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Through the lens of time-lapse photography: uncovering hidden behaviours in the mesophotic coral *Dendrophyllia ramea* and other natural history observations

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ABSTRACT

Time-lapse photography provides unprecedented insights into marine organism behaviours that are otherwise difficult to detect through direct observations. We monitored a colony of the habitat-forming coral *Dendrophyllia ramea* at 70 m depth in the upper mesophotic zone for six consecutive days. Our observations aimed to describe the colony's polyp activity patterns, investigating diel periodicity and feeding preferences. We additionally documented interactions with associated marine fauna, including the homing behaviour of the sea urchin *Centrostephanus longispinus* and the composition of the local fish community. Results revealed that the natural state of *D. ramea* polyps is to have tentacles extended. However, by analysing polyp closure, distinct temporal patterns emerged, strongly influenced by tidal fluctuations. The description of interspecific relationships highlights the essential role of *D. ramea* in benthic ecosystems, particularly regarding the provision of shelters for benthic fauna and the attraction of several fish species, thus providing information for conservation strategies for vulnerable mesophotic habitats.

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Hexacoral; diel patterns; tide fluctuations; underwater photography; temperate reef

Introduction

The application of remote photography in ecological studies dates back to the 19th century, when it was first used on mammals and birds. The first record that immortalized a running horse dates back to 1877 (Cutler & Swann 1999). In aquatic environments, time-lapse cameras have been employed to investigate a variety of organisms and their behavioural pattens, morphological variation, reproduction modalities, feeding activities, habitat use, and multiple types of inter-individual relationships (Vardaro et al. 2007; Peirano et al. 2016). Porifera species, such as *Clathrina clathrus*, *Oscarella lobularis*, *Leucosolenia botryoides* and *Halichondria panicea*, have been investigated through time-lapse photos to report their growth, bud formation and filtration activity (Gaino et al. 1991; Bond 2013; Kumala et al. 2021; Rocher et al. 2024). The behaviour and diel rhythms of the Mediterranean red coral *Corallium rubrum* (Santarelli et al. 1999), and of the sea anemone *Halcampoides purpureus* (Boero et al. 1991), were analogously described. Behavioural changes linked to tidal cycles were documented in the limpet *Cellana rota* (Schnytzer et al. 2018). The posture and locomotion of a crinoid species on the Great Barrier Reef (Meyer et al. 1984), as well as the prey–predator interactions between *Hexaplex trunculus* and *Mytilus galloprovincialis* on a shallow mussel bed were documented thorugh time-lapse photography (Sawyer et al. 2009). With the same methodology, fish species composition was investigated around an anchored aggregated device via the installation of a time-lapse camera (Takahashi et al. 2019). Recently, the courtship behaviour of the fish *Apogon imberbis* was studied in the day and the night, providing the description of a prolonged activity occurring in their habitat (Gregorin et al. 2025).

These studies have continuously evolved, becoming a fundamental tool for biological investigations (Cutler & Swann 1999; Black 2019). Images, whether static or dynamic, can address diverse ecological questions depending on the research objectives, target organisms, and available technologies (Cutler & Swann 1999; Black 2019). For example, photogrammetry is extensively employed to reconstruct three-

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dimensional structures of habitats such as reefs and biogenic formations (Pulido Mantas et al. 2023). Similarly, photo-quadrats and transects have proven to be cost-effective methods for assessing benthic biodiversity and species distribution (Van Rein et al. 2011). However, these methods rarely provide insights into behavioural aspects, such as intra- and interspecific relationships. At depths beyond the range of divers, such studies commonly employ remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs), though these require substantial logistical support and incur high costs (Prado et al. 2023). In this context, time-lapse photography emerges as a powerful method for behavioural ecology studies, capturing physiological processes, activity rhythms, and organismal interactions in marine ecosystems over extended periods (Joan Edwards & McEntee 2015; Salvati et al. 2023). By collecting sequential images at fixed intervals and framing specific subjects or areas, this methodology reduces human intervention and allows for comprehensive temporal analyses of behaviour, including diel and circadian patterns (Joan Edwards & McEntee 2015; Pascalis et al. 2018; Salvati et al. 2023). The deployment of stationary cameras ensures minimal disturbance to the organisms, resulting in more accurate behavioural observations (Cartoni Mancinelli et al. 2023). This approach can be enhanced with sensors measuring abiotic factors such as temperature, salinity, currents, and turbidity, all of which are crucial determinants of marine species' behaviour (Bell et al. 2006; Salvati et al. 2023).

We employed a time-lapse camera to conduct observational studies on the colonial coral *Dendrophyllia ramea* (Linnaeus, 1758), a scleractinian species found in the eastern Atlantic and Mediterranean Sea (Salvati et al. 2021; Angiolillo et al. 2022). *Dendrophyllia ramea* forms structurally complex colonies reaching up to 90 cm in height and hosting diverse associated fauna such as bryozoans, echinoderms, crustaceans, and other invertebrates, thereby enhancing local biodiversity and ecosystem functionality (Salomidi et al. 2010; Orejas et al. 2019; Estévez et al. 2024). This species predominantly inhabits the upper mesophotic zone (40–80 m depth, Angiolillo et al. 2022), a transitional ecosystem characterized by light penetration that is reduced but sufficient for sustaining photosynthetic organisms (Cerrano et al. 2019). Such habitats are strongly influenced by hydrodynamic conditions, which play a pivotal role in shaping biological communities and their physiological processes (Burrows 2012; Bell et al. 2024).

Despite their ecological importance, mesophotic corals like *D. ramea* face severe anthropogenic threats, including destructive fishing practices, pollution, and climate-induced warming (Reynaud et al. 2021; Angiolillo et al. 2022; Estévez et al. 2024). These threats have resulted in their listing as "Vulnerable" by the International Union for Conservation of Nature (IUCN) Red List and inclusion in the Barcelona Convention's Annex II of endangered species (Orejas et al. 2019; Angiolillo et al. 2022).

We aimed to describe the behavioural patterns of *D. ramea* polyps, specifically investigating diel periodicity and potential feeding behaviours through expansion and retraction patterns. Additional observations included the movements of the native sea urchin *Centrostephanus longispinus* (Philippi, 1845), considered a sentinel species for the coralligenous habitats in the Mediterranean Sea (Marchesi et al. 2025), as well as interactions between the coral colony and the local ichthyofauna. We investigated whether the polyps of the coral *Dendrophyllia ramea* exhibit distinct diel patterns of activity indicative of feeding preferences, and if so, whether these patterns are correlated with surrounding abiotic conditions and local marine community interactions.

Materials and methods

Penta Palummo Bank (40°45'01.7"N, 14°07'55.8"E, WGS84) is located in the Gulf of Naples, Tyrrhenian Sea, at the southern boundary of Campi Flegrei, a submarine area constituted by monogenetic volcanoes (Figure 1). The repeated volcanic action built domes and cone formations of tuff and scoria (Milia 2010). The bank has a rectangular structure of 2×3.6 km characterized by pyroclastic flows, volcanic bedrock items and rising of fluids (Passaro et al. 2016). The time-lapse device was deployed at 70 m depth, from 14 June 2023 to 19 June 2023. The deployment and recovery of the camera were carried out by technical divers (using trimix).

The time-lapse device was composed of a rigid steel structure (AISI 316 L) and POM C compound cases including a custom GoPro 8 connected to a motherboard with an Atmel® ATmega 480 microcontroller, a datalogger that registers the times of image acquisition, and a dip switch controller for different record settings that allows the remote modification of the image-acquisition timing (Figure 2). The system was connected to an external battery with a wet-mate connection, and to a flashlight (model KX1, led Cree XML

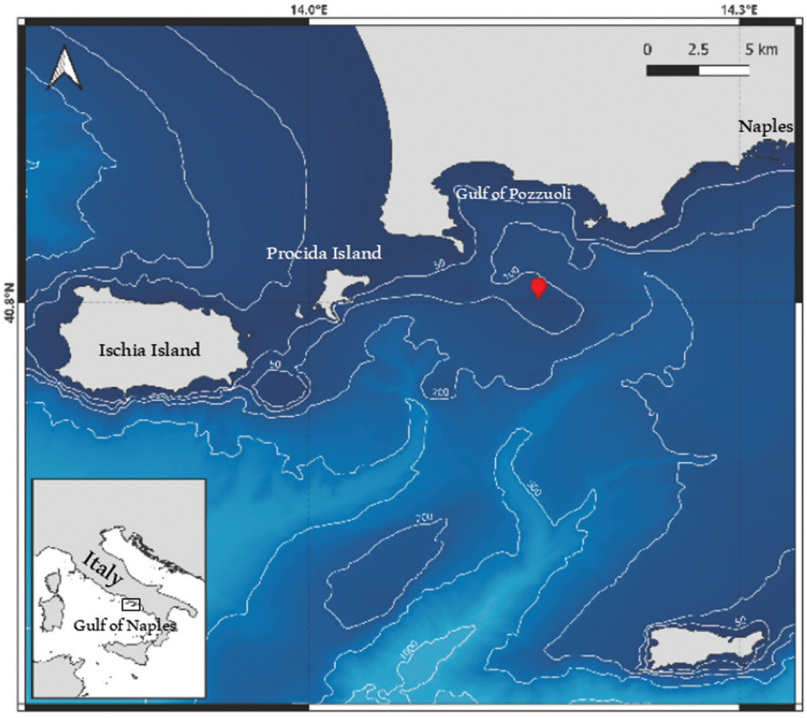

Figure 1. Penta Palummo Bank (red pin, 40°45′01.7″N, 14°07′55.8″E, WGS84), Gulf of Naples, Southern Tyrrhenian Sea, Italy (inset, black rectangle).

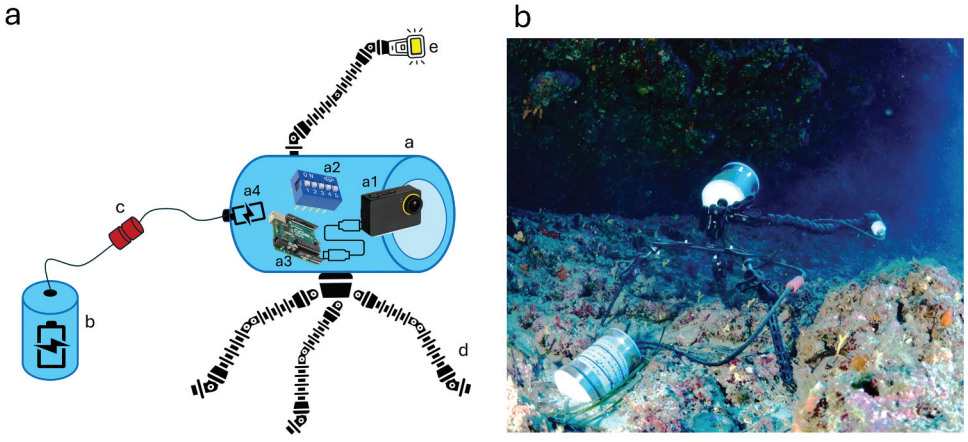

Figure 2. (a) Time-lapse device. The body is constituted by an underwater steel case (a) that includes the GoPro 8 custom camera (a1), the dip switch (a2), the motherboard (a3) and a backup battery (a4). The body is connected to an underwater steel case for the battery (b) through a wet-mate connection (c). The body is sustained by an adjustable tripod (d) and connected to a flashlight (e). (b) Photograph of the time-lapse device deployed underwater.

6500K) that operated at 3 min intervals synchronized with the image acquisition. This setting allowed an autonomy of 144 h. The field of view acquired with the photos was approximately 170 × 120 cm.

The colony of *Dendrophyllia ramea* framed within the camera objective grew on a rocky outcrop and consisted of 17 polyps, not counting those hidden from the camera frame (i.e. at the rear of the colony). The colony was approximately 19.4 cm wide and 19.9 cm high at its base, and the average oral diameter of polyps was 2.7 ± 1.0 cm.

A total of 2471 photos were acquired from 15:32:00 of 14 June 2023 to 17:21:00 of 19 June 2023, corresponding to the time of deployment and recovery of the device, respectively. Photographs were analysed with the open source software VLC MediaPlayer v. 3.0.21 and divided into six timeslots following Enrichetti et al. (2022): late night (LN) from 00:00:00 to 03:59:00, dawn (Da) from 04:00:00

Table 1. Day division by timeslots, following Enrichetti et al. (2022).

Timeslot	Day period	Hour interval	Abbreviation
T1	Late night	00:00:00–03:59:00	LN
T2	Dawn	04:00:00–07:59:00	Da
T3	Morning	08:00:00–11:59:00	Mo
T4	Afternoon	12:00:00–15:59:00	Af
T5	Evening	16:00:00–19:59:00	Ev
T6	Early night	20:00:00–23:59:00	EN

to 07:59:00, morning (Mo) from 08:00:00 to 11:59:00, afternoon (Af) from 12:00:00 to 15:59:00, evening (Ev) from 16:00:00 to 19:59:00, and early night (EN) from 20:00:00 to 23:59:00 (Table 1). Data on tides were retrieved from the Italian National Tide Gauge Network (https://www.mareografico.it/?syslng=ing) by the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), expressed as hydrometric level at the surface (m). As a proxy for feeding activity, the number of open/closed polyps was counted in each photo and expressed as a percentage of the total visible polyps of the *D. ramea* colony ($n = 17$). The effect of days, timeslots and tide fluctuations on the number of closed polyps was tested through a log-linear mixed model where the number of closed polyps (Y) was modelled as

$$Y_i \sim Poisson(\lambda_i) \quad [1]$$

where λ_i is the expected count of closed polyps for each observation, and $\log(\lambda_i)$ is modelled as a linear function of the effects. Here,

$$\log(\lambda_i) = \beta_0 + \beta_1 \cdot \text{Timeslots}_i + \beta_2 \cdot \text{Tide}_i + b_{\text{DAY}[i]} \quad [2]$$

where β_0 is the fixed intercept, β_1 and β_2 are fixed effect coefficients (for timeslot and tide, respectively), and $b_{\text{DAY}[i]} \sim \mathcal{N}(0, \sigma^2_{\text{DAY}})$ is a random effect for each level of DAY.

Statistical analyses and graphical representations were performed with the software R 4.4.1 (R Core Team 2021) using the packages *tidyverse* (Wickham et al. 2019), *lme4* (Bates et al. 2015), *DHARMa* (Hartig 2016), *performance* (Lüdecke et al. 2021) and *ggplot2* (Wickham 2016).

Results

Behavioural patterns of Dendrophyllia ramea

Polyps kept their tentacles extended for most of the time during both nocturnal and diurnal hours (Figure 3). The percentage of open polyps within the colony was greater than 90% from 20:00:00 (Ev) to 12:00:00 (Af) on all days (except EN of day 1, 77%). In timeslots Af and Ev, the percentages of open polyps were slightly lower, varying from 41% (Af, day 1) to 95% (Af, day 2) and 100% (Ev, day 2). The natural state of *D. ramea* polyps is to have tentacles extended. Here, we attempted to model the factors that influence the closure of the polyps. Log-linear model output indicated significant effects of both time of day (timeslot) ($p < .001$) and tide ($p < .001$), even after taking into account the random effect of day (Table 2). The frequency of polyp closure appeared to be higher in the afternoon (estimate = 0.82) and early evening (estimate = 0.29) (Figure 4). The model indicated that the effect of tide on polyp closure was higher than the effect of any timeslot (estimate = 1.6), influencing the closure of 5.1 polyps (with lower and upper 95% confidence limits of 3.1 and 8.3, respectively) (Figure 5). Periods of high and low tide (and hence low tidal current movement) coincided with the Af and Ev timeslots on each day, by chance. However, rerunning the model with high tidal values removed from the dataset (>0.12 m) did not substantively change the time-related estimates.

Side observation: Centrostephanus longispinus

During the recording of *D. ramea*, an individual belonging to the species *C. longispinus* was observed showing a strong circadian rhythm, resting during the diurnal hours and moving on the seabed during nights. The individual

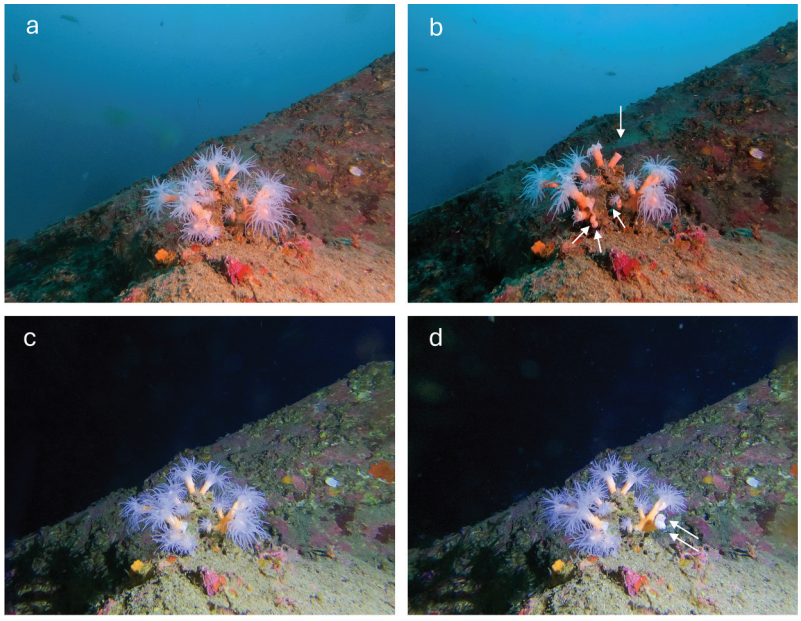

Figure 3. Colony of *Dendrophyllia ramea*, consisting of 17 polyps, under daytime (a, b) and night-time (c, d) conditions. Arrows in (b) and (d) indicate polyps in a closed state during the respective diurnal and nocturnal observations.

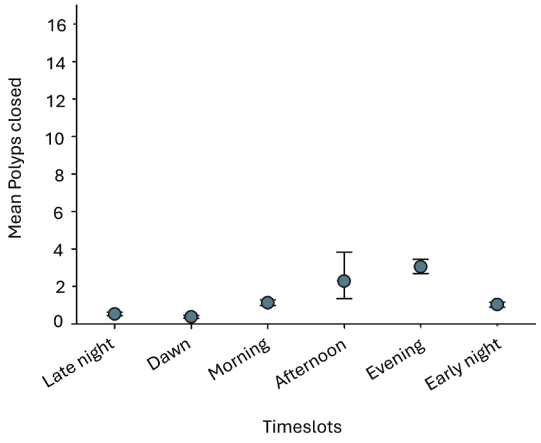

Figure 4. Estimated effects of time of day on the frequency of polyp closure in *Dendrophyllia ramea*. Error bars are 95% confidence intervals.

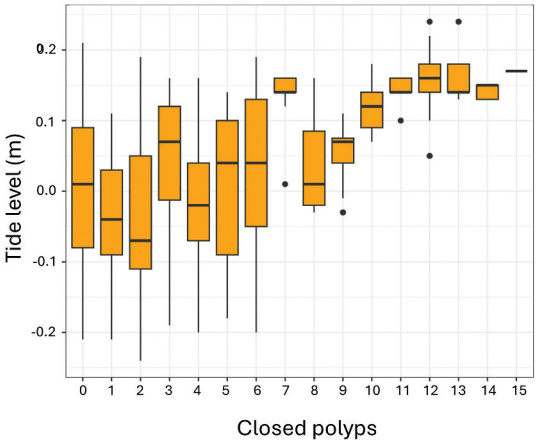

Figure 5. Number of closed polyps (of a possible 17) in relation to tidal state (m).

Table 2. Output of the log-linear model. LN = late night, Da = dawn, Mo = morning, af = afternoon, ev = evening, EN = early night. ** = $p < .01$; *** = $p < .001$.

Timeslot	Estimate	Std. error	z value	Pr (>|z|)
LN	−1.45833	0.08488	3.109	<2e-16 ***
Da	−1.79283	0.09975	−17.974	<2e-16 ***
Mo	−0.70188	0.06874	−12.308	<2e-16 ***
Af	0.82434	0.26512	4.593	0.00188**
Ev	0.29064	0.06327	−17.181	4.36e-06 ***
EN	−0.79071	0.06424	−10.210	<2e-16 ***
Tide	1.62921	0.24763	6.579	4.73e-11***

sheltered near the rocky outcrop hosting the *D. ramea* colony. Two shelters (here referred to as rooms) were used for diurnal rest, one on the left (room A, Figure 6(a)) and one on the right of the colony (room B, Figure 6(b)). The active movements of *C. longispinus* started around 20:00:00 (Table 3). The sea urchin left the shelter and moved in the surrounding area, being frequently visible within the photo frame. Regularly, before dawn around 04:30:00, the individual returned to its shelter, using both room A (days 1, 2, 5 and 6) and room B (days 3 and 4). The individual did not move during daylight hours. In Figure 7(a–e), the sequence of photographs taken at 3 min intervals showed the sea urchin moving on the rocky spot towards room B, from 04:25:00 to 04:36:00.

Side observation: associated ichthyofauna

A total of 16 fish species were observed, of which nine were recorded exclusively during daytime, four exclusively at night-time and three during both, including *Anthias anthias* (Linnaeus, 1758) and *Spicara smaris* (Linnaeus, 1758) which were the most abundant species (Table 4). These species were also the most frequently present, appearing in all of the daytime frames with abundances higher than 20 individuals per photo (Table 4), and being sporadic (or absent) during most of the night-time pictures, usually appearing around 04:00:00 (ca. 1 h 30 min before dawn) in high numbers (around 20 individuals). Their abundance started to decrease at around 20:00:00, ca. 30 min before sunset. Even though fishes were observed in the vicinity of the colony, especially those living in relation to the substratum, such as *Coris julis* (Linnaeus, 1758), *Serranus cabrilla* (Linnaeus, 1758) and *Mullus surmuletus* Linnaeus, 1758, no physical interactions were noticed between fish and the *D. ramea* colony. The only exception was *Phycis phycis* (Linnaeus, 1766), which was observed while swimming on top of the colony. A possible contact occurred between the fish and the colony since the subsequent photos showed retracted polyps. The species *C. julis*, *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817), *A. anthias*, *S. cabrilla*, *Spicara maena* (Linnaeus, 1758) and *Muraena helena* Linnaeus, 1758 were observed swimming in proximity to the colony during daytime, while *Phycis phycis* (Linnaeus, 1766) was frequently noticed around the colony during night. On one occasion, a conger eel *Conger conger* (Linnaeus, 1758) appeared from behind the colony, possibly indicating the use of the rocky outcrop as temporary shelter.

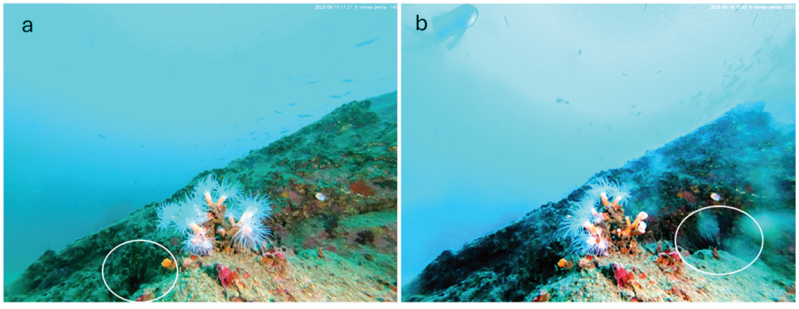

Figure 6. Footage of the rocky outcrop with the *Dendrophyllia ramea* colony during daytime: (a) *Centrostephanus longispinus* resting in room A (photo taken at 11:27:00 on 15 June 2023); (b) the same individual resting in room B (photo taken at 16:53:00 on 16 June 2023). White circles in both photographs indicate the sea urchin in its rooms.

Table 3. The daily routine of departure and return at the shelter of the observed *C. longispinus*, together with the total time spent out of the rooms during the night and the time spent in the shelter during the day, expressed in hours (h) and minutes (min).

Room	Day	Departure time	Time spent OUT	Return time	Time spent IN
A	1	20:42:00	7 h 48 min	04:30:00	16 h 12 min
A	2	20:19:00	8 h 26 min	04:45:00	15 h 34 min
B	3	19:54:00	7 h 34 min	04:28:00	15 h 26 min
B	4	20:33:00	8 h 8 min	04:41:00	15 h 52 min
A	5	20:26:00	8 h 5 min	04:31:00	15 h 55 min
A	6	Last photo at 17:21:00	–	–	–

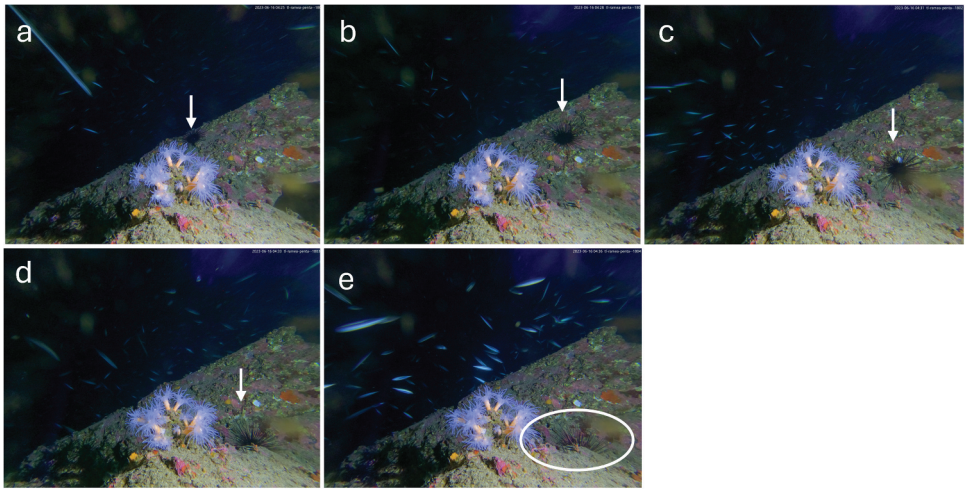

Figure 7. Sequence reporting *Centrostephanus longispinus* coming back home after a night spent out. The white arrows indicate the sea urchin while moving; the white ellipse in the last photo indicates the sea urchin in room B. Photo sequence taken on 16 June 2023, at the following times: (a) 04:25:00, (b) 04:28:00, (c) 04:31:00, (d) 04:33:00, (e) 04:36:00.

Table 4. The ichthyofauna species list observed during the 6 days of time-lapse recordings framed on the *Dendropyllia ramea* colony, categorized by diurnal and/or nocturnal presence and estimated abundance.

		Presence		Abundance	
Species	Taxon authority	Diurnal	Nocturnal	Day	Night
Anthias anthias	(Linnaeus, 1758)	×	×	>20	1–10
Spicara smaris	(Linnaeus, 1758)	×	×	>20	1–20
Diplodus vulgaris	(Geoffroy Saint-Hilaire, 1817)	×		1	
Spicara manea	(Linnaeus, 1758)	×	×	1–5	1–3
Coris julis	(Linnaeus, 1758)	×		1–3	
Dentex dentex	(Linnaeus, 1758)	×		1–5	
Serranus cabrilla	(Linnaeus, 1758)	×		1–5	
Mullus surmuletus	Linnaeus, 1758	×		1–3	
Sardina pilchardus	(Walbaum, 1792)	×		10–20	
Diplodus sargus	(Linnaeus, 1758)	×		2	
Sparus aurata	Linnaeus, 1758	×		1	
Scorpaena elongata	Cadenat, 1943		×		1–2
Phycis phycis	(Linnaeus, 1766)		×		1
Conger conger	(Linnaeus, 1758)		×		1
Muraena helena	Linnaeus, 1758	×		1	
Blenniidae/Gobiidae	-		×		1

Discussion

The visual analysis of the photographs allowed us to determine the extension and retraction of polyps. The minimum number of open polyps was 2 for less than 15 min, whilst for most of the time (ca. 116 h over the total of 123 recording hours), more than 10 of the 17 visible polyps were simultaneously open. This bears

similarities to the diel rhythm of two *D. ramea* colonies recorded over two months off the Sicilian coast, Ionian Sea, that were occasionally partially closed during daytime (Salvati et al. 2023). The statistical analysis indicated a significant difference in the number of closed polyps of *D. ramea* between timeslots, in higher numbers during nocturnal than diurnal hours. Sea level variation of tidal fluctuatinos also showed a significant effect, possibly indicating that the motion of the water mass could influence polyp behaviour. However, it must be highlighted that, even though the effects of timeslots and tides were statistically significant, the small values of estimated differences around the intercept mean and the small standard deviations support our visual observation that the colony did not show strong differences in terms of time preferences or periodicity patterns. These results could mean that, individually, polyps modified their behaviour according to changes in time and tide level, while as a whole the colony continued to be active regardless of these factors. Indeed, the colony never appeared completely retracted, indicating that the feeding activity was ensured by the open polyps to provide nutrition to the whole colony.

Many temperate anthozoans extend during night and retract fully or partially during daily light, with high current flows triggering polyp extension independently from time (Salvati et al. 2023). The circadian rhythm of polyps and their preferences for retraction or extension could be a species-specific trait depending on biological requirements (Bell et al. 2006). Possible factors influencing polyps' behaviour include the presence of symbiotic zooxanthellae, zooplankton availability and composition, predator avoidance, light exposure, and external disturbance, highlighting a profound link with the macro- and microecology of the site (Bell et al. 2006).

Similarly to *D. ramea*, the tropical scleractinian species *Pocillopora damicornis* (Linnaeus, 1758), *Acropora millepora* (Ehrenberg, 1834), *A. nobilis* (Dana, 1846), *Duncanopsammia axifuga* (Milne Edwards & Haime, 1848), and *Hydnophora rigida* (Dana, 1846) do not show clear time preferences and feed equally during day and night (Kuanui et al. 2016; Tagliafico et al. 2018). Similarities in species belonging to different latitudes, or, conversely, in different species inhabiting the same niche, further highlight the species-specificity of these patterns, which may be attributable both to intrinsic physiological characteristics and to external features influencing the organisms.

In the mesophotic zone, the presence of cold-water corals such as *D. ramea* provides new niches, increasing habitat exploitation opportunities for various organisms and facilitating inter-specific relationships (Lo Iacono et al. 2019; Orejas et al. 2019; Estévez et al. 2024).

The colony framed within this study attracted benthic vagile fauna and several fish species that were frequently observed near the colony. The individual *Centrostephanus longispinus* showed strong homing behaviour and fidelity to two niches used as diurnal shelters, departing punctually around 20:00:00 and returing to the shelter around 04:30:00. This behaviour has been documented for other sea urchins, such as *Centrostephanus coronatus* and *C. rodgersii*, and in *Diadema antillarum* (Nelson & Vance 1979; Carpenter 1984; Flukes et al. 2012). Nelson and Vance (1979) described shelter fidelity in *C. coronatus*, showing a circadian rhythm with inactivity during the daytime and feeding at night, suggesting an adaptation to avoid diurnal predation. Carpenter (1984) confirmed this suggestion, reporting that daytime shelter occupancy correlated positively with fish predator abundance. Accordingly, we hypothesize that the observed individual used the night-time for grazing, presumably to avoid visual-hunting predators (Andrew & Byrne 2007). The possibility for sea urchins to hide during daytime could support the maintenance of habitat stability, as their population decline is known to predict shifts from coral-dominated to macroalgae-dominated systems (Jackson et al. 2014; Delgado & Sharp 2021). Conversely, the absence of predators can lead to large barren areas due to over-grazing (Andrew & Byrne 2007). The recorded *D. ramea* colony was relatively small compared to the known size range for this species, which often displays patchy distribution with massive solitary colonies and small-sized corallites occurring in low densities (e.g. ca. 0.2–8 colonies per square metre; Angiolillo et al. 2022). Nonetheless, its presence can provide three-dimensional habitat heterogeneity, offering niches to various species including larval and juvenile stages of vertebrates and invertebrates, consistently with other branched coral species, and providing substrate for the settlement of epibionts (Jiménez et al. 2016; Gori et al. 2017; Puerta et al. 2020; Delgado & Sharp 2021).

At both micro- and macroscopic levels, the way organisms interact and are influenced by abiotic factors shapes their distribution, food webs, reproductive events, settlement success, nutrient cycling and ecosystem regulation, thus supporting the maintenance of stable populations (Rossi et al. 2017; Cerrano et al. 2019; Puerta et al. 2020; Ponti et al. 2021; Denis et al. 2024). The deployment of time-lapse cameras for several days, coupled with data on currents, turbidity, temperature, tidal fluctuations, and other site-specific abiotic factors, provides a non-invasive way to elucidate the relationships within deep habitats, which have been considerably neglected compared to more accessible shallow environments (Cerrano et al. 2019). This "in-depth" image analysis can help generate new

insights into behaviours and biotic/abiotic interactions among mesophotic species, enhancing awareness of this critical zone (Bongaerts & Smith 2019; Gregorin et al. 2025). In a global warming scenario, where extreme events increasingly impact local communities, mesophotic habitats could help preserve biodiversity by acting as refuges for shallower species (Bongaerts et al. 2010; Cerrano et al. 2010; Bramanti et al. 2023; Pulido Mantas et al. 2024). However, deep ecosystems face significant anthropogenic threats, including bottom fishing, temperature anomalies, sedimentation, eutrophication, ocean acidification, benthic infrastructure development, marine litter dispersion on the seafloor, and invasive species spread (Smith et al. 2019; Angiolillo et al. 2021; Bell et al. 2024; Pulido Mantas et al. 2024). Knowledge of these valuable and vulnerable environments remains limited, and their inclusion in protection plans must be improved (de Oliveira Soares et al. 2020). Expanding protection actions and establishing marine protected areas that include coral mesophotic ecosystems should be prioritized to maintain these rich biodiversity hotspots, driving species- and ecosystem-based conservation policies at national and international levels (de Oliveira Soares et al. 2020; Bell et al. 2024; Pulido Mantas et al. 2024).

Overall, this study demonstrates the ecological complexity and role of mesophotic habitats in sustaining biodiversity and promoting interspecific interactions (Cerrano et al. 2010). Long-term, multi-parameter monitoring and protection measures are essential to safeguard these ecosystems from escalating anthropogenic pressures and to maximize their potential as climate refugia for marine life in a changing ocean.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, CR, upon reasonable request.

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