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RESEARCH ARTICLE

Problem-solving of the cylinder, tile and lever tasks by wild animals in Dryandra National Park, Western Australia

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Abstract

Problem-solving is an important ability that allows animals to overcome environmental challenges. As such, it is a useful measure of behavioural flexibility and could be beneficial for conservation work. However, there is currently little known about the solving abilities of many Australian species, despite the high threat of environmental degradation and loss that they face. We therefore measured the problem-solving abilities of native Australian species living in the Dryandra National Park, Western Australia using food-baited puzzles (cylinder task, tile task and lever task) placed in front of camera traps. We recorded 12 species on cameras, with 10 species interacting with at least one puzzle. Of these species, woylies and koomal solved all tasks across multiple sites and using multiple behaviours, suggesting that they may be capable of adapting to novel conditions or environments. We also recorded a chuditch solving the tile task at one site. Regardless of species and puzzle type, animals had a higher chance of solving puzzles with increasing interactions. Our results document the first occurrence of problem-solving in woylies and chuditch, and highlight the potential for problem-solving measures to be incorporated into conservation management.

KEYWORDS

behavioural flexibility, brush-tailed bettong *Bettongia penicillata ogilbyi*, cognition, common brushtail possums *Trichosurus vulpecula*, innovation, western quoll *Dasyurus geoffroii*

INTRODUCTION

Problem-solving is the ability of an animal to manipulate or move itself around an obstacle to obtain a reward, such as food or shelter (Rowell et al., 2021). Animals can solve problems innovatively (using a novel behaviour or existing behaviour in a novel circumstance; Reader & Laland, 2003) or through trial and error over experience with the problem (Thornton & Samson, 2012). The ability to solve problems is not taxonomically constrained and has been found in mammals, birds, reptiles, fish, and invertebrates (Rowell et al., 2021). Furthermore, the ability to solve problems is not constrained by foraging, reproductive, or social strategies. For example, carnivores (Drea & Carter, 2009) and herbivores (Guenther & Brust, 2017), r-selected (Ellen et al., 1984) and K-selected (Dean et al., 2011) species, and social (Thornton & Samson, 2012) and solitary (Rowell & Rymer, 2020) species have all been recorded solving problems.

Instead, an animal's problem-solving ability is more likely to be influenced by intra-individual factors, including motivation, exploration and learning ability (Griffin & Guez, 2014).

The ability to solve problems can also be beneficial to animals as it can increase their ability to cope with new or harsh conditions. For example, pair-wise comparisons of related species showed that birds that successfully invaded New Zealand showed higher rates of foraging innovations than unsuccessful invaders (Sol & Lefebvre, 2000). Similarly, mountain chickadees *Poecile gambeli* living at higher altitudes in North America, and therefore experiencing harsher winters, were better solvers than chickadees living at lower altitudes (Kozlovsky et al., 2015). Furthermore, problem-solving is often associated with higher exploration behaviour (Biondi et al., 2010), lower neophobia (Webster & Lefebvre, 2001), and better learning (Bouchard et al., 2007) and memory (Chow et al., 2017) abilities, for innovative individuals are often more likely to move into and survive in urban spaces (e.g., house finches *Haemorhous mexicanus*, Cook et al., 2017). Problem-solving is therefore a useful behavioural and cognitive indicator of survivability and flexibility.

While recent studies have demonstrated that some native Australian animals across multiple taxa can solve problems (i.e., birds, Isden et al., 2013; reptiles, Manrod et al., 2008; mammals, Wat et al., 2020), including in the wild (Rowell & Rymer, 2023), the problem-solving abilities of many native species have not been studied. Furthermore, many of the Australian species that have been studied are found in structurally complex environments, (e.g., rainforest, Isden et al., 2013; urban landscape, Lermite et al., 2017) where this complexity may be driving the evolution of behavioural and cognitive responses such as problem-solving (Griffin et al., 2017). As such, it is not well understood if there are differences between the problem-solving abilities of taxa across different environments. We therefore investigated the problem-solving abilities of native Australian animals in Dryandra National Park, Western Australia, an environment dominated by powderbark wandoo *Eucalyptus accedens* and wandoo *Eucalyptus wandoo*. We presented animals with a series of puzzles (cylinder, tile, and lever tasks) baited with peanut butter and oat balls in this study. These puzzles have previously been solved by other native wildlife species in captivity and in the natural habitats of the Wet Tropics of Queensland (Rowell & Rymer, 2023). We hypothesized that the native animals living in Dryandra National Park would also be able to successfully solve the puzzles. However, as the problem-solving abilities of the species found here have mostly not been studied, we could not make predictions about how well each species would perform, or how they might compare to each other.

METHODS

Site set up

Trail cameras (Reconyx Hyperfire 2) were placed at four sites in Dryandra National Park, Western Australia in November 2022 (Figure 1), where a range of mammals occur, including woylies (brush-tailed bettong *Bettongia penicillata ogilbyi*), koomal (common brushtail possums *Trichosurus vulpecula*), quenda (south-western brown bandicoot *Isoodon fusciventer*) and chuditch (western quoll *Dasyurus geoffroii*). Sites were at least 500 m apart to minimize the chances of the same individual animals being recorded across sites (as local mammal home ranges can vary from 0.02 km^2 (quenda, Broughton & Dickman, 1991) to 0.65 km^2 (woylies, Yeatman & Wayne, 2015). Cameras were attached to tree trunks approximately 25 cm

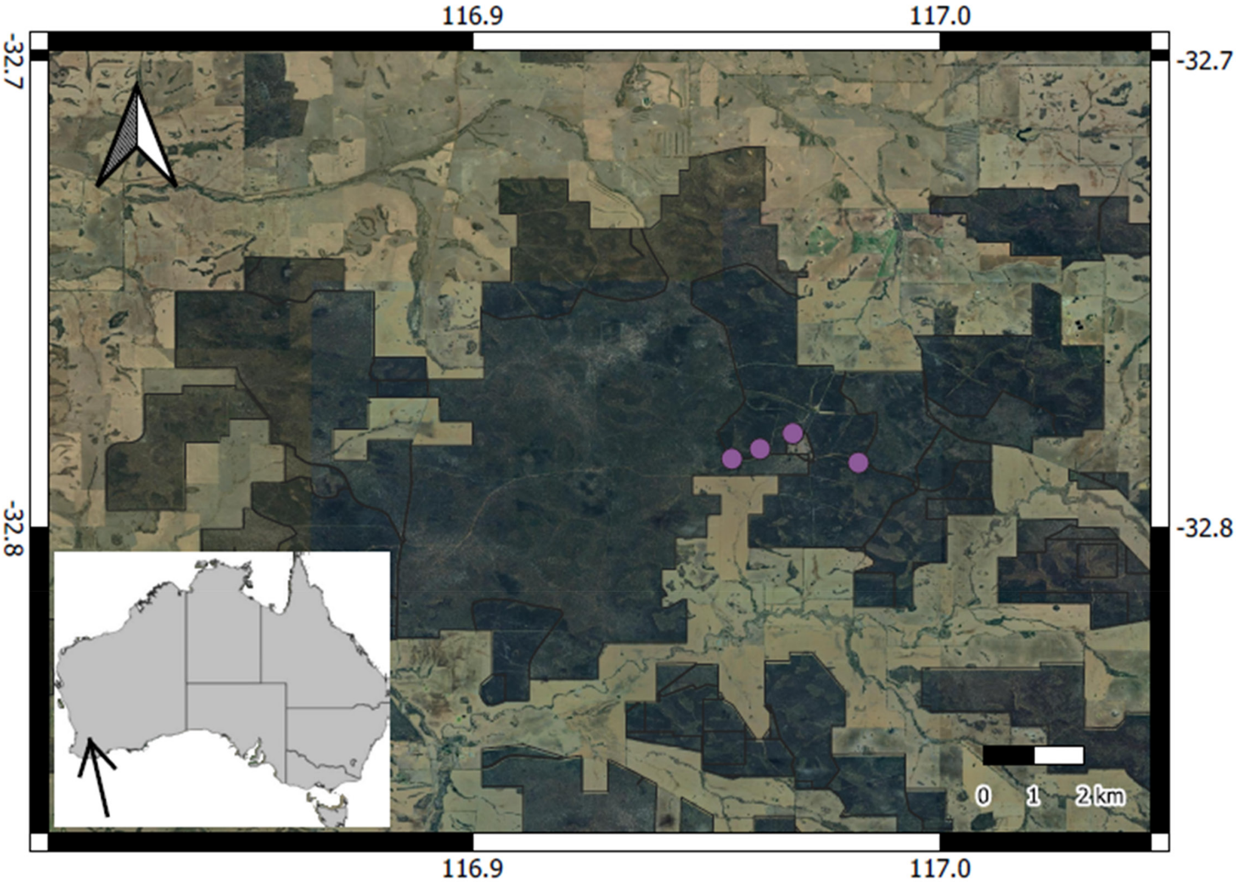

FIGURE 1 Location of sites (purple dots) where puzzles were deployed within Dryandra National Park, Western Australia. Site names from left to right: Tomingley, Kawana, Irabina and Phone Hill.

above the ground and were angled toward the puzzles. The cameras were programmed to record a 30 s video after being triggered by movement. A food-baited puzzle (see below) was secured in view of each camera.

Puzzles

We used three food-baited puzzles to test problem-solving following Rowell and Rymer (2023). Puzzles were all baited daily with balls made of universal bait (rolled oats, peanut butter and sardines) aimed at attracting medium mammal species. The cylinder task was created using a plastic cylinder (2 cm × 2 cm × 5 cm) with one open end that was covered in tinfoil (Figure 2a). Animals needed to push through, or pull off, the tin foil to access the food reward. The cylinder was secured to a metal lawn peg to prevent it from being carried away but could still be lifted and angled while animals tried to solve it. The other two puzzles were presented on the Trixie Dog Activity Board (Level 2; Figure 2b) and consisted of plastic tiles that could be slid to the side to access food, and plastic levers that could be pushed or pulled to lift a flap covering the food reward. The activity board was weighed down by filling empty space at the base of the board with cement (which still allowed the puzzle pieces to move) to keep it in front of the camera.

From these videos, we recorded (1) what species were observed, (2) whether species interacted with the puzzles, (3) how many interactions each species made with each puzzle type, (4) whether each species solved

FIGURE 2 Puzzles presented to animals in Dryandra National Park, Western Australia showing (a) the cylinder task and (b) the tile and lever tasks on the Trixie Dog Activity Board (Level 2).

each puzzle type (defined as removing the barrier to obtain the food reward) and (5) how the puzzle was solved (i.e., pushed tile with snout). As we could not tell different individuals of the same species apart, we considered observations to be only one interaction if they were captured within a 5-min timeframe (as per Rowell & Rymer, 2023).

Species identification

Field guides (reptiles: Swanson, 2012; mammals: Hall & Parish, 2016; birds: Pizzey & Knight, 2012) were used to identify animals to genus or species level (where possible).

Statistical analysis

We analysed data using R version 4.0.2 (R Core Team, 2020). To look at the factors that influenced solving success (1 = solved, 0 = not solved), we used a generalized linear mixed effects model (glmmTMB package, Magnusson et al., 2017) with a binomial distribution and logit link function. Site number, puzzle type and the number of interactions made with the puzzle were included as fixed factors. This model would not run when species name was included as a fixed factor, and so we also ran this model again but with only species and number of interactions as fixed factors. As this second model would not run with null data records (i.e. where a species recorded did not interact with or solve the puzzle), we only included data where animals interacted with the puzzle. We report the effect of species from this model, and report all other results from the first model. For both models, we used the effsize package (Torchiano, 2020) to calculate the effect size (Cohen's *d*) for each fixed factor.

RESULTS

Twelve species, including birds, mammals and a reptile, were identified across the four sites from camera trap footage, with 10 species interacting with the puzzle (Table 1). Three of these species (30%) solved at least one type of puzzle (Table 1).

Woylies and koomal were recorded solving all puzzle types and a chuditch was recorded solving the tile task (Table 1). We captured records of woylies and koomal solving each problem across multiple sites, suggesting multiple individuals were able to solve the tasks. This footage also showed that animals within a species often used a variety of techniques to solve each task (Table 2). The chuditch was only recorded solving the tile task once (Table 2). For all species, the number of interactions made with the puzzle by all individuals ($\chi^2_1 = 29.39$, $p < 0.001$, $d = -0.19$) significantly affected whether that species could successfully solve the puzzle, with more interactions increasing the chance of solving (Figure 3). There

TABLE 1 The species observed on the camera traps in Dryandra National Park and whether they interacted with or solved the different puzzle types. It is noted if this is the first record of problem-solving for the species (references are provided if not the first instance).

Species	Investigated puzzles?	Puzzles solved	First solving
Aves			
Australian Ringneck *Barnardius zonarius*	No	–	–
Western Australian Magpie *Gymnorhina tibicen dorsalis*	Yes	No	–
Red wattlebird *Anthochaera carunculata*	Yes	No	–
Mammalia			
Koomal (common brushtail possum) *Trichosurus vulpecula*, Kerr 1792	Yes	Cylinder, Tile, Lever	Wat et al. (2020)
Woylie (brush-tailed bettong) *Bettongia penicillata ogilbyi*, Grey 1837	Yes	Cylinder, Tile, Lever	X
Kangaroo spp.	No	–	–
Short-beaked echidna *Tachyglossus aculeatus*	Yes	No	–
Quenda (south-western brown bandicoot) *Isoodon fusciventer*	Yes	No	–
Gilbert's dunnart *Sminthopsis gilberti*	Yes	No	–
Chuditch (western quoll) *Dasyurus geoffroii*, Gould 1841	Yes	Tile	X
Antechinus spp.	Yes	No	–
Reptilia			
Western shingleback skink *Tiliqua rugosa rugosa*	Yes	No	–

TABLE 2 A description of the methods used to solve each puzzle type by woylies (brush-tailed bettongs) *Bettongia penicillata ogilbyi*, koomal (common brushtail possums) *Trichosurus vulpecula,* and chuditch (western quoll) *Dasyurus geoffroii* in the Dryandra National Park, Western Australia.

	Methods used		
Puzzle type	**Woylie**	**Koomal**	**Chuditch**
Cylinder task	Pulled foil off with paws	Pulled foil off with mouth Unscrewed cylinder from peg	N/A
Tile task	Pushed tile with snout Pushed tile with left paw	Pushed tile with snout Pulled tile with left paw Pulled tile with right paw	Pushed with snout
Lever task	Pushed lever with right paw Pushed lever with snout Pulled lever with left paw Pulled flap open with left paw Pulled flap open with right paw Pulled flap open with both paws	Bit lever and pushed to open Pushed lever with left paw Pushed lever with right paw Pulled lever with left paw Pulled lever with right paw Pulled lever with mouth and both paws Pulled flap open with left paw Pulled flap open with right paw	N/A

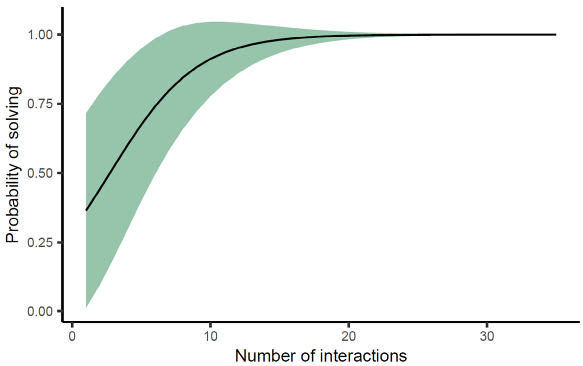

FIGURE 3 Model predictions of the effect of number of interactions by all animals on the probability (±SE) of a puzzle being solved in Dryandra National Park, Western Australia.

was no significant difference in solving success between sites (χ^2_3=2.02, p=0.569, d=0.00), puzzle types (χ^2_2=0.06, p=0.971, d=0.03), or species (χ^2_1=11.09, p=0.269, d=−0.33).

DISCUSSION

Here, we demonstrate that multiple wild species found in the Dryandra National Park, Western Australia are capable of problem-solving, representing the first documentation of problem-solving by wild woylies and chuditch, and the first food-motivated solving in wild koomal. Furthermore, we recorded woylies and koomal using multiple strategies to solve puzzles (i.e., pushing with snout and pulling with forelimb) across multiple sites, showing that this behaviour was not a random occurrence in either species. There were no significant site or puzzle type effects on solving success rates, further supporting the idea that problem-solving behaviours were not a rare occurrence in these species. The frequent occurrence of problem-solving behaviours observed may indicate that these species are potentially more adaptable to environmental changes (Sol et al., 2002), such as novel predators/resources, urbanization, or change climate. Recent work has begun to incorporate behaviour into population conservation and management

(Berger-Tal et al., 2016; Blumstein & Fernández-Juricic, 2004; Harrison, Phillips, et al., 2023). For example, the personality and plasticity of eastern quolls *Dasyurus viverrinus* (Wilson et al., 2022) and anti-predator and ranging behaviour of burrowing bettongs *Bettongia lesueur* (West et al., 2019) affected their post-release behaviour after translocation. Our findings here could also work toward such a goal as problem-solving is indicative of behavioural flexibility (Leal & Powell, 2012). If future studies show that problem-solving is individually repeatable in woylies, chuditch, or koomal, and that there is intra-individual variation in this ability, problem-solving ability could be used to inform the selection of individuals for translocation. This would allow individuals that are better suited to cope with a novel environment to be selected, increasing the chances of the new population being established, and minimizing mortality in 'unsuitable' individuals. Future work should therefore investigate correlations between problem-solving ability and reintroduction success.

Across all puzzle types, species were more likely to solve the puzzle if they made more interactions with it. This has previously been found with other species using these puzzle types (Rowell & Rymer, 2021a, 2023) and with many other puzzle box designs (spotted hyenas *Crocuta crocuta*, Benson-Amram et al., 2013; chimango caracara *Milvago chimango*, Biondi et al., 2010; meerkat *Suricata suricatta*, Thornton & Samson, 2012). Interacting with the puzzle apparatus allows animals to learn through trial-and-error which components need to be moved, and how they can be moved, making successful solving more likely (Rowell & Rymer, 2021b). Inter-individual variation in neophobia (Webster & Lefebvre, 2001), behavioural flexibility (Griffin & Guez, 2014), and cognitive ability (Aplin et al., 2013) could therefore lead to these differences in solving success, but this remains to be tested in these species.

However, not all species that investigated the puzzles solved them, possibly due to methodological factors of this study or behavioural limitations. This lack of problem-solving could be attributed to these and other inter-individual factors, but also morphological and environmental factors. Firstly, the bait may not have been suitable to adequately motivate all species – Rowell and Rymer (2023) observed a greater variety of species solving puzzles when using multiple different bait types (fruit, seeds, peanut butter, or sardines). This may also explain why we only captured one record of a chuditch solving the puzzle, as this species is carnivorous and may not have been motivated to solve the puzzles baited with peanut butter balls (Soderquist & Serena, 1994). Some species may also have not been morphologically capable of solving the types of puzzles we used (e.g., echidnas do not possess teeth, and this may restrict their ability to pull the puzzle levers, Rowell & Rymer, 2023). Within a species, there are also many other intra-individual factors that may influence an individual's problem-solving abilities. This includes morphological limitations (e.g. juveniles not being large or strong enough to move a puzzle component, Thornton & Samson, 2012), personality differences (e.g., exploration, activity and boldness, Bell, 2007), cognitive capabilities (e.g. memory and learning ability, Rowell & Rymer, 2021a, 2021b), or physiological state (e.g. motivation, van Horik & Madden, 2016). Finally, the environment may also affect problem-solving abilities. For example, though we did not observe it here, Western Australian magpies are capable of problem-solving (Ashton et al., 2019), and their ability to do so is affected by temperature (Blackburn et al., 2022). It would therefore be worthwhile to continue investigating problem-solving in this environment by including different food and puzzle types and testing during different times of the year to account for some of these factors.

Finally, like other camera trapping studies (Schneider et al., 2019), our study was limited by the inability to accurately identify individuals. While we are confident that there were multiple individuals recorded among sites (owing to their distance from one another and the number of problem-solving behaviours recorded), we were unable to examine individual variability in solving, or look at repeated measures through time. Individual repeatability in behavioural assays, such as the ones tested here, is valuable for revealing personality phenotypes (Harrison et al., 2022) or increasing robustness, by ensuring that one observation of an individual will be adequately accurate (Harrison, Steven, et al., 2023). We recommend that future studies incorporate this where possible. The species examined here were also not distinguishable by sex, hampering ability to test for sex differences in solving ability. Mammals are known to show sexual dimorphisms in behaviour (Harrison, Steven, et al., 2023), and some studies report sex effects on solving ability (Hopper et al., 2014). Future research may wish to pursue this avenue.

Overall, our findings show that some native species, the woylie, koomal and chuditch, were capable of solving food-baited puzzles. We also found that species that interacted with puzzles more frequently were more likely to solve them, possibly due to differences in neophobia, motivation or cognitive ability, but this remains to be tested in these species. These results contribute to an increasing body of literature that describes problem-solving in native Australian species (Isden et al., 2013; Manrod et al., 2008; Rowell & Rymer, 2023; Wat et al., 2020), ultimately working toward a mechanistic understanding of how wildlife may respond to environmental change. As such, we recommend future studies should consider the relationship between inter-individual variation in problem-solving ability and reintroduction success.

Ethical note

This research was conducted in accordance with the University of Western Australia Animal Ethics Screening (2021_ET000428) and the Department of Biodiversity, Conservation, and Attractions Licence to Disturb Threatened Species (TFA 2021-0132). Research methodologies 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).

AUTHOR CONTRIBUTIONS

Misha K. Rowell: Conceptualization (equal); formal analysis (lead); investigation (equal); methodology (lead); resources (equal); software (equal); writing – original draft (lead); writing – review and editing (equal). **Natasha Harrison:** Conceptualization (equal); data curation (lead); investigation (equal); methodology (equal); resources (equal); software (equal); visualization (lead); writing – original draft (supporting); writing – review and editing (equal).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data used in this manuscript is attached as Appendix S1.

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REFERENCES

Aplin, L.M., Sheldon, B.C. & Morand-Ferron, J. (2013) Milk bottles revisited: social learning and individual variation in the blue tit, *Cyanistes caeruleus*. *Animal Behaviour*, 85(6), 1225–1232. Available from: https://doi.org/10.1016/j.anbehav.2013.03.009

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., Thornton, A. & Ridley, A.R. (2019) Larger group sizes facilitate the emergence and spread of innovations in a group-living bird. *Animal Behaviour*, 158, 1–7.

Bell, A.M. (2007) Animal personalities. *Nature*, 447(7144), 539–540. Available from: https://doi.org/10.1038/447539a

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(2), 349–356. Available from: https://doi.org/10.1016/j.anbehav.2012.11.003

Berger-Tal, O., Blumstein, D.T., Carroll, S., Fisher, R.N., Mesnick, S.L., Owen, M.A. et al. (2016) A systematic survey of the integration of animal behavior into conservation. *Conservation Biology*, 30(4), 744–753. Available from: https://doi.org/10.1111/cobi.12654

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(5), 701–710. Available from: https://doi.org/10.1007/s10071-010-0319-8

Blackburn, G., Broom, E., Ashton, B.J., Thornton, A. & Ridley, A.R. (2022) Heat stress inhibits cognitive performance in wild Western Australian magpies, *Cracticus tibicen dorsalis*. *Animal Behaviour*, 188, 1–11. Available from: https://doi.org/10.1016/j.anbehav.2022.03.016

Blumstein, D.T. & Fernández-Juricic, E. (2004) The emergence of conservation behavior. *Conservation Biology*, 18(5), 1175–1177. Available from: https://doi.org/10.1111/j.1523-1739.2004.00587.x

Bouchard, J., Goodyer, W. & Lefebvre, L. (2007) Social learning and innovation are positively correlated in pigeons (*Columba livia*). *Animal Cognition*, 10(2), 259–266.

Broughton, S.K. & Dickman, C.R. (1991) The effect of supplementary food on home range of the southern brown bandicoot, *Isoodon obesulus* (Marsupialia: Peramelidae). *Australian Journal of Ecology*, 16(1), 71–78. Available from: https://doi.org/10.1111/j.1442-9993.1991.tb01482.x

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(5), 941–952. Available from: https://doi.org/10.1007/s10071-017-1113-7

Cook, M.O., Weaver, M.J., Hutton, P. & McGraw, K.J. (2017) The effects of urbanization and human disturbance on problem solving in juvenile house finches (*Haemorhous mexicanus*). *Behavioral Ecology and Sociobiology*, 71(85). Available from: https://doi.org/10.1007/s00265-017-2304-6

Dean, L.G., Hoppitt, W., Laland, K.N. & Kendal, R.L. (2011) Sex ratio affects sex-specific innovation and learning in captive ruffed lemurs (*Varecia variegata* and *Varecia rubra*). *American Journal of Primatology*, 73(12), 1210–1221.

Drea, C.M. & Carter, A.N. (2009) Cooperative problem solving in a social carnivore. *Animal Behaviour*, 78(4), 967–977. Available from: https://doi.org/10.1016/j.anbehav.2009.06.030

Ellen, P., Soteres, B.J. & Wages, C. (1984) Problem solving in the rat: piecemeal acquisition of cognitive maps. *Animal Learning & Behavior*, 12(2), 232–237. Available from: https://doi.org/10.3758/BF03213147

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., Netto, K. & Peneaux, C. (2017) Neophilia, innovation and learning in an urbanized world: a critical evaluation of mixed findings. *Current Opinion in Behavioral Sciences*, 16, 15–22. Available from: https://doi.org/10.1016/j.cobeha.2017.01.004

Guenther, A. & Brust, V. (2017) Individual consistency in multiple cognitive performance: behavioural versus cognitive syndromes. *Animal Behaviour*, 130, 119–131. Available from: https://doi.org/10.1016/j.anbehav.2017.06.011

Hall, L. & Parish, S. (2016) *Field guide to Australian mammals*. Brisbane: Steve Parish Publishing.

Harrison, N.D., Frick, C.H., Wayne, A.F., Harrison, N.D., Frick, C.H. & Wayne, A.F. (2022) Repeatable measure of cage trap behaviour to quantify boldness and agitation in a macropod. *Australian Mammalogy*, 45, 237–240. Available from: https://doi.org/10.1071/AM22007

Harrison, N.D., Phillips, B.L., Mitchell, N.J., Wayne, J.C., Maxwell, M.A., Ward, C.G. et al. (2023) Perverse outcomes from fencing fauna: loss of antipredator traits in a havened mammal population. *Biological Conservation*, 281, 110000. Available from: https://doi.org/10.1016/j.biocon.2023.110000

Harrison, N.D., Steven, R., Phillips, B.L., Hemmi, J.M., Wayne, A.F. & Mitchell, N.J. (2023) Identifying the most effective behavioural assays and predator cues for quantifying antipredator responses in mammals: a systematic review. *Environmental Evidence*, 12(1), 5. Available from: https://doi.org/10.1186/s13750-023-00299-x

Hopper, L.M., Price, S.A., Freeman, H.D., Lambeth, S.P., Schapiro, S.J. & Kendal, R.L. (2014) Influence of personality, age, sex, and estrous state on chimpanzee problem-solving success. *Animal Cognition*, 17(4), 835–847. Available from: https://doi.org/10.1007/s10071-013-0715-y

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(4), 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(4), 635–643. Available from: https://doi.org/10.1007/s00265-015-1874-4

Leal, M. & Powell, B.J. (2012) Behavioural flexibility and problem-solving in a tropical lizard. *Biology Letters*, 8(1), 28–30.

Lermite, F., Peneaux, C. & Griffin, A.S. (2017) Personality and problem-solving in common mynas (*Acridotheres tristis*). *Behavioural Processes*, 134, 87–94. Available from: https://doi.org/10.1016/j.beproc.2016.09.013

Magnusson, A., Skaug, H., Nielsen, A., Berg, C., Kristensen, K., Maechler, M. et al. (2017) *Package 'glmmTMB'*. R Package Version 0.2. 0.

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(2), 267–273. Available from: https://doi.org/10.1007/s10071-007-0109-0

National Health and Medical Research Council (NHMRC), Nh. (2013) *Australian code for the care and use of animals for scientific purposes*. Canberra, ACT: National Health and Medical Research Council.

Pizzey, G. & Knight, F. (2012) *The field guide to the birds of Australia (ninth)*. New York: HarperCollins Publishers.

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

Reader, S.M. & Laland, K.N. (Eds.). (2003) *Animal Innovation*, Vol. 10. Oxfordshire: Oxford University Press.

Rowell, M.K., Pillay, N. & Rymer, T.L. (2021) Problem solving in animals: proposal for an ontogenetic perspective. *Animals*, 11(3), 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(2), 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(7), 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. (2023) Problem solving of wild animals in the wet tropics of Queensland, Australia. *Austral Ecology*, 48(2), 313–322. Available from: https://doi.org/10.1111/aec.13270

Schneider, S., Taylor, G.W., Linquist, S. & Kremer, S.C. (2019) Past, present and future approaches using computer vision for animal re-identification from camera trap data. *Methods in Ecology and Evolution*, 10(4), 461–470. Available from: https://doi.org/10.1111/2041-210X.13133

Soderquist, T.R. & Serena, M. (1994) Dietary niche of the western quoll, *Dasyurus geoffroii*, in the jarrah forest of Western Australia. *Australian Mammalogy*, 17(1), 133–136. Available from: https://doi.org/10.1071/am94019

Sol, D. & Lefebvre, L. (2000) Behavioural flexibility predicts invasion success in birds introduced to New Zealand. *Oikos*, 90(3), 599–605.

Sol, D., Timmermans, S. & Lefebvre, L. (2002) Behavioural flexibility and invasion success in birds. *Animal Behaviour*, 63(3), 495–502. Available from: https://doi.org/10.1006/anbe.2001.1953

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

Thornton, A. & Samson, J. (2012) Innovative problem solving in wild meerkats. *Animal Behaviour*, 83(6), 1459–1468. Available from: https://doi.org/10.1016/j.anbehav.2012.03.018

Torchiano, M. (2020) *effsize: efficient effect size computation*. R package version 0.8.1. Available from: https://doi.org/10.5281/zenodo.1480624; https://CRAN.R-project.org/package=effsize [Accessed 9th March 2021].

van Horik, J.O. & Madden, J.R. (2016) A problem with problem solving: motivational traits, but not cognition, predict success on novel operant foraging tasks. *Animal Behaviour*, 114, 189–198. Available from: https://doi.org/10.1016/j.anbehav.2016.02.006

Wat, K.K., Banks, P.B. & McArthur, C. (2020) Linking animal personality to problem-solving performance in urban common brushtail possums. *Animal Behaviour*, 162, 35–45.

Webster, S.J. & Lefebvre, L. (2001) Problem solving and neophobia in a columbiform–passeriform assemblage in Barbados. *Animal Behaviour*, 62(1), 23–32. Available from: https://doi.org/10.1006/anbe.2000.1725

West, R.S., Blumstein, D.T., Letnic, M. & Moseby, K.E. (2019) Searching for an effective pre-release screening tool for translocations: can trap temperament predict behaviour and survival in the wild? *Biodiversity and Conservation*, 28(1), 229–243. Available from: https://doi.org/10.1007/s10531-018-1649-0

Wilson, B.A., Evans, M.J., Gordon, I.J., Banks, S.C., Batson, W.G., Wimpenny, C. et al. (2022) Personality and plasticity predict postrelease performance in a reintroduced mesopredator. *Animal Behaviour*, 187, 177–189. Available from: https://doi.org/10.1016/j.anbehav.2022.02.019

Yeatman, G.J. & Wayne, A.F. (2015) Seasonal home range and habitat use of a critically endangered marsupial (*Bettongia penicillata ogilbyi*) inside and outside a predator-proof sanctuary. *Australian Mammalogy*, 37(2), 157. Available from: https://doi.org/10.1071/AM14022

SUPPORTING INFORMATION

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

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