

First record of Leisler's bat *Nyctalus leisleri* from the Maltese Islands

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Abstract:

Understanding species distributions is key to biodiversity conservation, particularly on islands where ecological communities may be vulnerable to anthropogenic pressures. The Leisler's bat *Nyctalus leisleri* is a widespread European bat known for long-distance migrations, whose occurrence in the central Mediterranean remains poorly documented. Here we present the first confirmed records of *N. leisleri* from the Maltese Islands, based on passive acoustic monitoring conducted between April and December 2024. Acoustic recorders were deployed across Malta, Gozo, and Comino using fixed recording stations and mobile transects, with automatic call classification followed by manual validation. A total of 528 nyctaloid bat passes were recorded, of which 124 were assigned to *N. leisleri* based on a quantitative assessment of echolocation calls. The species was detected across both main islands, showing widespread occurrence and a seasonal activity peak in summer, consistent with patterns observed in other resident high-flying bats. These findings expand the known bat fauna of the archipelago and suggest that *N. leisleri* has likely been overlooked rather than absent, highlighting the importance of long-term acoustic monitoring for detecting elusive species. The continuous seasonal presence and spatial distribution we found suggest that the species may be present year-round in Malta, yet roosts, reproduction or hibernation still await concrete evidence. Our results contribute to the understanding of Mediterranean bat biogeography and emphasize the need to incorporate migratory species into conservation planning on islands. Further research should investigate roost availability, habitat use, and seasonal dynamics to clarify the ecological role and conservation status of *N. leisleri* in the Maltese Archipelago.

Keywords: *Nyctalus leisleri*, Maltese Islands, Leisler's bat.

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Understanding species distributions is key to biodiversity conservation, particularly on islands where ecological communities may be vulnerable to anthropogenic pressures. The Leisler's bat *Nyctalus leisleri* is a widespread European bat known for long-distance migrations, whose occurrence in the central Mediterranean remains poorly documented. Here we present the first confirmed records of *N. leisleri* from the Maltese Islands, based on passive acoustic monitoring conducted between April and December 2024. Acoustic recorders were deployed across Malta, Gozo, and Comino using fixed recording stations and mobile transects, with automatic call classification followed by manual validation. A total of 528 nyctaloid bat passes were recorded, of which 124 were assigned to *N. leisleri* based on a quantitative assessment of echolocation calls. The species was detected across both main islands, showing widespread occurrence and a seasonal activity peak in summer, consistent with patterns observed in other resident high-flying bats. These findings expand the known bat fauna of the archipelago and suggest that *N. leisleri* has likely been overlooked rather than absent, highlighting the importance of long-term acoustic monitoring for detecting elusive species. The continuous seasonal presence and spatial distribution we found suggest that the species may be present year-round in Malta, yet roosts, reproduction or hibernation still await concrete evidence. Our results contribute to the understanding of Mediterranean bat biogeography and emphasize the need to incorporate migratory species into conservation planning on islands. Further research should investigate roost availability, habitat use, and seasonal dynamics to clarify the ecological role and conservation status of *N. leisleri* in the Maltese Archipelago.

Introduction

Understanding species' distributions is a key asset in biological conservation, especially in the case of protected species occurring on islands, where they may be more subjected to anthropogenic threats (Conenna et al. 2017). The Leisler's bat *Nyctalus leisleri* (Kuhl, 1817) is a medium-sized and fast-flying European bat, adapted to exploit open and semi-open habitats such as woodland clearings, forest edges, and urban parks, often foraging well above the canopy (Dietz & Kiefer 2016). Its echolocation calls are adapted for detecting prey in open space, and its roosting behaviour typically involves tree cavities or artificial structures in mature woodlands (Russ et al. 2003). *Nyctalus leisleri* is one of the few European bats considered to be a long-distance migratory species, with some individuals known to travel over 1,500 km between summer and winter roosts (Boston et al. 2021). This trait may contribute to its potential for colonizing new areas, especially in a context of changing environmental conditions (Dondini et al. 2025). Nonetheless, the species features a plastic spatial ecology, with parts of some populations being short-distance migrants or even sedentary (Ancillotto & Russo 2015; Boston et al. 2021). The species is widely distributed across temperate and Mediterranean Europe, with core populations in Central Europe, the British Isles, and parts of the Iberian and Italian Peninsulas (Boston et al. 2021). However, its distribution in the Mediterranean Basin remains relatively poorly known, particularly on islands, where the presence of migratory bats is often underreported due to logistical constraints on monitoring efforts and limitations in detection methods (Ancillotto et al., 2014). *Nyctalus leisleri* is though known to occur, among Western Mediterranean basin, at least in Corsica (Libois 1983), Sardinia (Mucedda 1997), and Pantelleria (Cistrone et al. 2024). The Maltese Archipelago, consisting of the main islands of Malta, Gozo, and Comino, lies at the southern edge of the central Mediterranean, approximately 93 km south of Sicily. The archipelago supports a diverse assemblage of bats, reflecting both its biogeographical position and the variety of roosting sites available in natural cliffs, anthropogenic structures, and karstic features (Baron 2007). Historical and recent studies have reported the presence of seven to ten bat species, including both sedentary and potentially migratory taxa (Baron 2007; Batsleer et al. 2019; Mifsud & Vella 2019). To date, *N. leisleri* has not been reported from the Maltese Islands in any faunal checklist or published survey. Its absence from the regional literature may reflect a true historical absence or simply a lack

54 54 of suitable survey effort and methodological sensitivity to detect the species. Given the recent
55 55 improvement and availability in passive acoustic monitoring, and the growing awareness of seasonal
56 56 bat movements across Europe (e.g., Dondini et al. 2012), it is timely to reassess the presence of
57 57 migratory bats in the archipelago. More specifically, the most recent acoustic sampling campaign
58 58 conducted on Malta so far (Mifsud and Vella 2019) used mobile acoustic transects only, a technique
59 59 that provides much lower amounts of recordings in comparison to passive autonomous recorders, and
60 60 that thus may more easily miss rare species (de Torrez et al. 2017).
61 61 In this study, we report the first records of *N. leisleri* for the Maltese Islands, based on acoustic
62 62 detections supported by manual validation. These findings represent a new addition to the known bat
63 63 fauna of the archipelago, and suggest that *N. leisleri* may be an overlooked component of the local bat
64 64 community. We discuss the implications of this finding for biogeographical patterns, potential
65 65 migratory habits by the local population, and the need to integrate migratory species into conservation
66 66 planning especially on Mediterranean islands.

67 67 **Methods**

68 68 Data for this study was collected during a monitoring project funded by the Maltese Environment and
69 69 Resources Authority (ERA) aimed at reassessing the conservation status of bats as per Article 17 of
70 70 the EU Habitats Directive. From April to December 2024, Audiomoth recorders (OpenAcoustics) were
71 71 deployed at 14 locations throughout Malta, Gozo, and Comino. Additionally, acoustic survey transects
72 72 were also conducted, using Anabat Swift (Titley) devices on 14 monitoring areas, which were each
73 73 designed to include about thirty 1x1km grid cells of the official grid map of the Maltese Islands as a
74 74 standard system, resulting in 10, 3 and 1 points – and as many transects – on Malta, Gozo, and Comino,
75 75 respectively. Sampling points and transects were not spatially overlapping (i.e., N sites = 28) and were
76 76 located in a stratified design in order to 1) cover all main habitat types on the Islands, and 2) comprise
77 77 both non-protected and protected areas under the Natura 2000 network. Recorders were placed inside
78 78 water-proof cases and mounted on elevated landscape elements (poles, rocks) at approx. 1.5 m from
79 79 the ground, minimizing environmental obstruction. Recording occurred continuously from sunset to
80 80 dawn, saving 10 s files – followed by 50 s of pause in the case of fixed points. Sampling rate was set

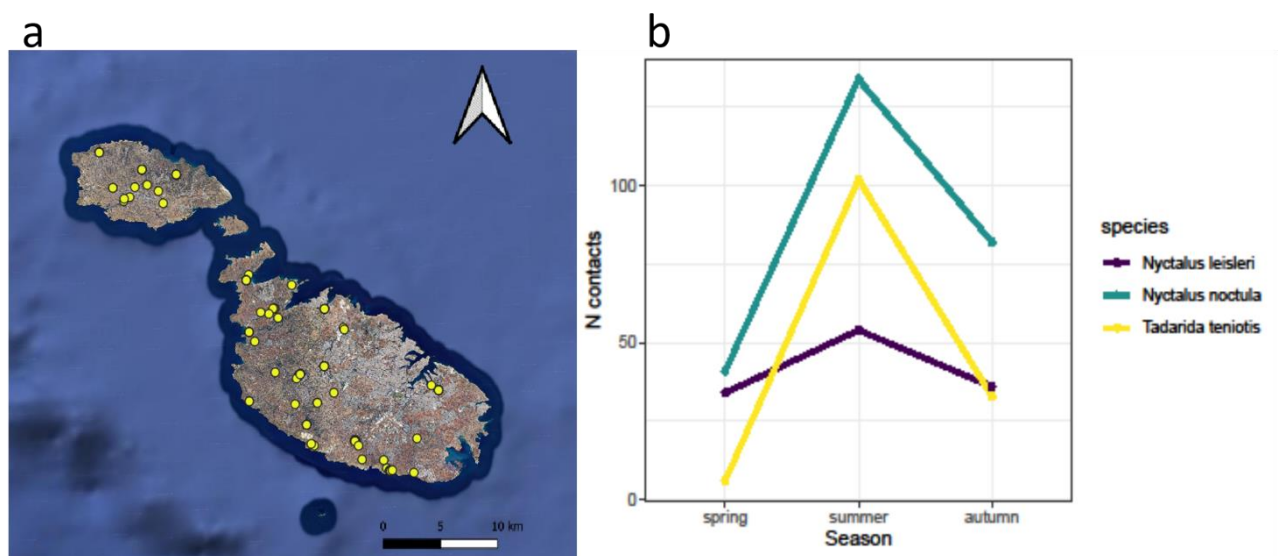
81 81 at 250 kHz; surveys were carried out only on nights with no rain and minimum temperatures $>10^{\circ}\text{C}$.
82 82 All fixed locations and transects were surveyed twice per season (spring, summer, autumn),
83 83 comprising 2 consecutive nights each survey in the case of fixed locations. We then employed Wildlife
84 84 Acoustics Inc.'s Kaleidoscope Pro ver.5.6.3 software to filter out files containing noise and to conduct
85 85 a preliminary automatic identification from recordings. After preliminary file inspection, we focused
86 86 specifically on “nyctaloid” bat calls i.e., low-frequency calls usually emitted by fast and high flyers
87 87 such as from genera *Eptesicus*, *Nyctalus*, and *Tadarida*, in order to clarify species’ identities. Manual
88 88 identification of species after automatic processing was then conducted; this procedure included the
89 89 manual measurement of key echolocation call parameters (FMaxE: frequency of maximum energy;
90 90 EF: ending frequency; Dur: call duration) known to provide diagnostic elements (following Russ
91 91 2021). More specifically, contacts were assigned to *N. leisleri* when the sequence showed the
92 92 alternance of frequency-modulated (FMaxE range: 25-30.8 kHz) and quasi-constant-frequency calls
93 93 (FMaxE range: 22-23.8kHz). Comparably alternating calls at lower frequencies (quasi-constant-
94 94 frequency calls: 18.5-21.0 kHz) were assigned to *N. noctula*, while sequences with no alternating calls
95 95 at even lower frequencies (FMaxE range: 10-18.0 kHz) were assigned to *T. teniotis*. In case inspection
96 96 of all the considered parameters was not sufficient, we refrained to assign the contact to any species.
97 97 As for investigating the potential role of Malta Islands as migratory stop-over and/or permanently
98 98 inhabited area, we assessed the phenology of the detected nyctaloid bats on the island by inspecting
99 99 the numbers of contacts (i.e., numbers of files with >2 echolocation calls assigned to a given species)
100 100 per species among different seasons. More specifically, we expect nyctaloids of all species to be actual
101 101 residents of the Islands, and thus predict their occurrence in the acoustic record year-round, with no
102 102 peak during migration seasons i.e., spring and autumn.

103 103

104 104 **Results and discussion**

105 105 We recorded 528 contacts belonging to low-echolocating ‘nyctaloid’ bats (182 from fixed points, 346
106 106 from moving transects). Of these, 398 were assigned to either *N. noctula* (N=257) or *T. teniotis*
107 107 (N=141), while 6 were considered as non-classifiable, and the remaining 124 were unequivocally

108 108 assigned to *N. leisleri* (see Figure S1 in Supplementary materials). The latter was recorded across all
109 109 the study area, including the two largest islands (Figure 1a), with most contacts occurring on Gozo and
110 110 on the western portion of Malta, but was not detected on Comino. Such pattern may be due to
111 111 differences in land cover composition – eastern Malta is more heavily urbanized and covered by
112 112 agricultural lands – since our sampling effort was constant across the study area. In terms of temporal
113 113 trends, both noctule species as well as *T. teniotis* were recorded across all sampling sessions, with a
114 114 peak during summer months (Figure 1b).



115 115
116 116 Figure 1. Presence of Leisler's bat (*Nyctalus leisleri*) on the Maltese Islands; a) occurrence records –
117 117 background ©Google Maps service. b) seasonal trends in the numbers of acoustic contacts by three
118 118 high-flying bat species on the Maltese Islands.

119 119 The new record of *N. leisleri* on both Malta and Gozo represents a remarkable addition to the known
120 120 bat fauna of the Maltese Islands, by expanding the current species list, and highlighting the importance
121 121 of continued survey efforts, particularly for elusive and high-flying bat taxa on islands. These findings
122 122 suggest that *N. leisleri*, though previously undetected, may occur regularly in the region, also
123 123 confirming recent comparable observations from relatively close Mediterranean islands (Pantelleria,
124 124 Sicily: Cistrone et al. 2024). Namely, the record from Pantelleria also refers to acoustic data only, with
125 125 the authors reporting the species as infrequent on the island, differently to our case on the Maltese

126 126 Islands; as such, both islands, despite being righteously included in the species' range, lack evidence
127 127 of resident populations.

128 128 From a biogeographical perspective, the occurrence of *N. leisleri* in the Maltese Islands is consistent
129 129 with its known migratory behaviour and capacity for long-distance dispersal, that allowed the species
130 130 to colonize several islands across the Mediterranean. No specific information is available on the
131 131 phylogeographical patterns of this species from the southern region of its range (Boston et al. 2015),
132 132 yet South-Western Europe likely played a key role of glacial refugium for one of the two main
133 133 mitochondrial haplotypes known so far. The archipelago's central location in the Mediterranean basin
134 134 places it within potential migratory corridors connecting North Africa with southern Europe. Similar
135 135 insular records have been reported from Corsica and Sardinia (Boston et al. 2021). The species is also
136 136 known to occur on several smaller Greek islands (Georgiakakis et al. 2023), as well as on Elba and
137 137 Capri islands in Italy (Ancillotto et al. 2015; Loy et al. 2019). The continuous occurrence of *N. leisleri*
138 138 in the acoustic record from the Maltese Islands we here report may support the resident nature of – at
139 139 least part of – the local population, yet more data are needed to ascertain this. The high summer peak
140 140 in activity as well as the wide distribution of *N. leisleri* on Malta and Gozo suggests the occurrence of
141 141 a resident population, despite no roosts are yet known to date. Moreover, the species also occurs in
142 142 Maghreb (N Africa; Boston et al. 2021), so we cannot exclude that the Maltese population fully or
143 143 partially migrates e.g., in winter, to and from north Africa. The detection of *N. leisleri* also underscores
144 144 the limitations of historical and conventional survey methods in assessing insular bat faunas. Due to
145 145 its fast and high flight style and large overlap with other species in its acoustic parameters of
146 146 echolocation calls, its reliable detection and identification are relatively challenging, and possibly lead
147 147 to under-detection in areas where it may be present. The use of full-spectrum acoustic detectors and
148 148 trained manual validation has though proven effective in identifying *N. leisleri* calls, leading to a recent
149 149 expansion of the known range of the species in the Mediterranean (Ancillotto & Russo 2015; Cistrone
150 150 et al. 2024, this work). The occurrence of *N. leisleri* in Malta and Gozo raises questions about roosting
151 151 opportunities and foraging habitat availability on small Mediterranean islands. While the species
152 152 typically roosts in tree cavities in temperate forests, it is also known to use anthropogenic structures
153 153 such as buildings and bat boxes in urban or semi-natural landscapes (Boston et al. 2021), and it is also

likely that rock crevices may also be used in absence of more favourite types of roosts e.g., on Canary Islands (Trujillo and Barone 1991), as documented for other tree-dwelling bat species (Ancillotto et al. 2014). Malta's modified landscape, characterized by a mix of urban settlements, agricultural land, and small scattered woodlands and water bodies, may offer suitable foraging and roosting opportunities, as also seen in similar Mediterranean insular contexts (Cistrone et al. 2024). Nonetheless, remnants of old-growth oak forests still occur on Malta (Spiteri and Stevens 2019), highlighting that even small, wooded fragments may still represent profitable habitats to a forest-specialist such as *N. leisleri*. In terms of conservation, the record of *N. leisleri* in the Maltese Islands prompts a reconsideration of its potential role in local ecosystems, and the need to include migratory species in conservation planning. Although the species is listed as Least Concern at the global and European levels by the IUCN (Juste & Paunović 2016; Russo & Cistrone 2023), it is included in Annex IV of the EU Habitats Directive and is subject to monitoring obligations in member states. Its detection in Malta has implications for national reporting and may require updates to conservation assessments and legal frameworks.

In conclusion, *N. leisleri* is a new addition to the bat fauna of the Maltese Islands, extending the known range of the species in the central Mediterranean, and underscoring the value of acoustic monitoring in bat surveys. Further research should aim at determining the status of the species in the archipelago—e.g., whether it is a migrant or transient—and possibly assess habitat use, roost selection, and potential threats. Coordinated regional and international efforts will be key to understanding broader migratory patterns across the Mediterranean and to ensuring the effective conservation of bats in insular environments.

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