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Crop phenology shapes foraging behaviour of the lesser bandicoot rat Bandicota bengalensis in irrigated rice

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Research Article

Keywords: Bandicota bengalensis, Activity patterns, Foraging behaviour, Home range, Rice phenology, Rodent management

Posted Date: July 21st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9191475/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at The Journal of Basic and Applied Zoology on September 28th, 2026. See the published version at https://doi.org/10.1186/s41936-026-00653-8.

Abstract

Background

The lesser bandicoot rat (*Bandicota bengalensis*) is a major rodent pest in irrigated rice ecosystems across South Asia, causing significant yield losses. However, continuous field-based quantification of its foraging behaviour across crop developmental stages remains scarce. This study used solar-powered infrared camera systems to examine activity patterns in relation to rice phenology under natural field conditions.

Results

Camera surveillance of six active burrows across three rice fields during the Kharif season (total 252 h) revealed predominantly crepuscular activity, accounting for 78.2% of observed movements. Activity cycles (complete burrow exit-to-re-entry sequences) declined significantly from the vegetative stage (30 days after transplanting, DAT; 10.71 ± 1.32 exits per 12 h) to pre-harvest (110 DAT; 3.99 ± 0.85; $F(2,10) = 28.47$, $p < 0.001$), while foraging duration per cycle increased four-fold from 1.38 ± 0.42 to 5.52 ± 2.61 min ($F(2,10) = 12.31$, $p = 0.002$). Exploration time also increased significantly across stages. Mean home range was 9.70 ± 1.21 m. Auxiliary burrow excavations suggested possible synchronization of reproduction with crop maturity.

Conclusions

B. bengalensis exhibits clear phenology-dependent shifts in foraging strategy, characterised by reduced activity frequency and increased foraging duration as crop resources mature. These behavioural patterns suggest that phenology-aligned management targeting pre-panicle initiation (55–65 DAT) for baiting and later stages (70–110 DAT) for burrow-based control, may improve intervention efficiency. Further multi-site validation is recommended.

BACKGROUND

Bandicota bengalensis (Gray & Hardwicke), the lesser bandicoot rat, is among the most damaging rodent pests in South Asian rice agroecosystems. In Andhra Pradesh, India, annual crop losses due to rodent damage range from 5–15%, corresponding to economic losses of Rs. 5,000–18,000 per hectare depending on season and infestation level (Rao, 2003). The species is highly fecund, producing 3–4 litters annually with 4–10 pups per litter, and breeding activity typically peaks during the reproductive stages of rice crops when grain nutritional value is highest (Rao et al., 2018; Rao & Kishore, 2009).

The species constructs complex, multi-chambered burrow systems that provide protection from predators and control interventions (Ramyasri et al., 2024). Its nocturnal habits, solitary behaviour, and

pronounced neophobia, avoidance of unfamiliar objects and baits, complicate management strategies (Ramyasri et al., 2025; Singleton et al., 2004; Meerburg et al., 2009). Crop damage varies across growth stages, remaining scattered during vegetative growth but becoming increasingly concentrated near burrow entrances as the crop matures (Rao et al., 2018). The characteristic 45° oblique tiller cut is widely recognized as a diagnostic indicator of rodent feeding activity (Lai et al., 2023; Lambert et al., 2018).

Most existing knowledge of *B. bengalensis* behaviour is derived from laboratory or semi-controlled studies, which may not accurately reflect field conditions (Prakash, 2018; Lund, 1988). Continuous, non-invasive monitoring using solar-powered camera systems now enables the study of rodent behaviour under natural environmental conditions (Lai et al., 2023; Lambert et al., 2018), offering a powerful tool for linking behavioural ecology directly with crop phenology.

Based on optimal foraging theory (Stephens & Krebs, 1986), which predicts that animals optimize energy acquisition relative to predation risk across a resource gradient, we hypothesized that *B. bengalensis* would shift from frequent, short foraging bouts during early crop stages — when food resources are diffuse and of low quality — to fewer, longer bouts during later stages as high-energy grain becomes available. Crop phenology thus functions as a temporal resource gradient expected to drive progressive changes in foraging strategy, with activity becoming increasingly localized around burrows as grain quality peaks at maturity. We further predicted that this behavioural shift would be accompanied by possible synchronization of reproductive activity with peak grain availability. To test these predictions, solar-powered camera systems were deployed across three rice fields throughout the 2023 Kharif season to quantify activity cycles, foraging and exploration time, home range, and damage patterns across vegetative, reproductive, and pre-harvest crop stages. Our findings provide one of the first detailed field-based quantifications of phenology-driven foraging dynamics in *B. bengalensis* and identify critical temporal windows for targeted rodent management in irrigated rice systems.

METHODS

Study area

The study was conducted at the Regional Agricultural Research Station (RARS), Maruteru, ANGRAU, West Godavari district, Andhra Pradesh, India (16°37’ 48" N, 81°44’ 47" E; altitude 10 m asl) during the Kharif rice season (June–November 2023). Observations were made at vegetative (July 2023), reproductive (September 2023), and pre-harvest (October–November 2023) crop stages. The Kharif season was selected as it accounts for approximately 70% of annual rice cultivation area in the Krishna-Godavari delta and coincides with peak *B. bengalensis* population densities and reproductive activity in the region.

The region has a tropical climate with annual rainfall of 900–1100 mm, concentrated during the southwest monsoon (June–September). Fields are irrigated year-round through canal systems, except during the May–June fallow period. Field bunds supported grass species including *Cynodon dactylon*,

Paspalum distichum, and *Echinochloa colona*, and broadleaf weeds including *Eclipta alba* and *Commelina benghalensis*. Bunds were 30–50 cm high and 40–60 cm wide, with heavy clay (Vertisol) soils characteristic of the alluvial delta. The primary crop was transplanted *Oryza sativa* L. (variety MTU 1010). The study area is endemic to *B. bengalensis*, with population densities of 8–12 active burrows per hectare during peak crop seasons (Rao et al., 2018).

Study design and camera deployment

Six active burrows on rice field bunds were selected for continuous camera-trap surveillance across three separate fields (two burrows per field; total monitored area ≈ 2.5 ha). Burrows were monitored throughout the entire cropping period across all three crop growth stages. This study prioritises behavioural resolution over population-level inference; findings therefore reflect the foraging ecology of the monitored individuals rather than population-wide estimates.

B. bengalensis burrows were identified by species-specific characteristics: circular entrance diameter of 8–12 cm, freshly excavated soil mound (20–30 cm diameter) at the entrance, cylindrical droppings (1–1.5 cm), obliquely cut tiller fragments nearby, and multiple tunnel openings on bund slopes. These features distinguish *B. bengalensis* burrows from those of the smaller *Mus booduga*, whose entrance diameter is 3–5 cm.

Burrows were selected based on: (i) evidence of recent activity (droppings, freshly excavated soil); (ii) no signs of abandonment or predation; (iii) accessibility for camera installation without bund disturbance; (iv) spatial separation of at least 50 m between burrows — substantially exceeding the mean home range of 9.70 m — to ensure spatial independence and preclude the possibility of individuals ranging between monitored burrows; and (v) stable occupancy confirmed through preliminary observations. Although burrows were spatially separated beyond the estimated home range, the absence of individual marking or tracking prevents absolute confirmation of independence among monitored individuals. However, given the limited home range (~ 10 m) and ≥ 50 m spacing between burrows, home range overlap among monitored individuals is highly unlikely.

Six burrows were sufficient given the repeated-measures design, in which each burrow served as its own control across three crop stages. Post-hoc power analysis (G*Power 3.1) confirmed achieved power > 0.95 for all primary outcomes with observed effect sizes (partial $\eta^2 > 0.80$) (Faul et al., 2007; Potvin & Schutz, 2000), validating this sample size for detecting the large behavioural differences documented.

One solar-powered 4G-enabled infrared bullet camera (1080p, 2 MP, IP66-rated) was installed per burrow, supported by a 40W solar panel, 12V/10Ah battery backup, and a 32 GB SD card. To minimise behavioural disturbance, cameras were installed at least 72 h before data collection began at each crop stage and camouflaged with local vegetation. Research personnel did not approach monitored burrows during observation periods. Cameras operated continuously from 16:00 to 06:00 h daily; behavioural

data were extracted from the core active window of 17:00–05:00 h. Real-time motion alerts were transmitted via the IP Pro Android application.

Behavioural data recording

All video footage was reviewed by the lead researcher and a trained field assistant. An activity cycle is defined as one complete burrow exit-to-re-entry sequence and is used as the primary unit of behavioural measurement throughout the study. For each rodent emergence event, four parameters were recorded: (i) **exit time (E)** — the precise time of burrow emergence (nearest 30 seconds); (ii) **exploration time (EX)** — duration (min) spent within 0–1 m of the burrow exhibiting searching or sniffing behaviour; (iii) **foraging time (F)** — duration (min) spent outside the burrow moving through crop rows, feeding, and collecting plant material; and (iv) **entry time (EN)** — the time of burrow re-entry. Activity cycle duration was calculated as total elapsed time from exit to re-entry (E–EN).

Events with uncertain species identity were excluded from analysis. Non-target events involving other vertebrates (frogs, snakes, birds) were excluded based on morphological identification from video footage. Activity was categorised as crepuscular (17:00–22:00 h [dusk] and 03:00–05:00 h [dawn]) or nocturnal (22:00–03:00 h [deep night]). To validate behaviour identification, 20% of randomly selected video segments were independently reviewed by two additional observers blinded to crop stage. Inter-rater agreement exceeded 92%, confirming methodology reliability.

Plate 1 Representative solar-powered infrared camera image sequence illustrating a single activity cycle of *Bandicota bengalensis* at a bund-side burrow entrance during the reproductive rice stage: (a) emergence from burrow, (b) exploration and vigilance at burrow mouth, and (c) return and re-entry. Foraging movements into the adjoining crop area were not consistently captured owing to camera field-of-view limitation.

Damage assessment and home range

Home range was estimated using the minimum convex polygon (MCP) method, encompassing all recorded foraging, exploration, and damage locations. GPS coordinates were recorded for each activity and damage site, with the distance from burrow to the furthest recorded location serving as the primary home-range estimate (mean 9.70 ± 1.21 m; range 8.10–11.80 m). Damage patches were delineated using GPS waypoints and mapped in ArcGIS 10.3. Within each patch, tiller damage (%) was calculated by counting damaged and total tillers in five randomly placed 1 m² quadrats. Damage patches were attributed to monitored burrows based on: (i) spatial proximity (within 9.70 ± 1.21 m); (ii) temporal correlation with high-activity days; and (iii) the characteristic 45° oblique cut pattern.

To document breeding phenology, burrow excavations were conducted on 3–4 additional active burrows (not among the six camera-monitored burrows) at each crop stage following mild smoking with burning rice straw. These auxiliary excavations provided complementary information on reproductive status

across crop stages and were not used to directly infer the reproductive condition of the camera-monitored individuals.

Statistical analysis

Foraging time, exploration time, and activity cycles were tested for normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test). Data were analysed using repeated-measures ANOVA with crop stage as the within-subject factor. Mauchly's test assessed sphericity; Greenhouse-Geisser corrections were applied when violated. Post-hoc comparisons used Bonferroni-adjusted paired *t*-tests ($\alpha = 0.05$). For non-normally distributed data, the Friedman test was applied with Wilcoxon signed-rank post-hoc tests. Seven daily measurements per burrow per stage were averaged prior to analysis (N = 42 observation cycles per stage across six burrows). Descriptive statistics are expressed as mean ± SEM; where appropriate, 95% confidence intervals were calculated to complement mean ± SEM estimates. All analyses were performed in R (version 4.2.0); significance level was $p < 0.05$.

RESULTS

Circadian activity patterns

B. *bengalensis* exhibited bimodal crepuscular activity with peaks at dusk (17:00–22:00 h) and dawn (03:00–05:00 h) (Fig. 1). The dusk period accounted for 42.1% and the dawn period for 36.1% of total activity, collectively representing 78.2% of nocturnal surveillance records. Activity during the deep night period (22:00–03:00 h) was substantially reduced (21.8%), with extended quiescence near or inside burrow entrances. As an anecdotal observation, snake movement was occasionally recorded near burrows during this period, which may be consistent with predation pressure contributing to reduced midnight activity; however, predation was not directly quantified in this study.

Activity cycles across crop stages

Mean activity cycles per 12-hour period declined significantly across crop stages (repeated-measures ANOVA: $F(2,10) = 28.47$, $p < 0.001$; partial $\eta^2 = 0.85$; Table 1; Fig. 2). All pairwise stage comparisons were significant (Bonferroni-adjusted paired *t*-tests, all $p < 0.05$). Cycle frequency declined from 10.71 ± 1.32 (SEM) at vegetative stage to 6.71 ± 1.07 at reproductive and 3.99 ± 0.85 at pre-harvest stage, a 63% reduction overall. As cycle frequency declined, individual cycle duration increased, indicating a progressive shift from frequent brief forays to fewer extended foraging bouts as the crop matured.

Table 1
Exploration time, foraging time, total cycle time, and activity cycles of *Bandicota bengalensis* across three rice crop growth stages (mean ± SEM; *n* = 6 burrows)

Crop Stage	Exploration Time (min)	Foraging Time (min)	Total Cycle Time (min)	Cycles per 12 h
Vegetative (30 DAT)	0.50 ± 0.21	1.38 ± 0.42	1.88 ± 0.63	10.71 ± 3.23
Reproductive (70 DAT)	1.49 ± 0.35	4.68 ± 1.58	6.17 ± 1.93	6.71 ± 1.07
Pre-harvest (110 DAT)	2.24 ± 0.44	5.52 ± 2.61	7.76 ± 3.05	3.99 ± 0.95
F-statistic F(2,10)	8.47	12.31	9.58	28.47
p-value	0.005	0.002	0.003	< 0.001
Partial η²	0.63	0.71	0.66	0.85

DAT: days after transplanting. Values are mean ± SEM based on seven-day averages per burrow per stage (N = 42 observation cycles per stage). Repeated-measures ANOVA; F(2,10).

Exploration and foraging time

Exploration time increased progressively across crop stages, from 0.50 ± 0.21 min (SEM) at vegetative stage to 1.49 ± 0.35 min at reproductive and 2.24 ± 0.44 min at pre-harvest stage ($F(2,10) = 8.47$, $p = 0.005$; partial $\eta^2 = 0.63$; Fig. 3). Foraging time per cycle also increased significantly, from 1.38 ± 0.42 min (SEM) at vegetative stage to 4.68 ± 1.58 min at reproductive and 5.52 ± 2.61 min at pre-harvest stage ($F(2,10) = 12.31$, $p = 0.002$; partial $\eta^2 = 0.71$; Table 1; Fig. 4). Post-hoc tests indicated significant increases from vegetative to reproductive ($p = 0.012$) and from vegetative to pre-harvest stages ($p = 0.003$). The difference between reproductive and pre-harvest stages was not significant ($p = 0.681$), indicating that extended foraging established during grain development persisted through physiological maturity.

Home range and damage patterns

Mean home range was 9.70 ± 1.21 m (SEM; range 8.10–11.80 m) across six burrows (Table 2), consistent with published estimates for *B. bengalensis* in irrigated rice fields (Rao, 2003). A mean of 40.20 ± 5.31% of tillers within damage patches showed characteristic rodent damage (oblique 45° cuts, tooth marks, fresh appearance). Spatial coincidence of recorded activity locations with damage patch locations was 87.5 ± 4.2%, validating the damage attribution methodology. Damage became increasingly localised near burrow entrances as the crop matured, shifting from scattered patches at the vegetative stage to 2.50 ± 0.65 concentrated patches per burrow by pre-harvest.

Table 2
Home range and damage assessment parameters for *Bandicota bengalensis* across six monitored burrows (mean ± SEM)

Parameter	Value	Units	Notes
Mean home range	9.70 ± 1.21	m	MCP method; n = 6 burrows
Maximum distance from burrow	12.30 ± 1.75	m	Furthest recorded activity/damage location
Mean damage patch size	11.93 ± 2.14	m²	Average patch area per burrow
Damage patches per burrow	2.50 ± 0.65	n	Average number of patches per monitored burrow
Mean tiller damage within patches	40.20 ± 5.31	%	Based on five 1 m² quadrats per patch

MCP: minimum convex polygon.

Burrow occupancy and breeding phenology

Auxiliary burrow excavations (separate from the six camera-monitored burrows) revealed distinct occupancy patterns across crop stages. During vegetative and reproductive stages, all excavated burrows (n = 7) contained solitary individuals with no evidence of litters. In contrast, all burrows excavated at pre-harvest stage (n = 4) contained lactating females with pups (4–8 per litter). These observations suggest possible synchronization of breeding activity with crop maturity (Rao et al., 2018; Rao & Kishore, 2009), although direct confirmation from the camera-monitored individuals was not possible in this study.

DISCUSSION

This study provides field-based evidence that *B. bengalensis* systematically modifies its foraging strategy across rice crop phenology. The observed shift from frequent, short-duration activity cycles during the vegetative stage to fewer, longer bouts during reproductive and pre-harvest stages is consistent with optimal foraging theory (Stephens & Krebs, 1986), which predicts that animals balance energy optimization against predation risk as resource quality changes across a phenological gradient. Crop phenology thus appears to function as a temporal resource gradient driving progressive changes in foraging strategy, with activity becoming increasingly localised and consolidated around burrows as grain quality peaks.

The predominance of crepuscular activity (78.2% at dusk and dawn) is consistent with documented circadian rhythms of the species (Singleton et al., 2004; Meerburg et al., 2009; Lambert et al., 2018) and may be consistent with predator avoidance behaviour, as deeper nocturnal periods coincide with peak owl activity (Rao, 2003). Anecdotal observations of snake movement near burrows during deep night

hours are consistent with this interpretation, though predation pressure was not directly quantified and should be interpreted cautiously.

During the vegetative stage, frequent brief excursions (10.71 cycles, 1.38 min each) with minimal exploration time (0.50 min) are consistent with rapid spatial sampling of diffuse, low-quality resources, as predicted by optimal foraging models for patchy environments. As grain availability increased during reproductive and pre-harvest stages, fewer but longer bouts (3.99 cycles, 5.52 min at pre-harvest) likely reflect maximisation of energy intake per trip. Similar phenology-linked foraging shifts have been reported in *Rattus argentiventer* in irrigated rice systems in Myanmar (Nyo Me Htwe et al., 2012) and *Mastomys natalensis* in African agricultural systems (Schradin & Pillay, 2005), suggesting that phenology-driven foraging plasticity may be a broadly adaptive strategy across agricultural rodent species inhabiting seasonal agroecosystems, including those dominated by *Rattus*, *Mus*, and *Mastomys* in tropical and subtropical regions.

The extended foraging duration at pre-harvest may be associated with increased energetic demands during lactation. This interpretation is consistent with auxiliary burrow excavation data suggesting the likely presence of lactating females during this stage (König et al., 1988). However, as the camera-monitored individuals were not captured or sexed, all sex- and maternity-related interpretations are inferential and should be treated as hypotheses requiring experimental validation. Lactating females are expected to minimise trip frequency while maximising intake per trip (König et al., 1988), concentrating feeding close to burrows to reduce pup exposure time, consistent with central place foraging predictions (Lima & Dill, 1990).

The stable mean home range (9.70 ± 1.21 m) across all stages is consistent with prior estimates for the species (Rao, 2003), confirming burrow-centred territoriality without seasonal migration. Progressive damage localisation from scattered patches at vegetative stage to concentrated near-burrow patches at pre-harvest spatially reflects the temporal behavioural shift and validates the damage attribution methodology.

Management implications

These findings identify phenology-specific intervention windows that may substantially improve upon conventional fixed-interval rodent control programs. During the early vegetative stage (25–35 DAT), when rodent movements are spatially dispersed and food quality is low, habitat management (removal of alternative food sources, strategic waterlogging) and mechanical burrow destruction may be effective. The period immediately before panicle initiation (55–65 DAT) may represent the most critical window for anticoagulant baiting (e.g., bromadiolone, coumatetralyl) placed within 5–10 m of active burrows at 3–4 day intervals, as rodents exhibit heightened exploratory activity in the absence of ripening grain (Brown et al., 2006; Makundi et al., 2006).

During reproductive and pre-harvest stages (70–110 DAT), burrow-centred non-chemical methods may be most effective. Aluminium phosphide fumigation during midday hours (10:00–14:00 h), when rodents

are likely resting inside burrows, may enhance control effectiveness under field conditions. Burrow smoking with rice straw or neem leaves may compel lactating females to choose between evacuation (risking pup abandonment) and prolonged exposure, potentially enhancing control efficacy. The restricted home range (~ 9.70 m) may enable comprehensive treatment of all active burrows within a 10–15 m radius, making targeted community-level campaigns feasible (Massawe et al., 2011; Singleton et al., 2001). These recommendations are based on behavioural observations and require experimental validation before widespread adoption. All chemical interventions should be applied in accordance with local safety and regulatory guidelines.

Study limitations

This investigation used solar-powered cameras to eliminate observer bias and capture natural behaviour under field conditions. However, six-burrow selection based on specific criteria limits generalisability to unselected burrow populations, and this study should be regarded as providing behavioural resolution at the individual level rather than population-level inference. Single-location, single-season data are robust for this agroecological context but require cautious extrapolation to regions with different climates, rice varieties, or rodent genetics. Since monitored individuals were not captured or sexed, sex- and maternity-related interpretations are entirely inferential and should be treated as hypotheses for future experimental validation. Future research should include multi-season, multi-site replication, direct trapping of monitored individuals for demographic characterisation, and experimental measurement of food availability and predation risk to establish causality rather than correlation.

CONCLUSIONS

C. *bengalensis* exhibits distinct phenology-dependent foraging behaviour characterised by a trade-off between activity frequency and duration. Activity is predominantly crepuscular, with substantially reduced movement during midnight hours. As the crop matures, foraging shifts toward fewer but longer bouts, accompanied by localised activity around burrows and possible synchronisation of reproductive behaviour with grain maturity. Localised home range (9.70 m) and concentrated near-burrow damage (40.20% tiller damage) collectively validate the feasibility of targeted burrow-based management. These findings suggest that phenology-aligned strategies — pre-panicle anticoagulant baiting followed by burrow fumigation or smoking during reproductive and pre-harvest stages — may improve control efficiency compared with conventional fixed-interval approaches in irrigated rice systems across South Asia. Findings are broadly consistent with phenology-driven foraging adaptations documented in other agricultural rodent species, including *Rattus*, *Mus*, and *Mastomys*, suggesting applicability of phenology-aligned management across diverse tropical agroecosystems. Overall, these findings strengthen the ecological basis for phenology-aligned rodent management and provide a framework for integrating behavioural insights into sustainable pest control strategies in rice agroecosystems.

Abbreviations

4G
Fourth generation mobile network
ACIAR
Australian Centre for International Agricultural Research
AINP-VPM
All India Network Project on Vertebrate Pest Management
ANGRAU
Acharya N.G. Ranga Agricultural University
ANOVA
Analysis of variance
A.P.
Andhra Pradesh
asl
Above sea level
DAT
Days after transplanting
E
East (geographic coordinate)
F(2,10)
F-statistic with degrees of freedom 2 and 10
GPS
Global Positioning System
ha
Hectare
IAEC
Institutional Animal Ethics Committee
ICAR
Indian Council of Agricultural Research
IP66
Ingress protection rating (dust and water resistance)
IP Pro
Android application used for real-time camera monitoring
MCP
Minimum convex polygon
MP
Megapixel
N
North (geographic coordinate)

n
Number of burrows/observations
p
Probability value (significance level)
RARS
Regional Agricultural Research Station
SD card
Secure Digital memory card
SEM
Standard error of mean
α
Alpha (significance threshold)
η^2
Eta squared (effect size
reported as partial η^2).

Declarations

Ethics approval and consent to participate:

All surveillance methods were non-invasive and did not require direct animal handling. The study complied with ethical guidelines for wildlife observation research. Ethical approval was obtained from the Institutional Animal Ethics Committee (Approval No. IAEC/VPM/2015-02, dated March 15, 2022).

Consent for publication:

Not applicable.

Competing interests:

The authors declare that they have no competing interests.

Funding:

Financial support was provided by the All India Network Project on Vertebrate Pest Management, Indian Council of Agricultural Research (ICAR), New Delhi, India. The funding body had no role in study design, data collection, analysis, interpretation, or writing of the manuscript.

Author Contribution

NSR: Conceptualization, methodology, investigation, data analysis, writing — original draft. VRS and SGR: Field data collection, video analysis. SD and MVK: Supervision, resources, writing — review and editing. All authors read and approved the final manuscript.

Acknowledgements:

The authors thank the field staff at the Regional Agricultural Research Station, Maruteru, for technical assistance. This research was also supported by Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India.

Data Availability

The datasets generated and analysed during this study are available from the corresponding author on reasonable request.

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Plate 1

Plate 1 is available in the Supplementary Files section.

Figures

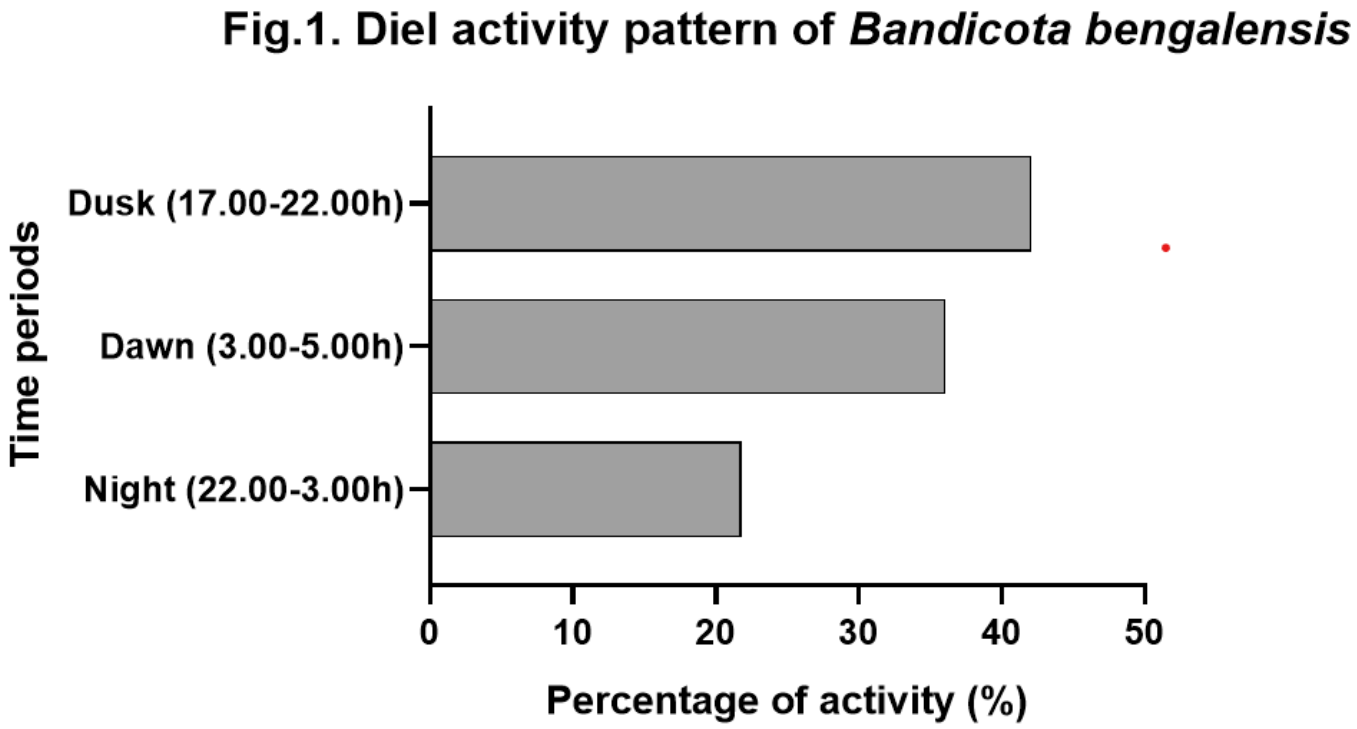

Figure 1

Diel activity pattern of *Bandicota bengalensis* during 12-hour nocturnal surveillance (17:00–05:00 h). Dusk (17:00–22:00 h) and dawn (03:00–05:00 h) together accounted for 78.2% of activity; the deep night period (22:00–03:00 h) showed substantially reduced activity (21.8%).

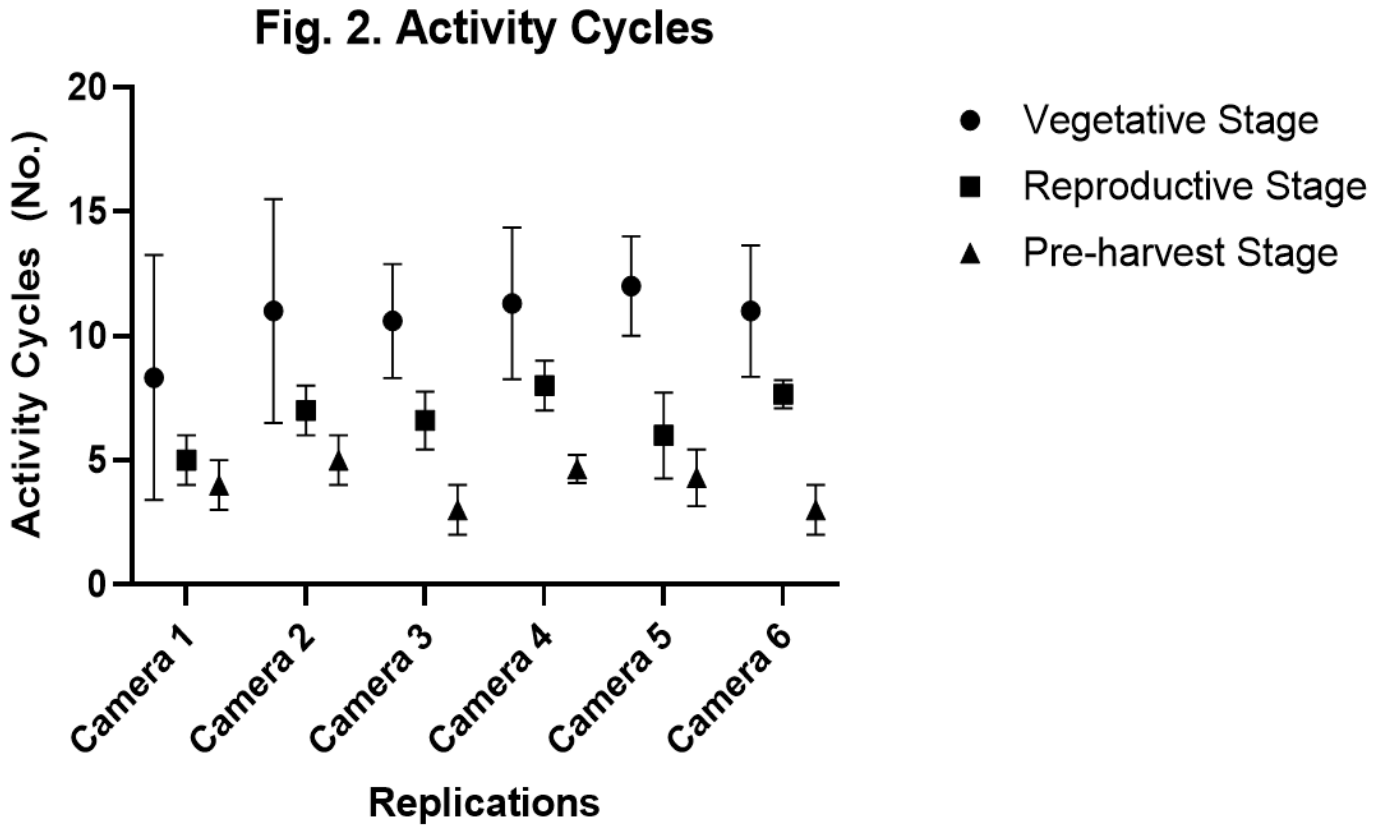

Figure 2

Activity cycles across crop development stages. Mean (± SEM) number of burrow exit-return sequences per 12-hour observation period for six camera replicates during vegetative (circles), reproductive (squares), and pre-harvest (triangles) stages. Different letters indicate significant differences between stages (Bonferroni-adjusted paired *t*-tests, $p < 0.05$). Error bars represent SEM. $n = 6$ cameras per stage.

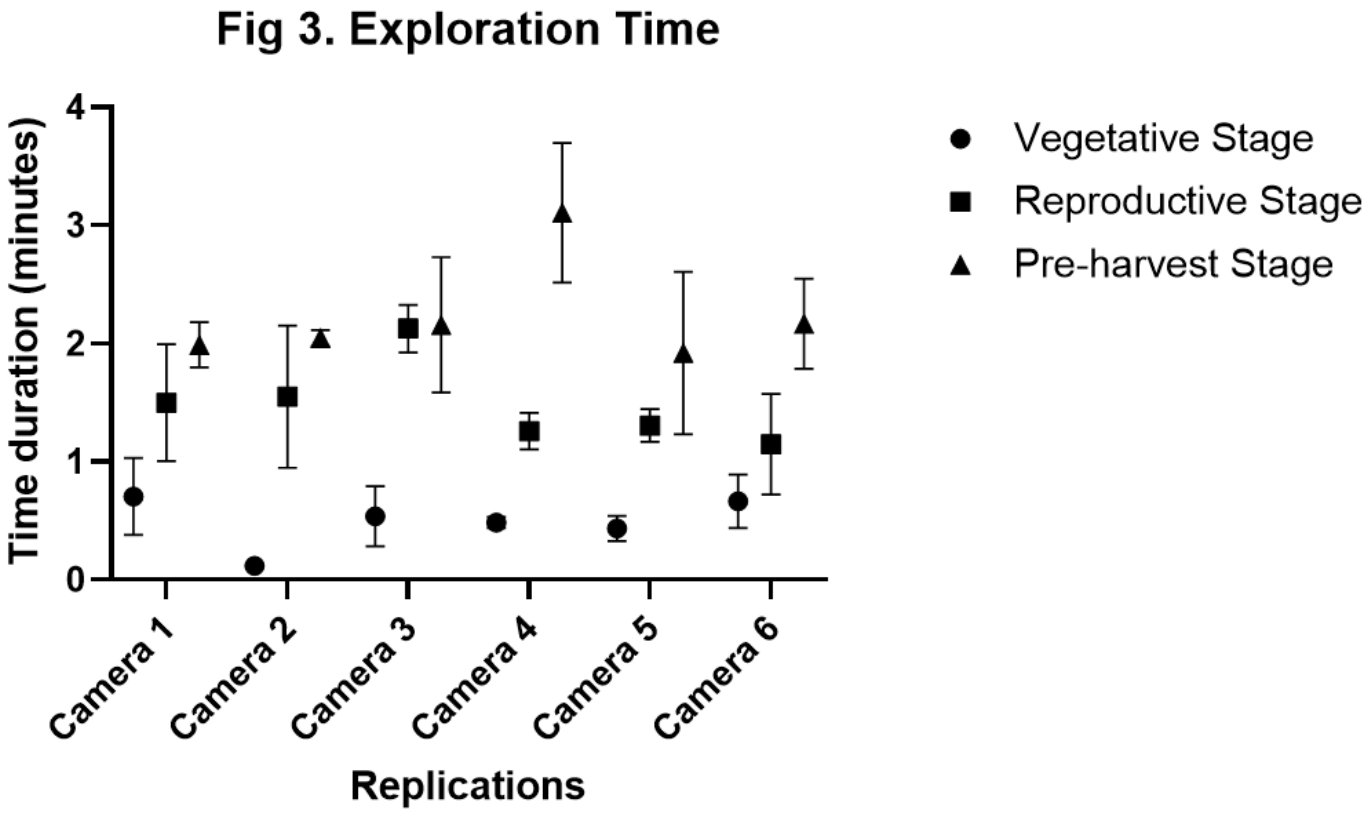

Figure 3

Exploration time across crop development stages. Mean (± SEM) exploration time per activity cycle for six camera replicates during vegetative (circles), reproductive (squares), and pre-harvest (triangles) stages. Exploration time increased significantly from vegetative (0.50 ± 0.21 min) to pre-harvest (2.24 ± 0.44 min) stages ($F(2,10) = 8.47$, $p = 0.005$). Error bars represent SEM. $n = 6$ cameras per stage.

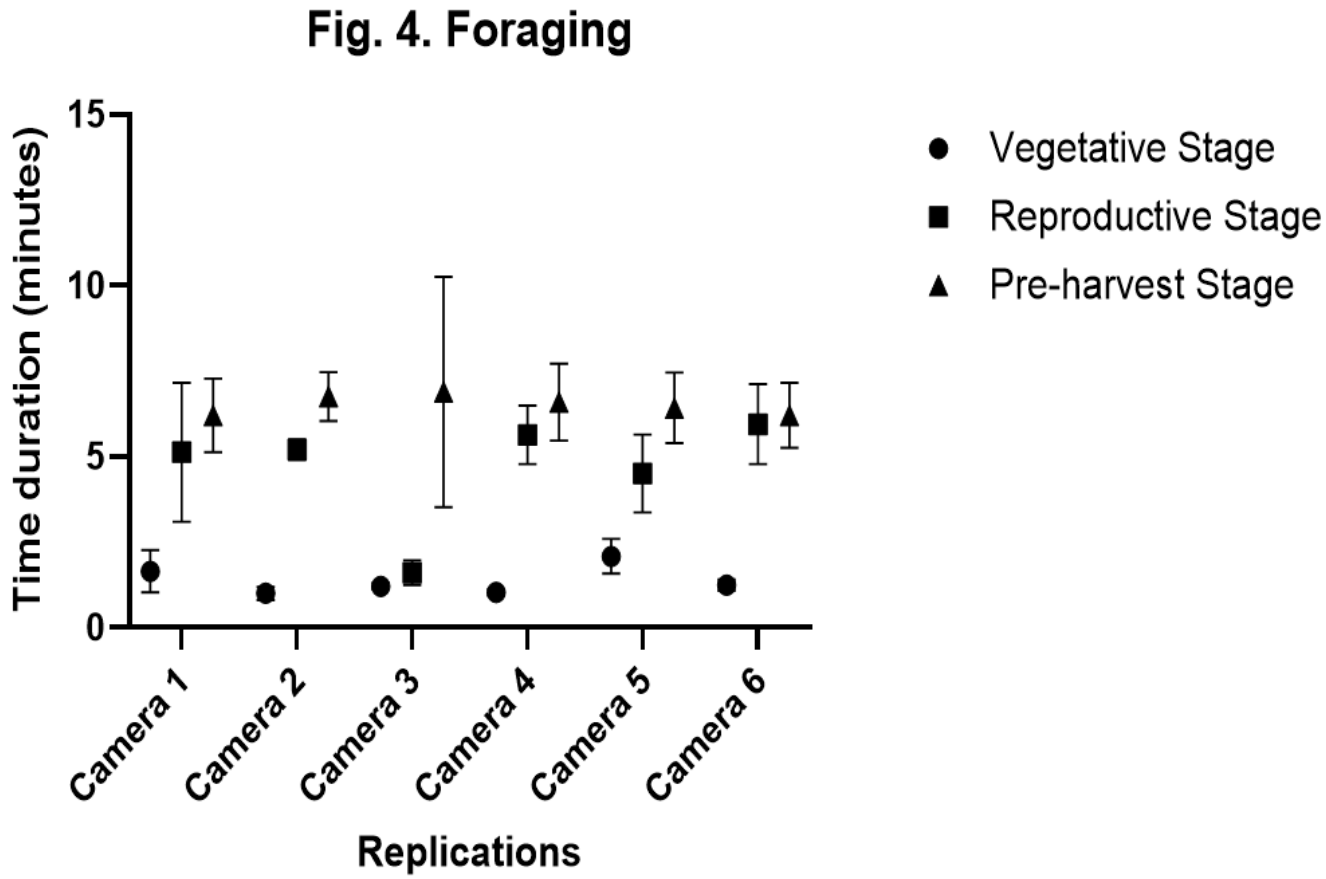

Figure 4

Foraging time across crop development stages. Mean (± SEM) foraging time per activity cycle for six camera replicates during vegetative (circles), reproductive (squares), and pre-harvest (triangles) stages. Foraging time increased significantly from vegetative (1.38 ± 0.42 min) to pre-harvest (5.52 ± 2.61 min) stages ($F(2,10) = 12.31$, $p = 0.002$). Error bars represent SEM. $n = 6$ cameras per stage.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Plate1.png