Received: 14 August 2022 | Revised: 6 November 2022 | Accepted: 24 November 2022

DOI: 10.1111/aec.13270

RESEARCH ARTICLE

Problem solving of wild animals in the Wet Tropics of Queensland, Australia

Misha K. Rowell[1,2] | **Tasmin L. Rymer**[1,2]

[1]College of Science and Engineering, James Cook University, Cairns, Queensland, Australia

[2]Centre for Tropical Environmental and Sustainability Sciences, James Cook University, Cairns, Queensland, Australia

Correspondence
Misha K. Rowell, College of Science and Engineering, James Cook University, P. O. Box 6811, Cairns, Queensland, 4870, Australia.
Email: misha.rowell@my.jcu.edu.au

Abstract

While many species of animals can solve food-baited problems, most studies are conducted in captivity, which may not reflect the natural behavioural and cognitive abilities of wild animals. As few studies have explored problem solving of Australian animals generally, we investigated the problem solving abilities of native Australian species in natural rainforest in the Wet Tropics of Queensland. We baited multiple types of puzzles (matchbox task, cylinder task, and tile and lever tasks on a Trixie Dog Activity Board) with different food types (seeds, fruit, sardines) and placed the puzzles in front of trail cameras. We noted the species captured on camera, whether or not individuals interacted with the puzzles, the number of interactions with puzzles, and whether or not different animals solved them. We found that seven species from multiple taxa (mammals, birds, reptiles) could solve food-baited problems in the wild, providing the first evidence of problem solving in these native species. As problem solving may help animals cope with anthropogenic threats, these results provide some insights into which Wet Tropics species may potentially be more vulnerable and which ones might be better at coping with changing conditions.

KEYWORDS

behavioural flexibility, cognition, innovation, novel object, rainforest

INTRODUCTION

Worldwide, animals are facing rapid human-induced environmental changes, including habitat loss, urbanization, and the threat of invasive species (Sih et al., 2016). However, many species have the potential to cope with these threats by innovatively solving problems (Griffin et al., 2013). Problem solving is an animal's ability to overcome a barrier and access a reward, such as a food resource or shelter (Rowell et al., 2021). Species that can problem solve are more likely to move into new environments (Sol & Lefebvre, 2000), cope with harsh environments (Kozlovsky et al., 2015), and live in urban environments (Papp et al., 2015). While this ability has been documented in all major taxa, there are differences in problem solving abilities between species, populations, and individuals (Rowell et al., 2021). Recent studies have investigated the mechanisms underpinning these differences (e.g. personality, cognitive ability, motor diversity; Griffin & Guez, 2014). While these studies can sometimes be conducted in the field (e.g. Shaw, 2017), the long-term monitoring and testing of many wild individuals is not always possible (Rowell et al., 2021) and, as a result, problem solving studies are often conducted on animals held in captivity.

Studying problem solving in captive animals is beneficial for controlling different variables (e.g. differences in previous experience in Chimango caracara *Phalcoboenus chimango*; Biondi et al., 2010), easily accessing multiple species of animals (e.g. various species of carnivores; Borrego & Gaines, 2016), or tracking how individuals change in performance over time (e.g. grey squirrels *Sciurus carolinensis*; Chow et al., 2017). However, the results of captive studies may not always reflect the abilities of the species under natural conditions. For example, Benson-Amram et al. (2013) found that captive spotted hyenas *Crocuta crocuta* were more exploratory, and therefore more likely to solve a novel problem, than their wild-living counterparts. Similarly, the effects of study setting (wild vs. captive conditions) influenced the relationship between individual variables, such as body condition, and problem solving ability across multiple species (Amici et al., 2019). However, differences in problem solving between wild and captive conditions are not always observed. For example, Webster and Lefebvre (2001) found that multiple species of Barbados passerine birds performed similarly in a problem solving task when the same individuals were tested in the wild and in captivity. As such, the ecological relevance of captive problem solving results cannot always be assumed, making it difficult to use these results for species conservation or to interpret the ultimate (sensu stricto Tinbergen 1963) perspectives of problem solving.

For native Australian species, while some bird species have been studied in free-ranging conditions (Ashton et al., 2018; Diquelou et al., 2016; Isden et al., 2013), most of the previous work on other groups has focused on the problem solving abilities of captive individuals (e.g. Manrod et al., 2008; Rowell & Rymer, 2021a, 2021b). Therefore, we investigated whether wild animals living in the Wet Tropics of Queensland could innovatively problem solve using a series of puzzles (matchbox, cylinder, tile and lever tasks) baited with a variety of food types (peanut butter, sunflower seeds, fruit, sardines). These tasks have been solved by fawn-footed mosaic-tailed rats *Melomys cervinipes* kept in a captive colony without prior training (Rowell & Rymer, 2020). We hypothesized that wild-living animals (e.g. mosaic-tailed rats) would be capable of solving the puzzles. However, as the problem solving abilities of most native species has not been studied, we made no a priori predictions about how well particular species would perform, or how they would compare to each other.

METHODS

General testing procedure

Trail cameras (Bushnell Trophy Cam HD Aggressor) were set up in the forests on the James Cook University Nguma-bada campus, and adjoining Smithfield Conservation Park (16°49′1.938″, 145°41′12.1884″) between November 2021 and May 2022. Cameras were secured to tree trunks close to the ground (sensor approx. 10 cm above leaf litter), angled towards the ground, and set to record 60 s videos after being triggered. A single puzzle or puzzle board was placed approximately 50 cm in front of each camera and baited with food (see below).

Puzzles

We used four puzzles to test problem solving (Rowell & Rymer, 2020): the matchbox task (a cardboard matchbox where animals could push or pull the box out of the sleeve, or chew through the sleeve; Figure 1a), the cylinder task (a plastic cylinder with an open end covered in tinfoil that could be pushed or pulled off; Figure 1b), the tile task (plastic tiles to slide), and the lever task (a plastic lever to pull to lift a plastic flap), both presented concurrently as part of a Trixie Dog Activity Board (Level 2; Figure 1c). Food (two sunflower seeds or 1 g fruit to attract small-bodied mammals (e.g. *Melomys* sp. and *Uromys* sp.), 1 g of peanut butter to attract larger-bodied mammals

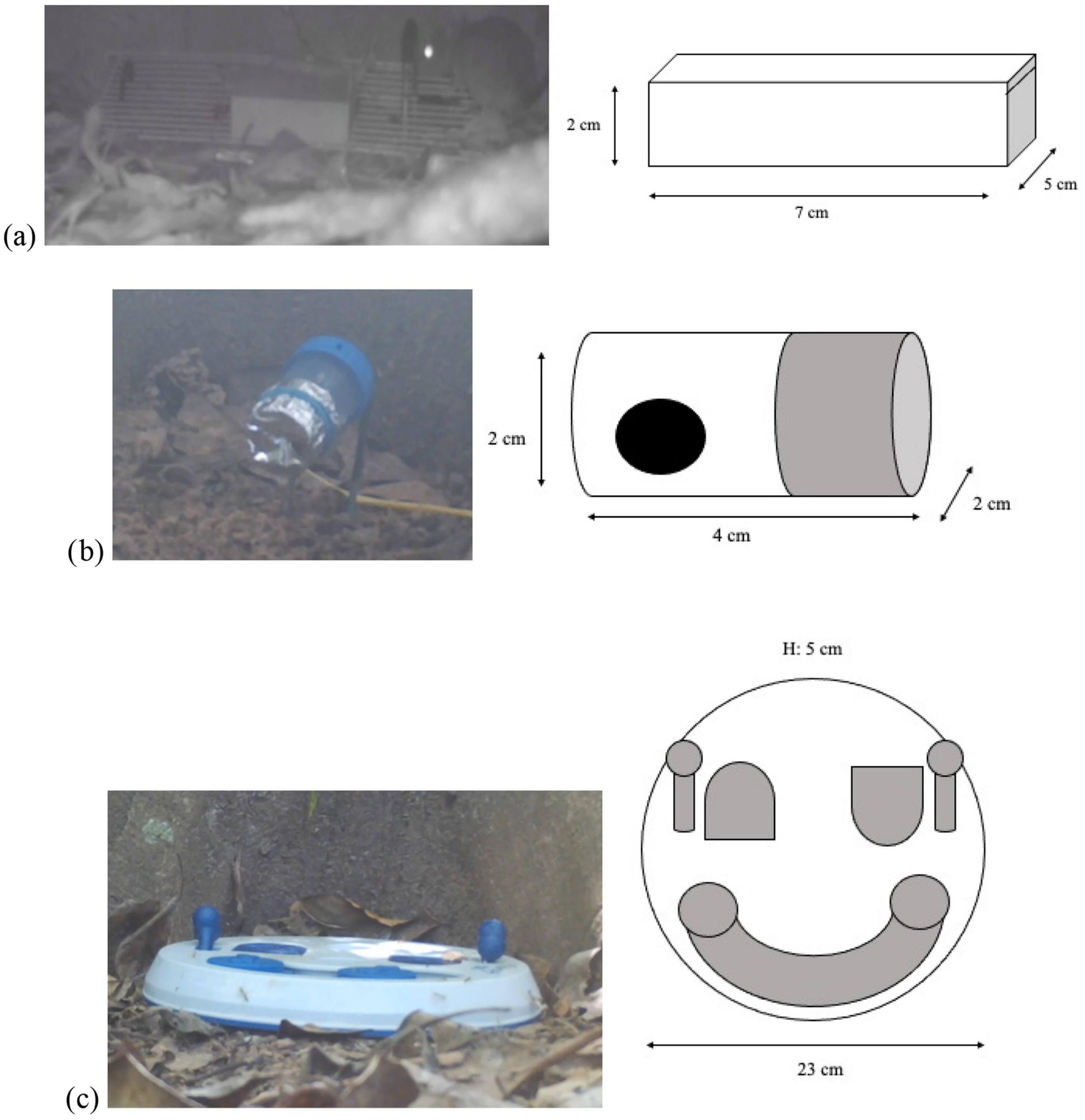

FIGURE 1 Puzzles set in the field in the Wet Tropics of Queensland including (a) the matchbox task, (b) the cylinder task and (c) the Trixie dog activity board (level 2) with the tile and lever tasks

(e.g. *Isoodon macrourus*), or 1 g of tinned sardines to attract carnivores (e.g. *Hydromys chrysogaster*)) was placed in each puzzle in the morning. Food options were chosen based on what is commonly used as bait for field work in the Wet Tropics region (Diete et al., 2016; Speldewinde et al., 2013). Puzzles were not set in wet or extreme weather to avoid them being damaged. All puzzles were secured to the ground by either tying the puzzle to a lawn peg (matchbox and cylinder task) or by using cement to weigh down the puzzle board (tile and lever task on the Trixie Dog Activity Board). This did not interfere with the movable pieces of the puzzle (e.g. the tiles could still slide easily) and did not limit the ways puzzles could be manipulated on that spot (i.e. the cylinder task could be moved up and down or side to side while animals handled it, but it could not be moved away from the location).

We could not always differentiate between individuals of the same species. Therefore, observations were considered to be one interaction if they occurred within a 5-min timeframe. We recorded whether observed animals of each species interacted with each puzzle type, the number of interactions made for each species for the different puzzles and whether each puzzle type was solved (i.e. whether the food reward was obtained). The solving success rate for each species was calculated by dividing the number of times the puzzle type was solved by the number of interactions.

Species identification

Animals were identified to genus or species level (where possible) using field guides (reptiles: Swanson, 2012, mammals: Hall & Parish, 2016; birds: Pizzey & Knight, 2012).

Statistical analysis

Statistical analyses were performed using R version 4.0.2 (R Core Team, 2020). We used a generalized linear mixed effects model (glmmTMB package, Brooks et al., 2022) with a binomial distribution and logit link function to investigate whether puzzles were solved or not (solved = 1, not solved = 0; dependent variable). We included the camera site number as a random effect, and puzzle type and taxon * number of interactions made with the puzzle as fixed factors. We calculated the effect size (Cohen's d) for each fixed factor using the effsize package (Torchiano & Torchiano, 2020). Camera site effects on problem solving success were calculated using a likelihood ratio test, where we compared a model including the random effect to a model excluding it.

Ethical note

This research was conducted in accordance with James Cook University Animal Ethics Screening (clearance number A2539) and the Queensland Department of Environment and Science (permit number WA0014502). The research methodologies also followed the ABS/ASAB guidelines for the ethical treatment of animals (ASAB Ethical Committee & ABS Animal Care Committee, 2022) and the Australian Code for the Care and Use of Animals for Scientific Purposes (National Health and Medical Research Council (NHMRC), 2013).

RESULTS

Twenty-three species were identified from camera trap footage, with 18 species interacting with the puzzles (Table 1). Seven of these species (39%) were recorded solving at least one type of puzzle (Table 1).

Melomys spp. and the giant white-tailed rat solved all puzzle types (Table 2). One species (brush turkey) solved three puzzle types, two species (orange-footed scrub fowl and northern brown bandicoot) solved two puzzle types, two species (black butcherbird and lace monitor) solved one puzzle type, and nine species solved no puzzles (Table 2). The number of interactions with the puzzle ($\chi^2_1 = 12.71$, $p < 0.001$, $d = -0.04$) and the interaction between number of interactions and taxon group ($\chi^2_3 = 7.91$, $p = 0.047$) significantly influenced whether animals were able to solve a puzzle, with puzzles being solved more

TABLE 1 The species observed on the camera traps and whether they interacted with or solved the different puzzle types

Species	Investigated puzzles?	Puzzles solved	Bait type	First solving
Aves				
Black butcherbird (*Cracticus quoyi*)	Yes	Cylinder	Sardines, fruit	X
Brush turkey (*Alectura lathami*)	Yes	Tile, lever, cylinder	Seeds, peanut butter, fruit	X
Bush-stone curlew (*Burhinidae grallarius*)	No	No	-	-
Noisy pitta (*Pitta versicolor*)	Yes	No	Seeds	-
Orange-footed scrubfowl (*Megapodius reinwardt*)	Yes	Tile, lever	Seeds, peanut butter	X
Pacific emerald dove (*Chalcophaps indica*)	No	No	-	-
Red-necked crake (*Rallina tricolour*)	No	No	-	-
Mammalia				
Agile wallaby (*Macropus agilis*)	Yes	No	Seeds	-
Echidna (*Tachyglossus aculeatus*)	Yes	No	Seeds	-
Giant white-tailed rat (*Uromys caudimaculatus*)	Yes	Tile, lever, cylinder, matchbox	Seeds, peanut butter, sardines, fruit	X
Mosaic-tailed rat *Melomys* spp.	Yes	Tile, lever, cylinder, matchbox	Seeds, peanut butter, fruit	(Rowell & Rymer, 2020)
Northern brown bandicoot (*Isoodon macrourus*)	Yes	Tile, lever	Peanut butter	X
Pig (*Sus scrofa*)	No	No	-	-
Prehensile-tailed rat (*Pogonomys mollipilosus*)	Yes	No	Seeds	-
Rattus spp.	Yes	No	Seeds, peanut butter	-
Red-legged pademelon (*Thylogale stigmatica*)	Yes	No	Seeds	-
Reptilia and *Anura*				
Cane toad (*Rhinella marina*)	No	No	-	-
Common tree snake (*Dendrelaphis punctulate*)	No	No	-	-
Lace monitor (*Varanus varius*)	Yes	Tile	Sardines	X
Major skink (*Egernia frere*)	Yes	No	Peanut butter	-
Pink-tongued skink (*Cyclodomorphus gerrardii*)	Yes	No	Fruit	-
Skink (*Carlia* spp.)	Yes	No	Seeds	-

Note: Bait type of solved puzzles and whether this is the first record of problem solving for the species is noted (references are provided if not the first instance).

often when more interactions were recorded (Figure 2). Taxon had a near significant effect on solving success (χ^2_3 = 7.71 p = 0.052, d = 0.33), with birds (0.4 ± 0.06) and placental mammals (0.32 ± 0.05) being more likely to solve puzzles than marsupials (0.06 ± 0.04) and reptiles (0.04 ± 0.04). There were no significant effects of puzzle type on solving success (χ^2_3 = 5.48, p = 0.140, d = −0.06). The inclusion of camera site as a random factor had no significant effect on the model (χ^2_1 = 0.00, p = 0.999).

DISCUSSION

We found that native Australian species from multiple taxa (mammals, reptiles, and birds) could solve food-baited problems in the wild. This study is the

TABLE 2 Solving success (1 = solved, 0 = not solved) of the species that interacted with at least one puzzle type

Species	Tiles	Levers	Cylinder	Matchbox
Aves				
Brush turkey (*Alectura lathami*)	1	1	1	0
Black butcherbird (*Cracticus quoyi*)	0	0	1	N/A
Noisy pitta (*Pitta versicolor*)	0	0	N/A	N/A
Orange-footed scrubfowl (*Megapodius reinwardt*)	1	1	0	N/A
Mammalia				
Agile wallaby (*Macropus agilis*)	0	0	0	N/A
Echidna (*Tachyglossus aculeatus*)	0	0	N/A	N/A
Giant white-tailed rat (*Uromys caudimaculatus*)	1	1	1	1
Long-nosed bandicoot (*Perameles nasuta*)	0	0	0	N/A
Melomys spp.[a]	1	1	1	1
Northern brown bandicoot (*Isoodon macrourus*)	1	1	0	N/A
Prehensile-tailed rat (*Pogonomys mollipilosus*)	0	0	N/A	N/A
Rattus spp.	0	0	N/A	N/A
Red-legged pademelon (*Thylogale stigmatica*)	N/A	N/A	0	N/A
Water rat (*Hydromys chrysogaster*)	0	0	N/A	0
Reptilia				
Lace monitor (*Varanus varius*)	1	0	0	0
Major skink (*egernia frere*)	0	0	N/A	N/A
Pink-tongued skink (*Cyclodomorphus gerrardii*)	N/A	N/A	0	N/A
Skink (*Carlia* spp.)	0	0	N/A	N/A

Note: Columns are marked N/A if no interactions were recorded for that puzzle type.

[a]One of two species: fawn-footed mosaic-tailed rat *Melomys cervinipes* or grassland mosaic-tailed rat *M. burtoni*.

first record of problem solving behaviour in seven native Australian species. These results support previous work observing problem solving in the wild in other species from other countries, including North Island robins *Petroica longipes* (Shaw, 2017), spotted hyenas (Benson-Amram & Holekamp, 2012), and brown anoles (*Anolis sagrei*; Storks & Leal, 2020). Problem solving is flexible (Rowell et al., 2021) and is suggested to be important for responding to dynamic and changing environmental conditions (Griffin et al., 2013).

We found a weak yet significant relationship between the number of interactions and solving success across taxonomic groups, which is similar to what has been found in previous studies (Benson-Amram et al., 2013). For all species, interacting with the puzzle allows individuals to learn to solve via trial-and error learning (Thornton & Samson, 2012), and if they remember the solution, this increases the chances of solving the puzzle in the future (Rowell & Rymer, 2021b). However, not all species that interacted with the puzzles solved them. For example, at least one individual water rat was observed interacting with tasks baited with a suitable food (e.g. sardines; Speldewinde et al., 2013) but did not solve it. Similarly, mosaic-tailed rats and giant white-tailed rats solved all of the puzzles, whereas another arboreal rodent species, the prehensile-tailed rat, did not. It is not clear whether the species that interacted with but did not solve a problem was a

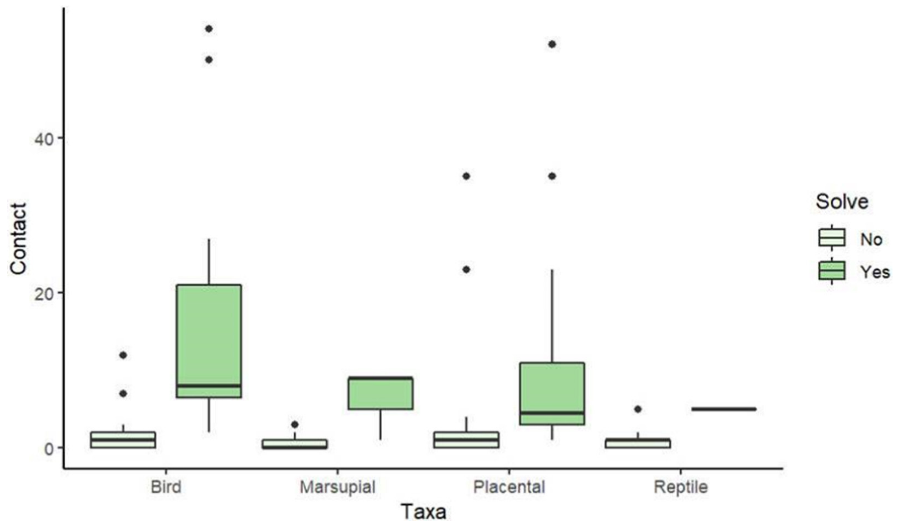

FIGURE 2 The number of interactions made with puzzles when puzzles were solved or not solved by different taxa in the Wet Tropics of Queensland.

consequence of a morphological (Rowell et al., 2021), cognitive (Rowell & Rymer, 2021b), physiological (Bókony et al., 2014) or behavioural (Rowell & Rymer, 2021a) factor. For example, an animal might not have been motivated to solve a puzzle because it could not smell it (e.g. passerine birds like the noisy pitta have a poor sense of smell, Padodara & Ninan, 2014), or an animal might not have had the mechanical ability to perform the task (e.g. echidnas do not have teeth Stannard et al., 2017) so could not grasp the lever handle in the jaws). More work, therefore, is needed over a longer sampling period to determine the underlying causes of a lack of solving.

We found that the problem solving abilities of Wet Tropics animals varied, with near significant differences in solving abilities being found between taxonomic groups across all camera sites and puzzle types. Placental mammals and birds tended to be more successful solvers than reptiles and marsupials. It is common to observe differences between groups of animals (Amici et al., 2019). The ability to solve these particular tasks might be related to the mechanical abilities of the individual species. Rodents, for example, have highly dextrous forelimbs due to their natural feeding behaviour (Carrizo et al., 2014), whereas reptiles like monitor lizards may be less dextrous because their forelimbs are adapted for digging and scraping (D'Amore et al., 2018). However, due to the lack of research on problem solving in reptiles (Szabo et al., 2021) and marsupials (McElligott et al., 2020) in general, more research is required before we can discern the underlying causes for these differences. When considering solving at the species level, some species were capable of solving tasks of varying complexities. Giant white-tailed rats, brush turkeys and mosaic-tailed rats were the most successful solvers, with all being capable of solving three or more puzzles. Due to the difficulty of actively observing animals in the wild, task complexity is often not considered in problem solving research using wild species, with only one puzzle typically being presented to animals (e.g. Storks & Leal, 2020). While we found no significant difference in the solving success of species in relation to task complexity or taxonomic group, this could be a function of low sample size of incidents of solving. Our method of using trail cameras to monitor puzzles allowed many species to be observed with relatively low human interference, and we suggest that future work could use similar methods to present wild animals with multiple puzzles of varying complexity, and a longer duration of time in the field may lead to interesting findings relating to species differences in solving puzzles of different complexities.

While fawn-footed mosaic-tailed rats have been found to solve problems (Rowell & Rymer, 2020, 2022), these previous studies were conducted in captivity. This is, therefore, the first study demonstrating problem solving ability in wild-living individuals of this genus. Numerous studies have suggested that behaviours measured under laboratory conditions might not be representative of conditions experienced in the wild (Hodgins-Davis & Townsend, 2009; Niemelä & Dingemanse, 2014). The findings from the present study support our previous work (e.g. Rowell et al., 2022; Rowell & Rymer, 2021b), and suggest that, at least for some species, problem solving ability in captivity is likely also reflective of problem solving ability in the wild, similar to those studies shown for personality traits in blue tits *Cyanistes caeruleus* (Herborn et al., 2010) and African striped mice *Rhabdomys pumilio* (Yuen et al., 2016).

Overall, these results show that some native Australian species of various taxa can solve food-baited problems in the wild. This study builds on our understanding of the behavioural and cognitive abilities of native Australian species. As problem solving may be important for coping with urbanization and other anthropogenic threats, these results provide some insights into which Wet Tropics species may potentially be more vulnerable to these threats, and which ones might be better at coping with changing conditions.

AUTHOR CONTRIBUTIONS

Misha Rowell: Conceptualization (equal); data curation (lead); formal analysis (equal); investigation (equal); methodology (equal); writing – original draft (lead); writing – review and editing (equal). **Tasmin Rymer:** Conceptualization (equal); formal analysis (equal); investigation (equal); methodology (equal); resources (lead); writing – review and editing (equal).

ACKNOWLEDGEMENTS

We thank Janelle Vanderbeek for assisting with reptile identification, Darren Crotty for assisting with weighing down activity boards, and Kailey Armstrong for helping check and rebait puzzles.

FUNDING INFORMATION

This work was supported by James Cook University.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data used in this manuscript is attached as supplementary material.

ORCID

Misha K. Rowell https://orcid.org/0000-0003-3829-9178

REFERENCES

Amici, F., Widdig, A., Lehmann, J. & Majolo, B. (2019) A meta-analysis of interindividual differences in innovation. *Animal Behaviour*, 155, 257–268.

ASAB Ethical Committee & ABS Animal Care Committee. (2022) Guidelines for the treatment of animals in behavioural research and teaching. *Animal Behaviour*, 183, I–XI. Available from: https://doi.org/10.1016/S0003-3472(21)00389-4

Ashton, B.J., Ridley, A.R., Edwards, E.K. & Thornton, A. (2018) Cognitive performance is linked to group size and affects fitness in Australian magpies. *Nature*, 554, 7692. Available from: https://doi.org/10.1038/nature25503

Benson-Amram, S. & Holekamp, K.E. (2012) Innovative problem solving by wild spotted hyenas. *Proceedings of the Royal Society B: Biological Sciences*, 279, 4087–4095. Available from: https://doi.org/10.1098/rspb.2012.1450

Benson-Amram, S., Weldele, M.L. & Holekamp, K.E. (2013) A comparison of innovative problem-solving abilities between wild and captive spotted hyaenas, *Crocuta*

crocuta. *Animal Behaviour*, 85, 349–356. Available from: https://doi.org/10.1016/j.anbehav.2012.11.003
Biondi, L.M., Bó, M.S. & Vassallo, A.I. (2010) Inter-individual and age differences in exploration, neophobia and problem-solving ability in a Neotropical raptor (*Milvago chimango*). *Animal Cognition*, 13, 701–710. Available from: https://doi.org/10.1007/s10071-010-0319-8
Bókony, V., Lendvai, A.Z., Vagasi, C.I., Patras, L., Pap, P.L., Nemeth, J. et al. (2014) Necessity or capacity? Physiological state predicts problem-solving performance in house sparrows. *Behavioral Ecology*, 25, 124–135. Available from: https://doi.org/10.1093/beheco/art094
Borrego, N. & Gaines, M. (2016) Social carnivores outperform asocial carnivores on an innovative problem. *Animal Behaviour*, 114, 21–26. Available from: https://doi.org/10.1016/j.anbehav.2016.01.013
Brooks, M., Bolker, B., Kristensen, K., Maechler, M., Magnusson, A., McGillycuddy, M. et al. (2022) glmmTMB: Generalized Linear Mixed Models using Template Model Builder (1.1.4). https://CRAN.R-project.org/package=glmmTMB
Carrizo, L.V., Tulli, M.J., Dos Santos, D.A. & Abdala, V. (2014) Interplay between postcranial morphology and locomotor types in Neotropical sigmodontine rodents. *Journal of Anatomy*, 224, 469–481. Available from: https://doi.org/10.1111/joa.12152
Chow, P.K.Y., Lea, S.E.G., Hempel de Ibarra, N. & Robert, T. (2017) How to stay perfect: the role of memory and behavioural traits in an experienced problem and a similar problem. *Animal Cognition*, 20, 941–952. Available from: https://doi.org/10.1007/s10071-017-1113-7
D'Amore, D.C., Clulow, S., Doody, J.S., Rhind, D. & McHenry, C.R. (2018) Claw morphometrics in monitor lizards: Variable substrate and habitat use correlate to shape diversity within a predator guild. *Ecology and Evolution*, 8, 6766–6778. Available from: https://doi.org/10.1002/ece3.4185
Diete, R.L., Meek, P.D., Dixon, K.M., Dickman, C.R. & Leung, L.K.P. (2016) Best bait for your buck: Bait preference for camera trapping north Australian mammals. *Australian Journal of Zoology*, 63, 376–382. Available from: https://doi.org/10.1071/ZO15050
Diquelou, M.C., Griffin, A.S. & Sol, D. (2016) The role of motor diversity in foraging innovations: A cross-species comparison in urban birds. *Behavioral Ecology*, 27, 584–591. Available from: https://doi.org/10.1093/beheco/arv190
Griffin, A.S. & Guez, D. (2014) Innovation and problem solving: A review of common mechanisms. *Behavioural Processes*, 109, 121–134. Available from: https://doi.org/10.1016/j.beproc.2014.08.027
Griffin, A.S., Guez, D., Lermite, F. & Patience, M. (2013) Tracking changing environments: Innovators are fast, but not flexible learners. *PLoS One*, 8, e84907. Available from: https://doi.org/10.1371/journal.pone.0084907
Hall, L. & Parish, S. (2016) *Field guide to Australian mammals*. Brisbane, Australia: Steve Parish Publishing.
Herborn, K.A., Macleod, R., Miles, W.T.S., Schofield, A.N.B., Alexander, L. & Arnold, K.E. (2010) Personality in captivity reflects personality in the wild. *Animal Behaviour*, 79, 835–843. Available from: https://doi.org/10.1016/j.anbehav.2009.12.026
Hodgins-Davis, A. & Townsend, J.P. (2009) Evolving gene expression: From G to E to G×E. *Trends in Ecology & Evolution*, 24, 649–658. Available from: https://doi.org/10.1016/j.tree.2009.06.011
Isden, J., Panayi, C., Dingle, C. & Madden, J. (2013) Performance in cognitive and problem-solving tasks in male spotted bowerbirds does not correlate with mating success. *Animal Behaviour*, 86, 829–838. Available from: https://doi.org/10.1016/j.anbehav.2013.07.024
Kozlovsky, D.Y., Branch, C.L. & Pravosudov, V.V. (2015) Problem-solving ability and response to novelty in mountain chickadees (*Poecile gambeli*) from different elevations. *Behavioral Ecology and Sociobiology*, 69, 635–643. Available from: https://doi.org/10.1007/s00265-015-1874-4
Manrod, J.D., Hartdegen, R. & Burghardt, G.M. (2008) Rapid solving of a problem apparatus by juvenile black-throated monitor lizards (*Varanus albigularis albigularis*). *Animal Cognition*, 11, 267–273. Available from: https://doi.org/10.1007/s10071-007-0109-0
McElligott, A.G., O'Keeffe, K.H. & Green, A.C. (2020) Kangaroos display gazing and gaze alternations during an unsolvable problem task. *Biology Letters*, 16, 20200607. Available from: https://doi.org/10.1098/rsbl.2020.0607
National Health and Medical Research Council (NHMRC), Nh. (2013) *Australian code for the care and use of animals for scientific purposes*. Canberra: National Health and Medical Research Council.
Niemelä, P.T. & Dingemanse, N.J. (2014) Artificial environments and the study of 'adaptive' personalities. *Trends in Ecology & Evolution*, 29, 245–247. Available from: https://doi.org/10.1016/j.tree.2014.02.007
Padodara, R.J. & Ninan, J. (2014) Olfactory sense in different animals. *The Indian Journal of Veterinary Science*, 2, 1–14.

Papp, S., Vincze, E., Preiszner, B., Liker, A. & Bókony, V. (2015) A comparison of problem-solving success between urban and rural house sparrows. *Behavioral Ecology and Sociobiology*, 69, 471–480. Available from: https://doi.org/10.1007/s00265-014-1859-8

Pizzey, G. & Knight, F. (2012) *The field guide to the birds of Australia*, 9th edition. Sydney, Australia: Harper Collins Publishers.

R Core Team. (2020) *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rowell, M.K., Pillay, N. & Rymer, T.L. (2021) Problem solving in animals: proposal for an ontogenetic perspective. *Animals*, 11, 866. Available from: https://doi.org/10.3390/ani11030866

Rowell, M.K. & Rymer, T.L. (2020) Innovation in a native Australian rodent, the fawn-footed mosaic-tailed rat (*Melomys cervinipes*). *Animal Cognition*, 23, 301–310. Available from: https://doi.org/10.1007/s10071-019-01334-6

Rowell, M.K. & Rymer, T.L. (2021a) Exploration influences problem solving in the fawn-footed mosaic-tailed rat (*Melomys cervinipes*). *Ethology*, 127, 592–604. Available from: https://doi.org/10.1111/eth.13166

Rowell, M.K. & Rymer, T.L. (2021b) Memory enhances problem solving in the fawn-footed mosaic-tailed rat *Melomys cervinipes*. *Animal Cognition*, 25, 347–358. Available from: https://doi.org/10.1007/s10071-021-01556-7

Rowell, M.K. & Rymer, T.L. (2022) Problem solving in fawn-footed mosaic-tailed rats Melomys cervinipes is not significantly influenced by maternal care or genetic effects. *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology*, 337, 802–811. Available from: https://doi.org/10.1002/jez.2637

Rowell, M.K., Santymire, R.M. & Rymer, T.L. (2022) Corticosterone metabolite concentration is not related to problem solving in the fawn-footed mosaic-tailed rat *Melomys Cervinipes*. *Animals*, 12, 82. Available from: https://doi.org/10.3390/ani12010082

Shaw, R.C. (2017) Testing cognition in the wild: factors affecting performance and individual consistency in two measures of avian cognition. *Behavioural Processes*, 134, 31–36. Available from: https://doi.org/10.1016/j.beproc.2016.06.004

Sih, A., Trimmer, P.C. & Ehlman, S.M. (2016) A conceptual framework for understanding behavioral responses to HIREC. *Current Opinion in Behavioral Sciences*, 12, 109–114. Available from: https://doi.org/10.1016/j.cobeha.2016.09.014

Sol, D. & Lefebvre, L. (2000) Behavioural flexibility predicts invasion success in birds introduced to New Zealand. *Oikos*, 90, 599–605. Available from: https://doi.org/10.1034/j.1600-0706.2000.900317.x

Speldewinde, P.C., Close, P., Weybury, M. & Comer, S. (2013) Habitat preference of the Australian water rat (*Hydromys chrysogaster*) in a coastal wetland and stream, two peoples bay, South-Western Australia. *Australian Mammalogy*, 35, 188–194. Available from: https://doi.org/10.1071/AM12001

Stannard, H.J., Bekkers, J.M., Old, J.M., McAllan, B.M. & Shaw, M.E. (2017) Digestibility of a new diet for captive short-beaked echidnas (*Tachyglossus aculeatus*). *Zoo Biology*, 36, 56–61. Available from: https://doi.org/10.1002/zoo.21347

Storks, L. & Leal, M. (2020) Thinking outside the box: Problem-solving in free-living lizards. *Behavioral Ecology and Sociobiology*, 74, 1–9. Available from: https://doi.org/10.1007/s00265-020-02852-x

Swanson, S. (2012) *Field guide to Australian reptiles*. Brisbane, Australia: Steve Parish Publishing Pty Ltd.

Szabo, B., Noble, D.W. & Whiting, M.J. (2021) Learning in non-avian reptiles 40 years on: advances and promising new directions. *Biological Reviews*, 96, 331–356. Available from: https://doi.org/10.1111/brv.12658

Thornton, A. & Samson, J. (2012) Innovative problem solving in wild meerkats. *Animal Behaviour*, 83, 1459–1468. Available from: https://doi.org/10.1016/j.anbehav.2012.03.018

Tinbergen N. (1963) On aims and methods of ethology. *Zeitschrift für tierpsychologie*, 20(4), 410–433. Available from: https://doi.org/10.1111/j.1439-0310.1963.tb01161.x

Torchiano, M. & Torchiano, M.M. (2020) Package 'effsize'. Package "Effsize" [(Accessed on 9 March 2021)]. https://pbil.univ-lyon1.fr/CRAN/web/packages/effsize/effsize.pdf

Webster, S.J. & Lefebvre, L. (2001) Problem solving and neophobia in a columbiform–passeriform assemblage in Barbados. *Animal Behaviour*, 62, 23–32. Available from: https://doi.org/10.1006/anbe.2000.1725

Yuen, C.H., Pillay, N., Heinrichs, M., Schoepf, I. & Schradin, C. (2016) Personality traits are consistent when measured in the field and in the laboratory in African striped mice (*Rhabdomys pumilio*). *Behavioral Ecology and Sociobiology*, 70, 1235–1246. Available from: https://doi.org/10.1007/s00265-016-2131-1

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:
Rowell, M.K. & Rymer, T.L. (2022) Problem solving of wild animals in the Wet Tropics of Queensland, Australia. *Austral Ecology*, 00, 1–10. Available from: https://doi.org/10.1111/aec.13270