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Temporal segregation and coexistence between the Lanner Falcon *Falco biarmicus* and the Western Barn Owl *Tyto alba* in a shared secondary cavity in a cliff

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ABSTRACT

Temporal segregation between diurnal and nocturnal raptors is a well-known ecological principle, yet it has rarely been documented with direct, continuous observations in shared nesting environments. In this study, we provide one of the first camera-trap based documentations of such segregation between the Lanner Falcon and the Western Barn Owl using the same secondary cavity in a cliff in eastern Sicily (Italy). Using automatic camera traps installed inside the cavity, we collected 785 video recordings between April and June 2025, yielding 547 detection events for the Lanner Falcon and 197 detection events for the Western Barn Owl. The analysis of diel activity patterns revealed an almost complete temporal separation ($\Delta = 0.043$; 95% CI: 0.036–0.049) between the strictly diurnal Lanner Falcon and the nocturnal Western Barn Owl. Since the Western Barn Owl is occasionally preyed upon by the falcon, this near-complete temporal separation prevents direct encounters and is consistent with predation risk reduction. Our findings illustrate how pre-existing differences in daily activity timing – inherent to the respective chronotypes of each species – can allow a predator and a potential prey to exploit the same physical refuge without direct encounters, thereby increasing the ecological diversity of cliff ecosystems.

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Diurnal and nocturnal raptors are generally viewed as occupying complementary temporal niches within the 24-hour cycle, a pattern so intuitive that it is often taken for granted and rarely quantified in detail (see Jakšić 1982 for a review). Understanding how such temporal complementarity operates in shared refuges can, however, provide valuable insights into conditions under which a predator and its potential prey may use the same physical space without direct conflict (Helm *et al.* 2017).

In Sicily, the Lanner Falcon *Falco biarmicus feldeggii* is an apex predator of medium-to-large vertebrates, whereas the Western Barn Owl *Tyto alba* (hereafter 'Barn Owl') represents a smaller meso-predator that may occasionally become a prey item of the former (Leonardi 2015). Despite this predator–prey relationship, both species may use the same cliffs for resting or roosting, raising the question of how this shared use of space is structured in time.

The Lanner Falcon represents one of the most threatened raptors in the Western Palearctic (BirdLife

International 2024). In Europe, its range is largely restricted to fragmented populations in the central and eastern Mediterranean, with Sicily hosting the core stronghold of the *feldeggii* subspecies (Leonardi *et al.* 2024). Continuous monitoring of breeding territories in Sicily is therefore crucial to assessing population trends, reproductive performance and potential threats, and to inform effective conservation strategies (Amato *et al.* 2014, 2021, Sarà 2014, Sarà *et al.* 2023). As part of a pilot monitoring study relying on direct observations and a small array of two automatic camera traps, a rock cliff in eastern Sicily regularly occupied by a pair of Lanner Falcons during the breeding season was selected.

Camera traps placed on perches and at breeding sites are among the most efficient indirect methods for assessing survival, feeding habits, predation risk and other behavioural patterns that are difficult to observe directly (Trolliet *et al.* 2014, Bruce *et al.* 2025). This remote technology has significantly enhanced our understanding of wildlife behaviour and has crucial

conservation applications, particularly for rare and sensitive species (Caravaggi *et al.* 2017, Wearn & Glover-Kapfer 2019, Hending 2025). Camera-trap monitoring is considered a non-invasive technique and has been successfully applied to falcons and other endangered raptors (Gil-Sánchez *et al.* 2021, Bontrager *et al.* 2023, Bamber *et al.* 2025).

After confirming that the Lanner Falcon pair had not initiated breeding activity during the current season, camera traps were installed in two distinct cavities: (1) the nest cavity, normally used for egg-laying, and (2) a secondary cavity used by the Lanner Falcons as a resting place and prey-storage site. The present note focuses on observations from the secondary cavity, where episodes of temporal partitioning in cavity use between the Lanner Falcon and the Barn Owl were documented.

The primary objective of this study was to quantify and describe, using continuous camera-trap monitoring, the temporal partitioning in use of a shared secondary cavity (within a cliff) between a diurnal raptor (the Lanner Falcon) and a nocturnal raptor (the Barn Owl), which have an asymmetric predator–prey relationship. Two secondary exploratory objectives were to assess whether the Lanner Falcon's departure time from the cavity shifted seasonally, and also to compare the duration of morning versus afternoon visits. To our knowledge, this is one of the first camera-trap-based quantifications of temporal partitioning in cavity use between these two species within the same cliff system.

Methods

Camera trapping and data collection

Observations were conducted using a digital camera trap (DSOON model H8WIFI-BT) installed inside the secondary cavity (Figure 1). The camera was configured to record 30-second video clips with a five second delay between consecutive triggers. The device operated from 2 April to 22 June 2025, yielding a total of 785 video clips. To avoid false detections, clips triggered by wind, insects, or without a clearly identifiable subject were excluded, resulting in a final dataset comprising 745 valid clips.

Because the inter-trigger delay was five seconds (a hardware constraint of the camera model), consecutive valid clips of the same species recorded within that interval were merged into a single detection event to avoid pseudo-replication from a single uninterrupted visit. This conservative merging criterion may still leave limited temporal

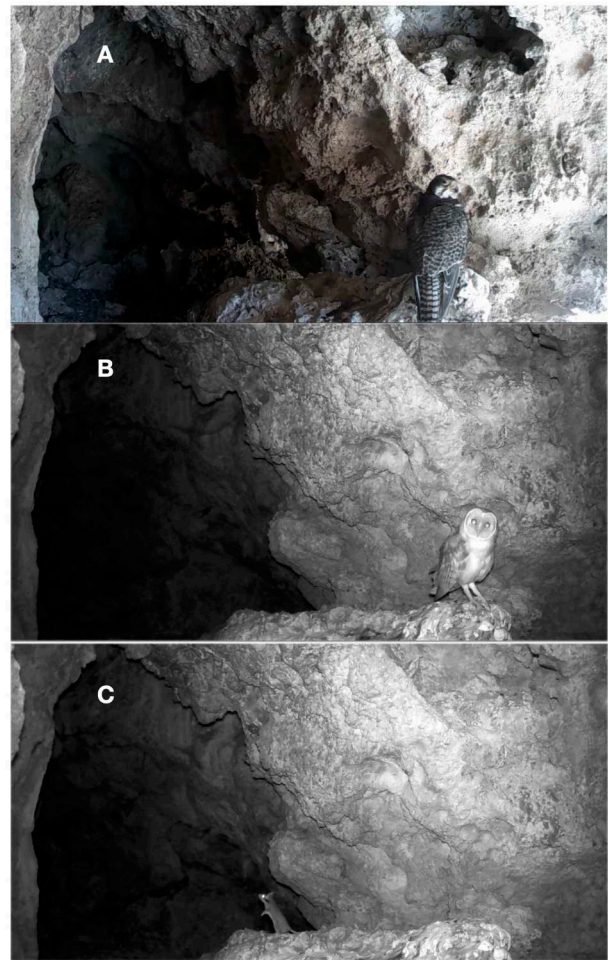


Figure 1. Selected still frames from camera-trap footage taken inside the secondary cavity within a cliff: (a) Lanner Falcon; (b) Barn Owl; (c) Garden Dormouse, an example of another vertebrate species occasionally using the site.

autocorrelation for extended visits; a sensitivity check using a one minute independence threshold did not substantially alter the activity distributions or the overlap coefficient. The final analytical dataset comprised 547 detection events for the Lanner Falcon and 197 detection events for the Barn Owl. Data were imported into R (v. 4.x; R Core Team) using the package readxl. The remaining clips documented the Garden Dormouse *Eliomys quercinus* and other occasional visitors. Date and time values were converted to R date-time objects, and each detection time was expressed as a decimal hour (0–24) to enable analysis of diel activity patterns.

Day/night classification

To classify detections as ‘diurnal’ or ‘nocturnal’, sunrise and sunset times for the cliff site were calculated for each date using the suncalc package in R. A detection

was classified as diurnal if it fell strictly between official sunrise and sunset times for that date, and as nocturnal otherwise. Civil twilight periods (approximately 30 minutes before sunrise and after sunset) were also identified to characterize crepuscular activity but are not separately labelled in the figures.

Temporal overlap analysis

Temporal activity distributions were explored using kernel density estimation plots produced with the *ggplot2* package on a linear 0–24 hour axis. To enable circular statistical analyses, detection times were transformed from decimal hours to radians ($0-2\pi$) representing the 24 hour cycle. The degree of overlap in diel activity between the Lanner Falcon and the Barn Owl was quantified using the overlap coefficient Δ , calculated with the *overlap* package. Given the sample sizes available (> 50 per species), the *Dhat4* estimator was used, following the recommendations of Ridout & Linkie (2009). Δ ranges from 0 (no overlap) to 1 (complete overlap). Ninety-five per cent confidence intervals for Δ were estimated using bootstrap resampling (1,000 iterations) with percentile-based limits.

Circular test of homogeneity

Differences in temporal activity between the two species were tested using the Watson-Wheeler test for homogeneity of circular distributions, implemented in the *circular* package. This non-parametric test evaluates whether two samples share the same underlying activity distribution. Ties in detection times were handled according to package defaults. Statistical significance was inferred at $P < 0.05$.

Exploratory analyses of the Lanner Falcon data

Exit time was defined as the decimal hour of the last detection event of the Lanner Falcon on days when an individual was observed leaving the cavity (i.e. the last detection was not immediately followed by another later the same day; $n = 33$ days). A simple linear regression was fitted using the *lm()* function in R (response: exit time in decimal hours; predictor: Julian date) to assess whether departure time changed progressively across the season. Permanence duration was calculated as the elapsed time (hours) between the first and the last detection event of the Lanner Falcon within a single cavity visit, for visits spanning ≥ 2 detection events. Visits were classified as ‘morning’ if the first detection occurred before 12:00 local solar

time, and as ‘afternoon’ if the first detection was at or after 12:00. Differences in permanence duration between the two groups were tested with the Mann-Whitney U test.

Results

The temporal overlap coefficient between the two species was very low ($\Delta = 0.043$; 95% CI = 0.036–0.049), indicating almost complete temporal segregation (Figures 1 and 2). Of all Lanner Falcon detection events, 92.7% occurred during daylight hours, while 99.5% of Barn Owl detection events were recorded at night. A negligible fraction of events ($< 1\%$) for both species occurred outside their predominant activity periods. The Watson-Wheeler test confirmed that the two species exhibited significantly different diel activity distribution ($W = 420.6$; $df = 2$; $P < 2.2 \times 10^{-16}$).

The linear regression of exit time on Julian date was significant ($R^2 = 0.554$, $P < 0.001$; $n = 33$; Figure 3(A)), indicating that the Lanner Falcon tended to leave the cavity progressively later in the day as the season advanced from April to June. Permanence duration differed significantly between morning and afternoon visits (Mann-Whitney $U = 25.0$, $P < 0.001$; Figure 3(B)): afternoon stays were substantially longer (median = 3.09 hours) than those recorded in the morning stays (median = 0.21 hours; morning $n = 136$; afternoon $n = 411$).

Discussion

Sharing the same cliff site can have significant implications for birds of prey (Sergio & Hiraldo 2008). Barn Owls have been reported to abandon traditional nesting sites shortly after the arrival of larger, aggressive falcons such as the Peregrine Falcon *Falco peregrinus* (Sergio *et al.* 2003, Lusby & O’Clery 2014). In environments where suitable nesting cliffs are scarce, access to high-quality cavities represents a critical limiting resource. The data presented here illustrate a different scenario: rather than spatial exclusion, temporal complementarity in diel activity allows a predator (the Lanner Falcon) and a potential prey species (the Barn Owl) to use the same secondary cavity without direct encounters.

The Lanner Falcon is an apex predator whose diet includes smaller raptors, harriers and several owl species (Leonardi 2015). The Barn Owl has been recorded as a prey item in Sicily (accounting for approximately 0.6% of the diet) and in South Africa (Tarboton & Allan 1984, Massa *et al.* 1991). Because

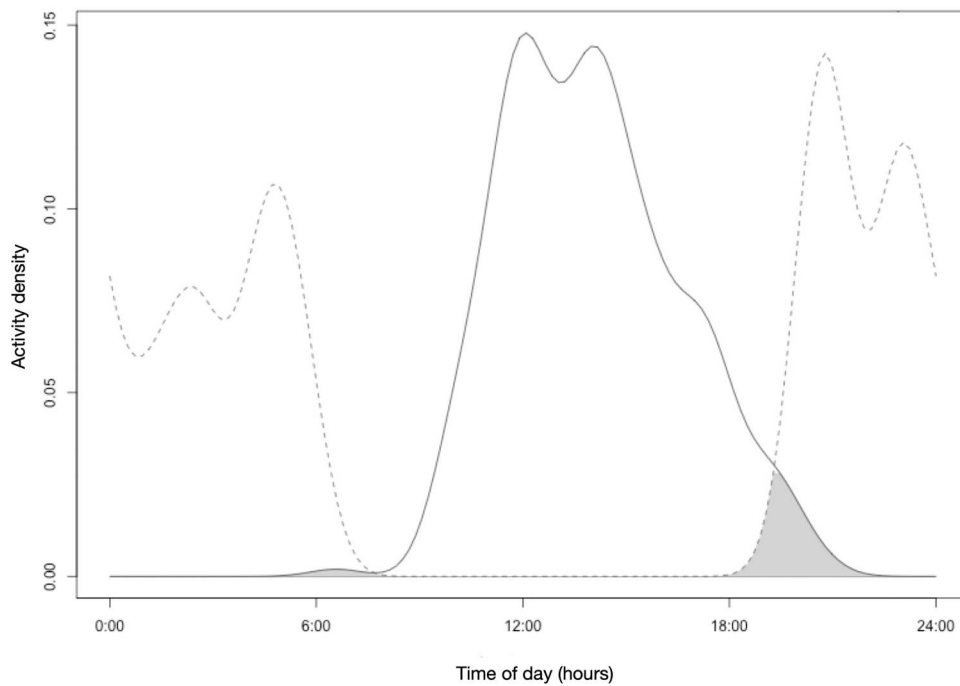


Figure 2. Kernel density estimates of diel activity patterns for the Lanner Falcon (solid line) and Barn Owl (dashed line) detected inside the secondary cavity (April–June 2025; linear 0–24 hour axis). The shaded region indicates the area of overlap between the two distributions. Because the density function was computed on a linear axis, detections near midnight were handled by extending the time range (–2–26 hours) before truncating to 0–24 hours for display, following standard practice for linear activity plots of predominantly non-crepuscular species.

the Barn Owl is inherently nocturnal and the Lanner Falcon strictly diurnal – traits that evolved independently in these lineages in response to their respective foraging ecologies – these pre-existing differences in chronotype result in near-complete temporal segregation in cavity use ($\Delta = 0.043$). As illustrated in Figure 2, the two species were active at essentially distinct times of day, and their diel schedules were highly complementary: the cavity was used exclusively by the Lanner Falcon during the day and almost exclusively by the Barn Owl at night. This temporal complementarity effectively allows both species to exploit the same physical refuge and is consistent with a reduction of predation risk for the Barn Owl, even though nocturnality was not developed in response to the presence of this particular predator at this site. A slight overlap at dusk likely reflects transitional activity periods when both species briefly exploit the environment under reduced light conditions; the rare predation events on Barn Owls reported for the Lanner Falcon may thus be associated with these narrow crepuscular windows.

The analysis of seasonal exit-time trends revealed that the Lanner Falcon left the cavity progressively later in the day as the season advanced from April to June (Figure 3(A)). We hypothesize that this trend

reflected the increasing photoperiod: as days lengthen, the available window of diurnal activity expands, and individuals may correspondingly delay their afternoon/evening departure. The residual scatter around the regression line, however, suggests that additional factors, such as weather, wind exposure at the cliff face or individual variation in daily routines, may contribute to variability in departure time; these sources of variation could not be assessed with the present dataset. The afternoon cavity stays were substantially longer than morning ones (median 3.09 hours vs. 0.21 hours; Figure 3(B)). We interpret this pattern as consistent with the use of the cavity as a sheltered resting site during the warmest hours of the day, when falcons typically reduce hunting activity (Leonardi 2015). We stress that these patterns in the Lanner Falcon’s temporal behaviour reflect the species’ own seasonal and diel ecology, and should not be interpreted as strategies to avoid encounters with the Barn Owl, which is active only at night.

An exploratory analysis of the Barn Owl dataset did not reveal a comparable seasonal trend in first nightly detection time ($R^2 = 0.035$; $P = 0.154$; $n = 60$ nights), most likely because the Barn Owl accessed the cavity both at dusk and near dawn, depending on nightly foraging activity, making the first nightly detection an

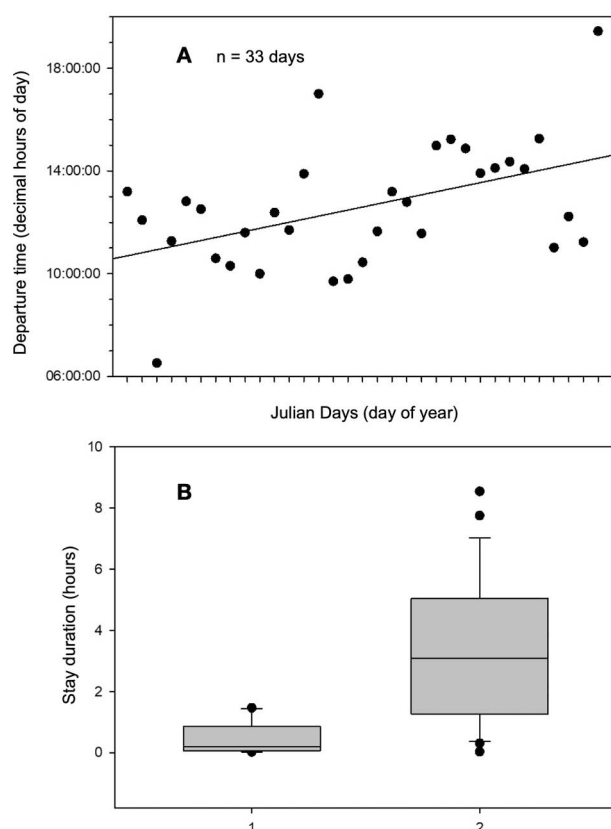


Figure 3. (A) Seasonal trend in the departure time (hours of day) of the Lanner Falcon from the secondary cavity (x-axis: Julian date, April–June 2025; y-axis: departure time in decimal hours; $n = 33$ observations). The regression line indicates a significant positive relationship ($R^2 = 0.554$; $P < 0.001$). The residual scatter around the trend line reflects additional sources of variation not captured by the seasonal predictor alone. (B) Comparison of duration of cavity stays (hours) between morning visits (Group 1: first detection before 12:00 local solar time; $n = 136$) and afternoon visits (Group 2: first detection $\geq 12:00$; $n = 411$) of the Lanner Falcon. Boxes represent interquartile ranges (25th–75th percentile), horizontal lines indicate medians, and whiskers show minimum and maximum values.

inconsistent proxy for activity onset. Distinguishing consistently between evening-entry and pre-dawn return events, or collecting a longer time series, would be necessary to test whether the Barn Owl's temporal activity in this cavity is also dynamically coupled to daylength.

The present study has several important limitations. Data were collected at a single secondary cavity within one cliff site, over a single season (April–June 2025), and the Lanner Falcon pair did not breed during the monitored period. Inference is therefore restricted to the use of a secondary rest-cavity outside of the breeding context. Individual identity of the Lanner Falcon could not be confirmed from video recordings

alone, and the number of individuals using the cavity may vary across dates. These constraints preclude broader generalization about breeding-site coexistence or population-level temporal partitioning strategies, and the results should be regarded as a preliminary, single-case documentation.

The use of camera traps proved highly effective for documenting interspecific interactions in a confined, difficult-to-observe environment, offering continuous and minimally invasive monitoring (Bruce *et al.* 2025). Extending this approach to include active breeding periods and multiple cliff sites could yield further insights into the consequences of shared refuge use across different phases of the annual cycle. Future research could also profitably apply comparable camera-based approaches to artificial structures, such as nest boxes, where temporal partitioning, competitive exclusion and predator–prey avoidance between raptors have begun to be studied in standardized settings (Schalcher *et al.* 2024, Milliet *et al.* 2025), thus providing an opportunity to separate the effects of cavity availability from those of temporal and spatial partitioning among sympatric species.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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