along an urban-natural gradient in the Ventotene Island, Italy. – International Journal of Environmental Research and Public Health 17(22): 8300. DOI: 10.3390/ijerph17228300

Manzano-Rubio, R., Bota, G., Brotons, L., Soto-Largo, E. & Pérez-Granados, C. 2022. Low-cost open-source recorders and ready-to-use machine learning approaches provide effective monitoring of threatened species. – Ecological Informatics 72: 101910. DOI: 10.1016/j.ecoinf.2022.101910

Montemaggiori, A. & Spina, F. 2002. Il Progetto Piccole Isole (PPI): uno studio su ampia scala della migrazione primaverile attraverso il Mediterraneo [The Progetto Piccole Isole (PPI): a large-scale study of spring migration across the Mediterranean]. – In: Brichetti, P. & Gariboldi, A. (eds.) Manuale di ornitologia, 3. – Edagricole, Milan (in Italian)

Moreno-Opo, R., Núñez, J. & Pina Macías, M. 2018. European Bee-eaters *(Merops apiaster)* and apiculture: understanding their interactions and the usefulness of nonlethal techniques to prevent damage at apiaries. – European Journal of Wildlife Research 64: 55. DOI: 10.1007/s10344-018-1215-9

Morganti, M., Mellone, U., Bogliani, G., Saino, N., Ferri, A., Spina, F. & Rubolini, D. 2011. Flexible tuning of departure decisions in response to weather in Black Redstarts *Phoenicurus ochruros* migrating across the Mediterranean Sea. – Journal of Avian Biology 42(4): 323–334. DOI: 10.1111/j.1600-048X.2011.05331.x

Moskát, C., Elek, Z., Bán, M., Geltsch, N. & Hauber, M. E. 2017. Can Common Cuckoos discriminate between neighbours and strangers by their calls? – Animal Behaviour 126: 253–260. DOI: 10.1016/j.anbehav.2017.02.013

Mota, P. G. 1999. The functions of song in the Serin. – Ethology 105(2): 137–148. DOI: 10.1046/j.1439-0310.1999.00366.x

Mota, P. G. & Cardoso, G. 2001. Song organisation and patterns of variation in the Serin *(Serinus serinus)*. – Acta Ethologica 3: 141–150. DOI: 10.1007/s102110000034

Naguib, M., Hammerschmidt, K. & Wirth, J. 2001. Microgeographic variation, habitat effects and individual signature cues in calls of Chiffchaffs *Phylloscopus collybita canarensis*. – Ethology 107(4): 341–355. DOI: 10.1046/j.1439-0310.2001.00669.x

Naguib, M., Mundry, R., Hultsch, H. & Todt, D. 2002. Responses to playback of whistle songs and normal songs in male Nightingales: effects of song category, whistle pitch, and distance. – Behavioral Ecology and Sociobiology 52(3): 216–223. DOI: 10.1007/s00265-002-0511-1

Nice, M. M. 1941. The Role of territory in bird life. – The American Midland Naturalist 26(3): 441–487. DOI: 10.2307/2420732

Panuccio, M., Martín, B., Morganti, M., Onrubia, A. & Ferrer, M. 2017. Long-term changes in autumn migration dates at the Strait of Gibraltar reflect population trends of soaring birds. – Ibis 159(1): 55–65. DOI: 10.1111/ibi.12420

Pérez-Granados, C., Bota, G., Giralt, D., Barrero, A., Gómez-Catasús, J., Bustillo-de la Rosa, D. & Traba, J. 2019. Vocal activity rate index: a useful method to infer terrestrial bird abundance with acoustic monitoring. – Ibis 161(4): 901–907. DOI: 10.1111/ibi.12728

Petrusková, T., Kahounová, H., Pišvejcová, I., Čermáková, A., Brinke, T., Burton, N. H. K. & Petrusek, A. 2021. Evaluating the potential effects of capturing and handling on subsequent observations of a migratory passerine through individual acoustic monitoring. – Journal of Avian Biology 52(6): e02739. DOI: 10.1111/jav.02739

Petrusková, T., Osiejuk, T. S. & Petrusek, A. 2010. Geographic variation in songs of the Tree Pipit *(Anthus trivialis)* at two spatial scales. – The Auk 127(2): 274–282. DOI: 10.1525/auk.2009.09077

Pretto, F., Celesti-Grapow, L., Carli, E. & Blasi, C. 2010. Influence of past land use and current human disturbance on non-native plant species on small Italian islands. – Plant Ecology 210(2): 225–239. DOI: 10.1007/s11258-010-9751-8

QGIS.org. 2025. QGIS Geographic Information System. – QGIS Association http://www.qgis.org

Romagosa, C. M. & Mlodinow, S. G. 2022. Eurasian Collared Dove *(Streptopelia decaocto)*, version 1.1. – In: Pyle, P., Rodewald, A. D. & Billerman, S. M. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, New York, USA. DOI: 10.2173/bow.eucdov.01.1

Rose, E. M., Prior, N. H. & Ball, G. F. 2022. The singing question: re-conceptualizing birdsong. – Biological Reviews 97(1): 326–342. DOI: 10.1111/brv.12800

Sanders, C. & Mennil, D. J. 2014. Acoustic monitoring of nocturnally migrating birds accurately assesses the timing and magnitude of migration through the Great Lakes. – Ornithological Applications 116(3): 371–383. DOI: 10.1650/CONDOR-13-098.1

Schwilch, R., Mantovani, R., Spina, F. & Jenni, L. 2001. Nectar consumption of warblers after long-distance flights during spring migration. – Ibis 143(1): 24–32. DOI: 10.1111/j.1474-919X.2001.tb04166.x

Spector, D. A. 1994. Definition in biology: The case of "Bird Song". – Journal of Theoretical Biology 168(4): 373–381. DOI: 10.1006/jtbi.1994.1117

Spina, F., Massi, A., Montemaggiori, A. & Baccetti, N. 1993. Spring migration across central Mediterranean: general results from the "Progetto Piccole Isole". – Vogelwarte 37: 1–94.

Tenan, S. & Spina, F. 2010. Timing and condition-related effects on recapture probability, mass change, and stopover length of spring migrating songbirds on a small Mediterranean island. – Ardeola 57(1): 121–132.

Tyler, S. 2020. Tree Pipit *(Anthus trivialis)*, version 1.0. – In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A. & de Juana, E. (eds.) Birds of the World. – Cornell Lab of Ornithology, Ithaca, NY, USA. DOI: 10.2173/bow.trepip.01

Wrege, P. H. & Cade, T. J. 1997. Courtship behavior of large falcons in captivity. – Journal of Raptor Research 11(1–2): 1–46.

Wroza, S. 2024. Identifying Migratory Birds by Sound in Britain and Europe. – Bloomsbury Publishing PLC, London

Xia, C., Deng, Z., Lloyd, H., Møller, A. P., Zhao, X. & Zhang, Y. 2019. The function of three main call types in Common Cuckoo. – Ethology 125(9): 652–659. DOI: 10.1111/eth.12918