Received: 3 June 2024 | Revised: 19 July 2024 | Accepted: 30 August 2024

DOI: 10.1002/wll2.12041

Wildlife Letters WILEY

LETTER

More problems sampling wildlife with baits: Environmental food resources influence trapping rates

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Funding information
Australian Research Council Discovery Early Career Award, Grant/Award Number: DE210101440; Smithsonian Institution's ForestGEO program and Southern University of Science and Technology

Abstract

Baits are often used to increase wildlife capture rates; however, there has been little work exploring the effect of varying environmental conditions on bait effectiveness. Here we show that environmental food availability influences wildlife detection probability when using food baits. We sampled small mammals in Borneo with live traps baited with fruit before, during and after the rainforest experienced a mast fruiting event, which drastically altered environmental food availability. Compared to sampling before the mast, community-wide trap success plummeted by 94% during the mast when fruit resources were abundant then increased back 10-fold the month following peak masting. We conclude that environmental food availability can strongly influence bait effectiveness and thus detectability. Therefore, researchers using food baits should control for background food conditions when sampling. Alternatively, population models need to account for these variations in detection probability. These methodological insights are especially important in ecosystems where resources strongly fluctuate.

KEYWORDS

baiting, capture-recapture, detection, masting, small mammals

INTRODUCTION

Ecologists use foods, scents, and other lures to increase detections of target wildlife species, whether for physical traps like foothold snares and wire cages or passive sampling like camera traps (Holinda et al., 2020; Leirs et al., 2023). However, in their textbook, Rovero and Zimmermann (2016) suggest that "Attaining a better understanding of the effect of attractants on [population] studies is necessary as the few studies that have so far investigated this issue have produced contrasting results." The use of baits introduces complications owning to their declining effectiveness over time and their inconsistent effect among species and individual animals (e.g., trap happy/shy; Avrin et al., 2021; Mali et al., 2012; Willson et al., 2011). In certain cases, such as for rare or cryptic species, increased detection from baiting can outweigh the biases and can also lower fieldwork effort and cost (Du Preez et al., 2014; Gerber et al., 2012). However, detection biases from bait effectiveness are not always included in analyses and can require measuring key covariates, which is often unfeasible. Further, less work has investigated the environmental variations that influence bait performance. Here we explore the biases that arise from an underappreciated environmental factor that could mediate food-bait effectiveness: surrounding food availability in the environment.

The effectiveness of food-baited traps may vary with the animals' immediate need for food, and thus with food resources in the environment. This could result in repeated surveys of an unchanging community showing different detection probabilities when food conditions in the environment vary. For example, food baits may be more attractive during lean times. One early study found that baited-trap effectiveness on oldfield mice (*Peromyscus polionotus*) decreased with supplementary food added outside traps (Smith & Blessing, 1969); while a lab study found that the willingness of rats to consume bait laced with a chemical compound was affected by the effort needed to find alternative food (Weerakoon & Banks, 2011).

Bait effectiveness may be especially variable in ecosystems with large shifts in food availability, such as mast-fruiting forests. Masting refers to synchronized supra-annual plant reproductive events among single or multiple species with long intervals of no fruiting (Curran & Webb, 2000). This fruiting strategy may have evolved to increase seed survival by lowering seed predator populations via starvation during nonmast years followed by satiation during a short masting event (Zwolak et al., 2022). Masting in Southeast Asian tropical forests provides us with an opportunity to test the effect of food availability on the effectiveness of baited live traps on a community of tropical small mammals. Temporal shifts in food availability are common throughout ecosystems of the world so this issue is broadly applicable and could bias various wildlife surveys that rely on food baits (McMeans et al., 2015; Qiu et al., 2023).

To test the influence of environmental food availability on bait effectiveness, we compare capture rates for an assemblage of small mammals sampled using cage traps set before, during, and after a mast-fruiting episode. The study was conducted in a Malaysian Borneo tropical forest where the canopy is dominated by trees in the Dipterocarpaceae family that follow masting cycles (Sakai, 2002). To quantify food availability, we estimated dry seed-fall weight before and during masting. For each masting period, we compared community-level capture rates and species accumulation curves. We predicted that capture rates of baited traps would be lower during the mast-fruiting period when there is higher food availability in the environment compared to pre- and postmast periods (Figure 1).

Practitioner points

- The amount of food in ecosystems can influence food baits effectiveness. Variations in environmental food availability through space or time can thus cause variations in animal detection probabilities via baits.
- Practitioners need to either control for background food levels or account for possible changes in detection probabilities during population modeling if sampling with food baits.
- During periods of excessive food abundance, animals may be difficult to sample sufficiently using food baits. Alternative no-bait methods may be more effective or less bias depending on the situation.

METHODS

Study site

We sampled small mammals at the Danum Valley Conservation Area, Sabah, Malaysia from April 2019 to December 2019. Danum has 438 km^2 of undisturbed lowland rainforest and the tree phenology follows a community-scale mast-fruiting cycle with a canopy dominated by *Dipterocarp* tree species

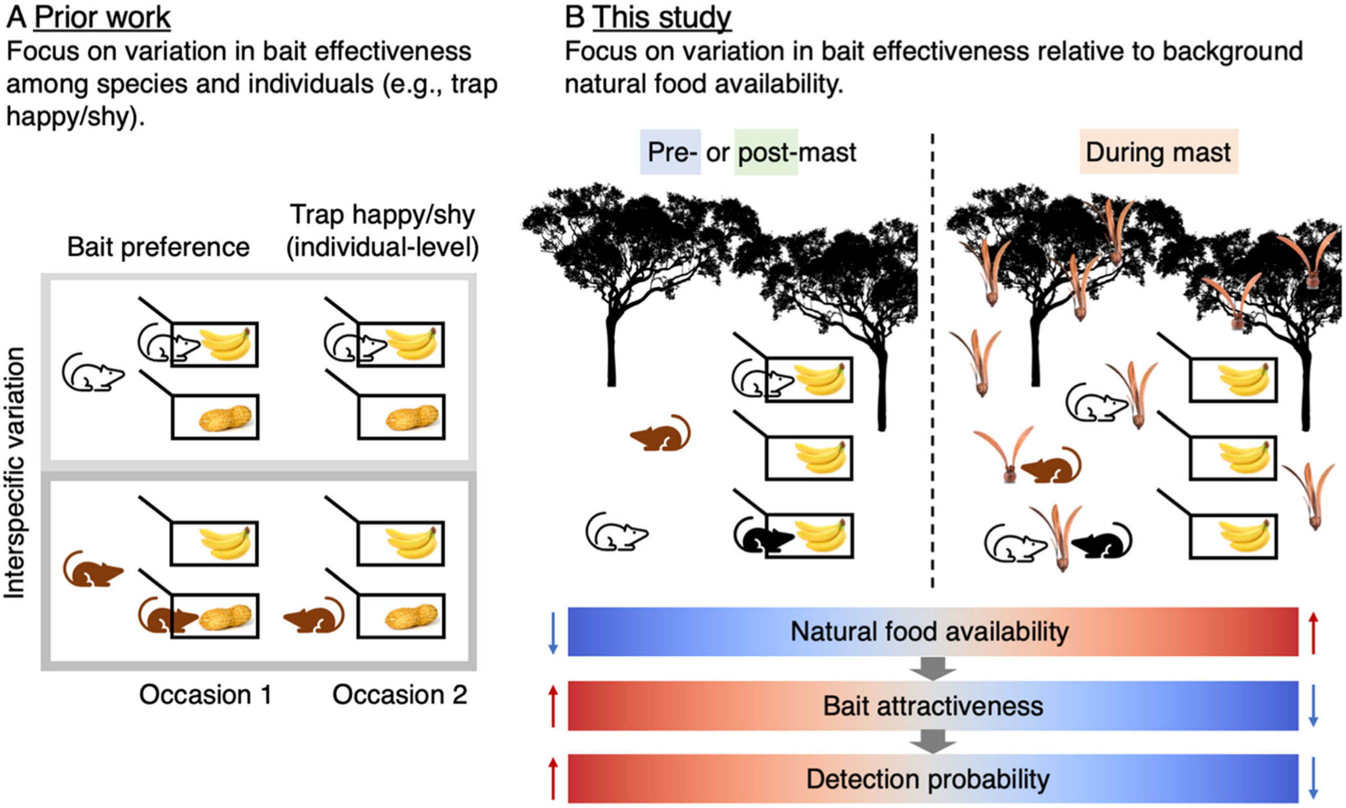

FIGURE 1 (a) Prior work has focused on bait preference, its variation between species, and individual variation (trap happy/shy), while (b) this study focuses on bait effectiveness under different conditions of environmental food. We hypothesized that higher environmental food availability, such as during a mast-fruiting event, would reduce the effectiveness of food baits, and thus detection probability, compared to pre- or postmast periods. Dipterocarp seeds represent environmental food available and bananas represent bait. Different colored animals represent different species.

TABLE 1 Number of small-mammal captures and individuals for each masting session.

		Premast		During mast		Postmast	
Species	**Common name**	**Capt. (Ind.)**	**RAI**	**Capt. (Ind.)**	**RAI**	**Capt. (Ind.)**	**RAI**
Maxomys surifer	Red spiny rat	137 (26)	0.93	1 (1)	0.03	8 (7)	0.25
Maxomys rajah	Rajah spiny rat	82 (17)	0.55	2 (2)	0.07	6 (5)	0.18
Tupaia tana	Large treeshrew	57 (10)	0.39	1 (1)	0.03	18 (3)	0.55
Leopoldamys sabanus	Long-tailed giant rat	47 (2)	0.32	0 (0)	0	1 (1)	0.03
Tupaia gracilis	Slender treeshrew	26 (5)	0.18	0 (0)	0	4 (3)	0.12
Sundasciurus hippurus	Horse-tailed squirrel	18 (7)	0.12	0 (0)	0	2 (2)	0.06
Sundasciurus lowii	Low's squirrel	18 (10)	0.12	1 (1)	0.03	0 (0)	0
Niviventer cremoriventer	Dark-tailed tree rat	8 (5)	0.05	0 (0)	0	2 (1)	0.06
Maxomys ochraceiventer	Chestnut-bellied spiny rat	7 (2)	0.05	0 (0)	0	0 (0)	0
Sundamys muelleri	Müller's giant Sunda rat	5 (4)	0.03	0 (0)	0	0 (0)	0
Callosciurus orestes	Borneo black-banded squirrel	2 (1)	0.01	0 (0)	0	0 (0)	0
Unknown	Unknown	2 (2)	0.01	0 (0)	0	10 (7)	0.31
Echinosorex gymnura	Moonrat	1 (1)	0.01	0 (0)	0	0 (0)	0
Maxomys baeodon	Small spiny rat	1 (1)	0.01	0 (0)	0	2 (1)	0.06
Tupaia dorsalis	Striped treeshrew	1 (1)	0.01	0 (0)	0	2 (1)	0.06
Tupaia longipes	Long-footed treeshrew	1 (1)	0.01	0 (0)	0	0 (0)	0
Total		413 (95)	2.79	5 (5)	0.17	55 (31)	1.69
Number of trapping days		77		15		17	

Note: RAI = (# captures/# trap nights) × 100. Color of column indicates masting period.

(Douglas, 2022; Reynolds et al., 2011). The mean annual rainfall surpasses 2800 mm and the mean annual temperature is 26.9°C (Walsh et al., 2011). The small mammal communities include rats and mice (muridae), treeshrews (tupaiidae), squirrels (sciuridae), and moonrats (*Echinosorex gymnura*). See Table 1 for specific species.

Seed fall quantity estimates

We estimated seed fall dry mass (g) premast and during mast at 144 plots clustered at 36 sites spaced at least 100 m apart. These sites were not associated with our trapping grids, but the data was collected in Danum Valley at the same time of our trapping survey, and thus give a comparison of the magnitude of food present before and during forest-wide masting. Each site comprised of four circular plots with 9 m diameter, set 15 m away from each other. We sampled each site once before masting and once during masting. Within each plot, we counted the number of seeds per species. We also collected samples for each species for identification by local experts, drying, and weighing to generate a dry weight average per species. We calculated seed fall dry mass for every site by multiplying the number of seeds of each species by its average dry weight. We then averaged the seed fall dry mass for all sites to compare before and during mast seed fall.

Baited live trapping

During each masting period (premast, during mast, and postmast), we set up three trapping grids using 64 live traps (192 traps total), with grids at least 100 m from each other. Each grid comprised 64 Tomahawk traps arranged in 8 × 8 perpendicular lines with 20 m spacing (Figure 2). Traps were secured to the ground, covered with a large leaf to protect animals from rain, baited with one slice of banana and one oil palm fruit kernel daily, and checked every morning. For each capture, we recorded the species, body length, sex, and weight, and attached ear tags with unique numbering to both ears before releasing. For recaptures, we noted the ear tag ID and trap location ID and released them immediately. Trapping lasted 77, 15, and 17 days for pre- (April to July), during (September to October), and post- (December) mast sessions respectively and grid setup remained the same across sessions.

Statistical analysis

For each of the three sampling sessions (pre-, during, and postmasting), we calculated the mean community-level daily capture rate per 100 trap nights and the 95% confidence intervals. We tested for normality using a Shapiro–Wilk test and then tested for significant differences in capture rates between sessions using a Kruskal–Wallis test followed by a Dunn's test. We also produced species

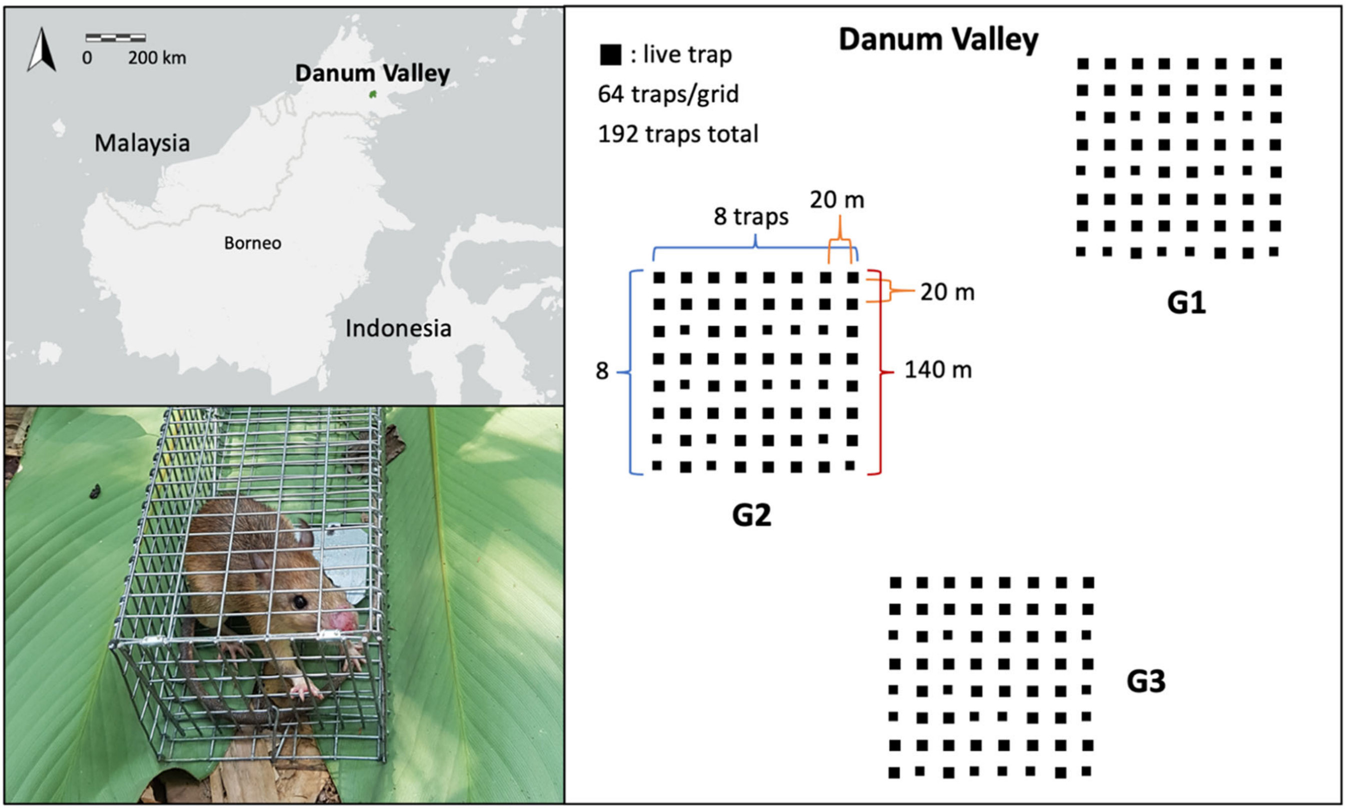

FIGURE 2 Location and methods for the baited traps and capture-recapture survey. Small mammals were baited inside Tomahawk traps using fruits, marked with ear tags, and released. The same trap layout was used for the three different masting periods. The photo shows a red spiny rat (*Maxomys surifer*), which was the most commonly captured species.

accumulation curves by adding the number of new species captured as each trapping session progressed. This analysis was conducted with R version 4.2.1 (R Core Team, 2022).

RESULTS

Seed fall quantity estimates

The estimated average seed fall dry mass was 84.3 g per site ($n = 36$, sd = 427.4) during the premast period and 2052.0 g ($n = 36$, sd = 1245.6) during mast, reflecting a 24-fold variation in the same sampled areas. Similar data was not available for the postmast period (Figure 3a).

Baited live trapping

There were 413 captures comprising 95 individual small mammals during the premast period (77 trapping days), 5 captures of 5 individuals during the mast fruiting period (15 days), and 55 captures of 31 individuals during the postmast period (17 days). We found 5.7% of individuals were captured during multiple periods. We identified 15, 4, and 9 different small mammal species for pre-, during, and postmasting sampling, respectively. The majority of captures were murids (rats and mice), such as red and Rajah spiny rats (*Maxomys surifer* and *Maxomys rajah*), but also included treeshrews, squirrels, and a moonrat (Table 1).

Capture rates varied significantly between all masting periods (Kruskal–Wallis: $\chi_2 = 38.4$, $df = 2$, $p < 0.0001$; Dunn's: $P_{\text{pre-during}} < 0.0001$, $P_{\text{during-post}} = 0.009$, $P_{\text{pre-post}} = 0.01$). The capture rate of baited traps during the masting event was only 0.17 captures/100 trap nights, 16- and 10-fold lower than premast (2.79 captures/100 trap nights) and postmast sampling (1.68 captures/100 trap nights), respectively (Figure 3b). The species accumulation curves for pre- and postmast sampling followed a similar trend, while the curve for during mast plateaued (Figure 3c).

DISCUSSION

Environmental food availability strongly influenced bait attractiveness and detection probability for a Bornean small mammal community sampled with cage traps. Specifically, mast-fruiting increased environmental food abundance by 24-fold compared to premast conditions, and this was associated with a 16-fold decrease in capture rates. These changes in bait attractiveness and trap success would bias analyses that do not account for detectability, such as relative abundance index or naïve occupancy (Sollmann et al., 2012). When bait effectiveness varies across time or space, we recommend using population models that account for changes in detection probability such as hierarchical models; however, this may require a covariate reflecting environmental food added to the detection formula. Although this study focused on tropical small mammals, baited capture rates of other species in other ecosystems may also be affected by shifts in environmental food abundance.

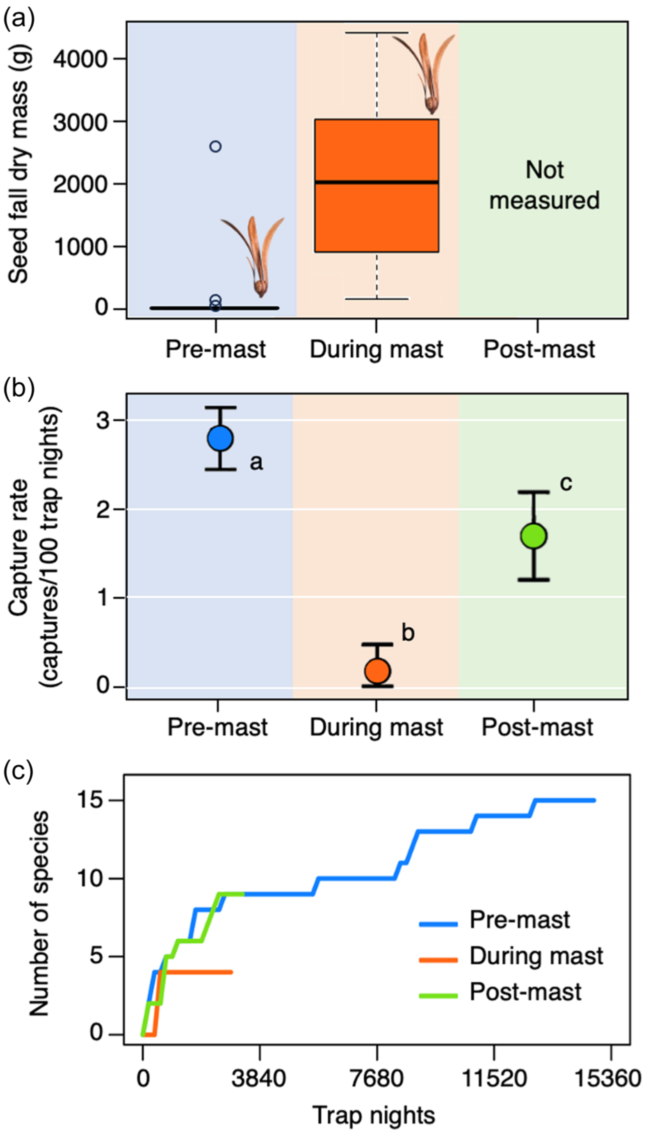

FIGURE 3 Baited trap effectiveness on a community of small mammals during variations in environmental food availability. (a) Quantity of seeds on the forest floor before and during a mast fruiting event. (b) Capture rates for premast, during mast, and postmast trapping sessions. Whiskers show 95% confidence intervals and different letters denote significant differences at $p < 0.05$. (c) Species accumulation curves during these same periods, noting the differences in session duration.

Scientists and managers should be wary of differences in environmental food availability when designing and analyzing baited wildlife surveys.

During extreme cases of high environmental food abundance, such as mast fruiting forests, food bait methods may require intensive sampling efforts to collect sufficient data for population modeling. Originally, we aimed to collect enough data to run spatially explicit capture-recapture (SECR) models for each mast fruiting period. However, the low number of small mammal captures due to high environmental food availability resulted in insufficient data for SECR models to converge during the masting period. SECR models did converge for the pre- and postmast periods when detection probability was higher (see Table S1, Figures S1 and S2). This problem could potentially be overcome by using food baits significantly more attractive than the surrounding food, but this would depend on species preferences (Diete et al., 2015). Unlike baited cage traps, baited camera traps do not have the negative incentives of capture and handling and thus may not experience as strong of a drop in detection rates; although, this remains to be tested. The increased effort, time, and cost required to sufficiently sample wildlife with food baits during periods of extreme environmental food availability should be considered, and other survey methods may be more efficient.

When should you consider baiting for a wildlife survey? Using baits to attract wildlife comes with both costs and benefits depending on the survey method, ecosystem, species, study aims, and timing. Cage traps often require baiting to be effective but others, like camera trapping, do not. Nonetheless, baiting cameras is still common to increase detection probability and decrease survey costs. This is best when surveying a single target species, especially if they are rare or cryptic, since a higher detection can improve model outputs (Du Preez et al., 2014; Rees et al., 2019). When surveying multiple species, it is preferable to avoid baiting due to its varying effect among species (Holinda et al., 2020; Paull et al., 2011; Rendall et al., 2021). Recently, nonbaited camera studies have overcome low detectability by pooling data from many surveys (Dehaudt et al., 2022; Ke & Luskin, 2019; Luskin et al., 2017; Mendes et al., 2024; Nursamsi et al., 2023). Lastly, this study emphasizes that the use of food baits should be especially reconsidered in surveys where environmental food availability varies across time or space. The hungrier the wildlife, the tastier the bait.

CONCLUSION

We found that the amount of food in an ecosystem can influence bait effectiveness and wildlife detection probabilities when using food baits. Researchers should thus control for background food levels when sampling with food baits, or account for the resulting variations in detection probability in population models. During periods of extremely high food levels, sampling with food baits may require additional efforts due to lower capture rates, or it may even be unfeasible to collect sufficient data for population models. This study highlights new factors to consider when weighing the pros and cons of using food baits for wildlife sampling, especially for ecosystems with strong variations in food availability.

AUTHOR CONTRIBUTIONS

Bastien Dehaudt: Conceptualization (equal); data curation (equal); formal analysis (lead); methodology (equal); project administration (equal); writing—original draft (equal); writing—review and editing (equal). **Jonathan Moore**: Data curation (equal); investigation (equal); writing—review and editing (supporting). **Luke Gibson**: Funding acquisition (equal). **Matthew S. Luskin**: Conceptualization (equal); data curation (equal); formal analysis (supporting); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); supervision (lead); writing—original draft (equal); writing—review and editing (equal).

ACKNOWLEDGMENTS

We are thankful for kind support from SEARRP and permissions granted from Yayasan Sabah, the Sabah

Forest Department, the Sabah Biodiversity Council, and the Danum Valley Management Committee. We thank A. Hamid, G. Reynolds, J. Brodie, and T. Karolus for facilitating and/or helping with fieldwork at Danum Valley. We thank the members of the Ecological Cascades Lab, and anonymous reviewers for comments that improved previous drafts. The research was supported by the Smithsonian Institution's ForestGEO program and Southern University of Science and Technology. M. S. L. was supported by an Australian Research Council Discovery Early Career Award (DE210101440).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data and R code are available at: https://doi.org/10.6084/m9.figshare.26909899.

ETHICS STATEMENT

All surveys in this study were carried out in accordance with regulations on animal ethics and permissions were granted by the Sabah Forestry Department (JPHTN/TKKH(PSH) 100-12/18/2/JLD5(36)), the Sabah Biodiversity Council (YS/DVMC/2019/35), and the University of Queensland (AE63295).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Dehaudt, B., Moore, J., Gibson, L. & Luskin, M.S. (2024) More problems sampling wildlife with baits: environmental food resources influence trapping rates. *Wildlife Letters*, 1–7. https://doi.org/10.1002/wll2.12041