

Short title: Foraging enrichment and cockatoo behavior

**Foraging enrichment alleviates oral
repetitive behaviors in captive red-tailed
black cockatoos (*Calyptorhynchus banksii*)**

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22 Abstract

23 The relationship between inadequate foraging opportunities and the expression of oral repetitive
24 behaviors has been well documented in many production animal species. However, this relationship has
25 been less-well examined in zoo-housed animals, particularly avian species. The expression of oral
26 repetitive behavior may embody a frustrated foraging response, and may therefore be alleviated with
27 the provision of foraging enrichment. In this study we examined the effect of different foraging-based
28 enrichment items on a group of captive red-tailed black cockatoos who were previously observed
29 performing oral repetitive behavior. A group of six cockatoos were presented with five foraging
30 enrichment conditions (no enrichment (control), sliced cucumber, fresh grass, baffle cages and millet
31 discs). Baseline activity budgets were established over a 10-day pre-intervention period and
32 interventions were then presented systematically over a 25-day experimental period. This study
33 demonstrated that the provision of foraging interventions effectively increased the median percentage
34 of time spent foraging compared to control conditions (range 5.0 – 31.7 % across interventions vs 5.0
35 % for control), with two of the interventions; grass and millet discs, significantly decreasing the
36 expression of oral repetitive behaviors (control = 16.6 vs 8.3 % for both grass and millet discs) . Finally,
37 a rapid-scoring method utilized by zookeepers during the study proved to be a useful proxy for the
38 amount of time the cockatoos spent interacting with the foraging interventions and overall time spent
39 foraging.

40 Key words

41 Environmental enrichment, Oral repetitive behavior, Stereotypic behavior, Captive environment, Parrot

42

43 Introduction

44 Zoos are increasingly playing an important role in wildlife conservation; through education,
45 interactive experiences, and captive breeding programs (Tribe, 2003; Webber et al., 2016). However,
46 the nature of the captive environment means that some of the survival strategies employed by animals

47 in the wild, such as foraging for food, can be constrained by captive conditions; often requiring less
48 time and energy expenditure to fulfil. As a result, the maintenance of species-typical behavioral profiles
49 and the provision of naturalistic foraging opportunities is a key challenge faced by zoos today.

50 Stereotypies (or other abnormal repetitive behaviours) are defined as repetitive, invariant behaviors
51 with no apparent goal in the context in which they are being performed (Dantzer, 1991; Garner, 2008;
52 Mason, 1993), and are not known to occur in the wild (Mason et al., 2008). This contrasts with the
53 complex, variable and diverse characteristics of adaptive, functional behavior (Lewis et al., 2006). The
54 development of stereotypies has been correlated with a restricted capacity to fulfil a specific behavioral
55 need (Appleby & Lawrence, 1987; Mason & Rushen, 2008). In many animal species, inadequate
56 foraging opportunities and the subsequent inability to carry out naturalistic foraging behaviors results
57 in the expression of abnormal oral behaviors. For example, licking of non-food objects in giraffe may
58 be significantly reduced by increasing the complexity of foraging devices to facilitate tongue
59 manipulation (Fernandez et al., 2008). In avian species, feather damaging behavior (e.g. feather picking
60 or chewing) is a detrimental form of abnormal repetitive behavior, whereby self-harm is inflicted by
61 excessive and dysfunctional preening behavior (for a review, see van Zeeland et al., 2009). Feather
62 damaging behavior can be alleviated however, as has been shown in the Crimson-bellied conure, where
63 excessive feather picking decreased as a result of the provision of natural and edible materials such as
64 fruit baskets and willow branches (van Hoek & King, 1997). Similarly, in Amazon parrots, feather
65 picking was significantly reduced with the provision of foraging-based enrichment (for example, fruit
66 cages), which was preferred over other non-foraging physical enrichments (for example, plastic toys)
67 (Meehan et al., 2003). These studies therefore not only suggest that abnormal oral behaviors may be
68 consequential to inadequate foraging opportunities, but that the provision of effective foraging
69 interventions can alleviate these behaviors.

70 Positive effects associated with providing foraging enrichment in zoos have been shown to improve
71 the welfare of captive avian species (Field & Thomas, 2000; Meehan & Mench, 2006), with many
72 studies further investigating their contribution towards reduced abnormal behavior (e.g. Amazon

73 parrots, Meehan et al., 2004; Grey parrots, Lumeij & Hommers, 2008; Budgerigars, Polverino et al.,
74 2015). Specifically, foraging enrichment aims to encourage behaviors involved in food acquisition (i.e.
75 hunting and scavenging) and consumption. However, compared to primates and carnivores, little is
76 known about what constitutes an effective foraging enrichment strategy in captive avian species, in
77 particular, there is little useful empirical data for cockatoo species (King, 1993; and for a recent review,
78 see Rodríguez-López, 2016). Furthermore, most studies investigating the efficacy of foraging
79 enrichment on captive avian species are performed on individually housed subjects (Meehan et al.,
80 2003; van Zeeland et al., 2013; Rozeck et al., 2010) or pairs (van Hoek & King, 1997). One study on
81 the effect of foraging enrichment on a group of captive macaws observed marked behavioral changes
82 (Reimer et al., 2016), but not in relation to improving foraging times or mediating abnormal behaviors.
83 Thus, the efficacy of foraging enrichment strategies for group-housed birds in zoos requires further
84 scrutiny.

85 Group-housing is a common occurrence in zoos. Birds that are trained to fly in free-flight bird shows
86 for educational and entertainment purposes are often housed in simple aviary environments and are
87 maintained on a restricted diet. These birds are therefore especially dependent on the provision of
88 environmental enrichment to facilitate the expression of normal behaviors in the absence of a
89 naturalistic environment, which might otherwise provide opportunities to forage and contribute to
90 wild-type activity budgets (Fàbregas et al., 2012). Moreover, enrichment can help to provide mental
91 stimulation for species with complex cognitive abilities such as Parrots (Emery & Clayton, 2004;
92 Emery, 2006), which have the ability to seek out stimulating activities to fulfil their own enjoyment
93 (Emery & Clayton, 2015). As such, the provision of a varied and complex foraging enrichment plan
94 will contribute to an improved welfare state of group-housed gregarious species such as psittacines.

95

96 At Taronga Zoo, captive red-tailed black cockatoos (*Calyptorhynchus banksii*; hereafter RTBC)
97 trained to fly in the daily free flight bird shows are maintained on a restricted diet. The ease at which
98 their food is accessed and consumed means that the RTBC spend little time searching, extracting and
99 processing their feed; activities which significantly contribute to overall foraging duration (van

100 Zeeland et al., 2013). As a result, they can spend as little as twenty minutes per day consuming their
101 allocated diet. This is in contrast to wild cockatoos that typically forage in the early morning and late
102 afternoon, spending anywhere from 13-44 % of the day finding and processing food (Chapman &
103 Paton, 2005; Stock et al., 2013; Styche, 2000). The lack of foraging opportunities may have
104 contributed to the development of oral stereotypies in this species (M. Fangmeier pers. obs.), therefore
105 given their natural food sources (seeds, nuts, fruits and berries from native trees; Mulawka, 2014) and
106 foraging patterns, we hypothesized that by providing more naturalistic foraging-based enrichment to
107 increase the amount of time birds spent extracting and processing food, we would see a decrease in
108 oral stereotypic behavior. We therefore aimed to, (1) identify the daily activity budget for a group of
109 captive RTBC trained to fly in a free-flight bird show to determine time spent performing foraging
110 and oral repetitive behavior under normal (baseline) conditions; (2) determine the effect of providing
111 a range of foraging interventions on the determined activity budget; and (3) to develop a rapid-
112 scoring method to assess the efficacy of the foraging interventions.

113 **Methods**

114 *Subjects, housing and husbandry*

115 Subjects were male (n = 3) and female (n = 3) RTBC aged 4 to 9 years. All subjects were housed at
116 Taronga Zoo, Sydney, Australia, in an off-exhibit area behind a free-flight bird show arena. The
117 youngest, a female, had an unknown rearing history as she was acquired through the Taronga Zoo
118 Wildlife Hospital as a juvenile. The remaining five RTBC were hand reared and acquired through a
119 local breeder. Housing consisted of two more or less identical covered aviaries (5 x 2 x 3m, depth x
120 length x height) side by side, with two small openings allowing free movement between them. The
121 walls and ceilings of the aviaries were constructed from stainless-steel mesh, with concrete flooring and
122 a tin roof covering a third of the enclosure. Branches were provided for perching and chewing. Various
123 types of fresh browse (Eucalyptus, Banksia, Casuarina and Callistemon depending on availability) were
124 attached to the aviary walls, and were replaced every Friday afternoon at 16:00. Aviaries were situated

125 along a single corridor in close proximity to other parrot species flown in the free-flight bird show. The
126 RTBC had visual access to adjacent aviaries and the corridor.

127 When weather conditions permitted, five of the six RTBC flew in the free-flight bird show twice
128 daily at 12:00 and 15:00, while the youngest remained in the aviary to feed. The RTBC were loaded
129 into individual mobile cages at approximately 11:30 and 14:30, and returned to their aviaries at 12:30
130 and 15:30 respectively following the free-flight bird show. During the shows, the RTBC were flown
131 briefly (<1 minute), and then returned to the off-exhibit area to be fed their daily feed rations in the
132 same individual mobile cages to monitor individual food intake (for husbandry purposes). If the bird
133 show was cancelled due to poor weather, such as heavy rain or strong winds, all six RTBC were instead
134 loaded into the individual cages to be fed at 11:30 and 14:30. Their feed consisted of equal portions of
135 multi-vitamin pellets and a soaked seed mixture, with an additional single fruit or vegetable item (apple,
136 paw-paw, corn, grapes, pear, peas or sweet potato rotated throughout the week). They received 50 % of
137 their daily feed intake after the first show, and the remaining 50 % after the second show.

138 Prior to this study, all birds trained to fly in the free-flight bird show, including the RTBC, were
139 given low calorie forage (sliced cucumber, kale or cauliflower) following feeding. At least once weekly,
140 this low-calorie forage was substituted with a random foraging intervention (including but not limited
141 to grass, millet discs, vegetable skewers, vegetables in cardboard tubes, shredded paper and leaf litter).
142 So as to facilitate the current study, this forage was not provided during the study period (including
143 baseline conditions).

144 The keepers interacted with the RTBC a minimum of six times a day during general husbandry
145 activities, with keeper interaction per bird lasting 1-5 minutes. Aviaries were cleaned daily between
146 8:00 and 10:00.

147 *Behavioral observations and foraging interventions*

148 Data was collected during November and December 2015 over 35 days, with observations occurring
149 Monday-Friday. Observations consisted of two weeks collecting baseline data (10 days), where the

150 RTBC did not receive any additional foraging intervention, followed by five weeks of data collection
151 where foraging interventions were introduced. The days that each foraging condition was presented
152 were randomized such that they were only presented once per week, and were presented on a different
153 day each week.

154 The birds were presented with five foraging conditions Foraging conditions included; (1) no
155 enrichment (control), (2) cucumber slices; twelve slices of cucumber (~1.5 cm width) spread on the
156 floor of the aviaries (six slices per aviary), (3) grass; four large clumps of long grass (grown in pots)
157 with the soil and roots spread on the floor of the aviaries (one pot divided into two clumps per aviary),
158 (4) baffle cages; four stainless steel baffle cages containing two whole kale leaves and one Banksia cone
159 hung on the walls of the aviaries (two baffle cages per aviary), and (5) millet discs; six small pancakes
160 (~6 cm diameter) made up of a mixture of flour, water and millet seed hung on the walls of the aviaries
161 near branches using twine (three discs per aviary) (Figure 1). All interventions were spread evenly over
162 the provided area and the position of the foraging interventions varied between provisions. On days
163 where data was not collected, the RTBC did not receive any additional foraging intervention.

164 Instantaneous scan sampling (Martin & Bateson, 2007) at 10-minute intervals from 8:10 to 11:30,
165 12:30 to 14:30, and 15:30 to 15:50 was used to record broad state behaviors for each individual. One-
166 zero time sampling (Martin & Bateson, 2007) at 1-minute intervals was used to record individual
167 interactions with foraging interventions, and summed as a proxy for duration of interaction.
168 Descriptions of recorded behaviors are listed in the ethogram (Table 1). Foraging interventions were
169 presented twice a day at 10:00 and 13:00 for 90-minutes. All data were collected by one researcher (M.
170 Fangmeier) who sat opposite the RTBC aviaries in a narrow corridor approximately 2m in width.

171 *Rapid assessment method*

172 At 11:30 and 14:30, once the RTBC had been removed from their aviaries, the keepers were asked
173 to visually assess the overall use of the foraging interventions, scoring the intervention usage (grass) or
174 consumption (millet discs, cucumber and baffle cages) on a scale of 1-5 (Table 2). For consistency, the
175 same two keepers were involved in this assessment. Where both keepers were present, they would give

176 one score collaboratively. This ensured that, where one keeper was absent, the score that was given in
177 the absence of that keeper was an accurate representation of previous observations. Scores were given
178 in the absence of, and without prior discussion with, the observer. These scores were collected by the
179 observer once all other data had been collected for the study.

180 *Statistical analysis*

181 To investigate whether foraging condition significantly affected either the time spent foraging or the
182 time spent performing oral repetitive behaviors, as a proportion of the total observation period, binomial
183 mixed effects models were constructed; with the proportion of time spent performing the behavior as
184 the dependent variable, forage condition as the independent variable, and individual identity as a
185 random factor. These models were compared to the null model for both behaviors. Some observation
186 times were under-represented in this sample due to the birds being removed from their aviaries for the
187 show early, or returned late. The data was therefore subsetted such that times when more than four
188 observations (across all birds, across the 20-day experimental period) were missing were excluded from
189 the dataset. This resulted in 30 observations per day, including a minimum of 5 birds per observation
190 period.

191 To test whether the keeper usage scores (KS) in the rapid-scoring method were related to the
192 proportion of time that the RTBC had spent interacting with the intervention, the overall time spent
193 foraging, or the overall time spent performing oral repetitive behaviors, Poisson generalized linear
194 models were constructed; with the KS as the response variable, and proportion of time spent performing
195 the behavior and enrichment type as explanatory variables. As KS was necessarily a single value for
196 each provision of enrichment, the RTBC behavior was also pooled for the period that the enrichment
197 was provisioned, i.e. the mean proportion of the 90-minute period spent performing a behavior was
198 calculated, across all birds.

199 All analyses were performed in the R environment for statistical computing (R core team, 2015).

200

201 **Results**202 *Baseline activity*

203 Baseline activity budgets revealed that the RTBC spent most of their morning (8:10-11:30) resting
204 or performing maintenance behaviors. Resting behaviors were highest in the early mornings, declining
205 towards 12:00, while maintenance behaviors increased across the morning proportionate to the decline
206 in time spent resting (Figure 2a). After the 12:00 bird show/feed, the RTBC would consistently perform
207 high levels of oral repetitive behaviors (median across birds of 35.0 % - 62.5 %; Figure 2b); including
208 both self-directed and metal-directed behaviors. In some individuals, this behavior would continue until
209 they were removed from their aviaries at 14:30, and would often continue following the 15:00 bird
210 show/feed. Foraging activity remained consistently low (median across birds of 0 – 21 % of the
211 observation period) throughout the day (Figure 2b).

212 When these behaviors were examined during the control phase of the experimental period, we found
213 that foraging behavior was similarly low (5.0 %, Q25 = 0.0 %, Q75 = 6.7 %), with no significant
214 difference compared to the baseline period (estimate = 0.10, $z = 0.452$, $p = 0.652$). Whereas, though
215 oral repetitive behavior remained relatively high (16.6 %, Q25 = 6.7 %, Q75 = 25.8 %), it was
216 significantly lower than during the baseline period (estimate = -0.65, $z = -6.18$, $p < 0.001$).

217 *Foraging interventions and their effect on behavior*

218 Models containing forage condition as an explanatory variable explained the data significantly better
219 ($\Delta AICc > 2$) than the null model for both foraging and repetitive behavior (Table S1). All four foraging
220 interventions significantly increased the percentage of time spent foraging when compared to the
221 control condition (Control: median = 5.0 %, Q25 = 0.0 %, Q75 = 6.7 %; Grass: median = 28.3 % Q25
222 = 20.8 %, Q75 = 36.6 %, estimate = 2.37, $z = 12.47$, $p < 0.001$; Millet discs: median = 31.6 %, Q25 =
223 10.0 %, Q75 = 39.2, estimate = 2.18, $z = 11.38$, $p < 0.001$; Baffle cages: median = 5.0 %, Q25 = 3.3 %,
224 Q75 = 13.3 %, estimate = 1.06, $z = 5.10$, $p < 0.001$; Cucumber: median = 5.0 %, Q25 = 3.3 %, Q75 =
225 10.0 %, estimate = 0.60, $z = 2.73$, $p = 0.006$). The provision of grass and millet discs significantly

226 decreased the expression of oral repetitive behavior compared to the control condition (Control: median
227 = 16.7 %, Q25 = 6.7 %, Q75 = 25.8 %; Grass: median = 8.3 %, Q25 = 4.2 %, Q75 = 15.8 %, estimate =
228 -0.63, $z = -4.318$, $p < 0.001$; Millet discs: median = 8.3 %, Q25 = 4.2%, Q75 = 16.7 %, estimate = -
229 0.38, $z = -2.775$, $p < 0.001$). The provision of baffle cages and cucumber had no effect on oral repetitive
230 behavior (Baffle cages: median = 15.0 %, Q25 = 6.7 %, Q75 = 19.2 %, estimate = -0.11, $z = -0.85$, $p =$
231 0.397; Cucumber: 13.3 %, Q25 = 10.0 %, Q75 = 29.2 %, estimate = 0.16, $z = 1.31$, $p = 0.191$) (Figure
232 3).

233 On the first day the duration of interaction with grass was a median of 19.5 minutes, this increased
234 to a median of more than 50 minutes for the next two days, before falling to a median of 32.5 minutes
235 on day 5. The duration of interaction with millet discs was also highest on days three and four (day 3
236 median = 63 minutes; day 4 median = 64 minutes).

237 *Relationship between keeper usage score and behavior*

238 Figure 5 shows the relationship between KS and the proportion of time spent performing behaviors
239 across all of the RTBC. There was a significant positive relationship between KS and both the
240 proportion of time spent interacting with the foraging item (Figure 5a, Table S2, estimate = 1.30, z value
241 = 3.601, $P < 0.001$), and the proportion of time spent foraging (Figure 5b, Table S2, estimate = 1.42, z
242 value = 3.55, $P < 0.001$). There was no significant relationship between KS and the proportion of time
243 spent performing repetitive behavior (Figure 5c, Table S2, estimate = -0.92, z value = -1.23, $P = 0.194$).
244 The KS for interaction with grass, baffle cages and cucumber discs corresponded with the duration of
245 interaction (see above), but the KS for millet discs remained high despite the duration of interaction
246 (see above) decreasing (Figure 4, Table S3).

247 **Discussion:**

248 This study demonstrates that providing foraging interventions can effectively decrease the amount
249 of time spent performing oral repetitive behavior in a captive group of RTBC, corresponding with an
250 increase in time spent foraging. During baseline and control conditions, the RTBC spent a median of

251 less than 5 % of their day engaging in foraging activity (range: 0.0 – 6.7 %). Our two most successful
252 interventions, grass and millet discs, significantly increased foraging during the observation period
253 (08:30 - 15:50) to a median of 28.3 and 31.7 % respectively. This increase in foraging was consistent
254 across birds (grass: range 16 – 46 %; millet discs: 23.3 – 46.6 %).

255 Oral repetitive behavior was significantly higher during baseline conditions than during control
256 conditions (Figure 3). Stereotypic behavior as a consequence of feeding anticipation has been reported
257 in many species (Robert et al., 2002; Swaisgood et al., 2001; Waitt & Buchanan-Smith, 2001). This
258 may be likely in this case as prior to the study the RTBC were routinely given a low-calorie forage or
259 other environmental enrichment when they were returned to the aviary following feeding. When this
260 husbandry practice was ceased, the RTBC likely resorted to performing oral repetitive behaviors in
261 anticipation of these food items. This may have also been exacerbated by the keepers providing birds
262 in adjacent aviaries with these enrichment items. Behaviors such as beak grinding, tongue rolling or
263 foot licking stimulate highly sensitive encapsulated nerve endings in the beak and tongue and, in tactile
264 feeders such as parrots (Schneider et al., 2016), may serve as a self-soothing or ‘coping’ mechanism.
265 This may be reflective of stress caused by a sudden change in husbandry during the initial baseline
266 period.

267 During baseline conditions oral repetitive behavior peaked following the 12:00 and 15:00 free-flight
268 bird shows and feeding (Figure 2). However, differences in foraging and oral repetitive behavior across
269 time of day were noted between individuals (Figure S1). Most notably, the youngest female (Iranda,
270 who was not flown in the free-flight bird show and who was acquired through the Taronga Wildlife
271 Hospital) did not exhibit this pattern in behavior. This may suggest that the observed peak in oral
272 repetitive behavior in the other RTBC may be an extended excitatory response following the free-flight
273 bird show. However, this pattern in behavior was also observed on days that the bird show was
274 cancelled. Thus, it is still likely that this behavior is due to the need to engage in extended foraging well
275 beyond the capacity of the restricted diet. During the experimental period, individuals responded
276 differently to each of the foraging interventions. While all subjects responded positively to grass and

277 millet discs, only Iranda and Noko (a male) performed extended foraging behavior when baffle cages
278 were presented. When grass was presented, Diyara (a female) completely ceased performing oral
279 repetitive behavior where she would have ordinarily spent 40-100% of her time doing so. Thus, all
280 individuals must be considered when designing an effective foraging enrichment strategy.

281 The success of grass and millet discs in this study may be attributed to an increase in time spent
282 extracting and processing feed; in line with previous findings (Rozek et al., 2010; van Zeeland et al.,
283 2013). When grass was presented, the RTBC would spend their time digging through the soil and
284 extracting individual blades of grass, manipulating each blade with their feet and tongue. Similarly, the
285 RTBC were required to grasp and manipulate the millet discs with their feet, and would spend time
286 extracting the millet seeds from the flour mixture. Additionally, the thick consistency of the mixture
287 contributed to an increased processing time, achieving a similar effect to increased pellet size (Rozek
288 et al., 2010; van Zeeland et al., 2013). As a result, some individuals spent over an hour of each provision
289 period interacting with these foraging interventions. In the wild, other cockatoo species spend 13 - 44
290 % of their day foraging (Sulphur crested cockatoos, Styche, 2000; glossy black cockatoos, Chapman &
291 Paton, 2005; Carnaby's black cockatoos, Stock et al., 2013). Previous work by Zeeland et al. (2013)
292 investigated the efficacy of eleven foraging interventions for captive Grey parrots (*Psittacus erithacus*
293 *erithacus*), and found that interventions designed to increase extraction time (such as offering pellets in
294 complex food reward devices) and food processing time (such as providing larger sized pellets) were
295 the most effective strategies. Similarly; Rozek et al. (2010) demonstrated that Amazon parrots
296 (*Amazona amazonica*) fed regular sized pellets spent 5.9 % of their daytime hours foraging, whereas
297 parrots fed over-sized pellets spent 25.7 % of their day foraging, a figure that more closely resembled
298 the activity budget of wild parrots.

299 An intervention is only successful if the animal is motivated to use it (Meehan & Mench, 2002;
300 Rozek & Millam, 2011). For instance, Meehan and Mench (2002) demonstrated that providing
301 continuous environmental enrichment may result in a decrease in the state of motivation for exploration.
302 This corresponds with observations made in the present study where the duration of interaction for grass

303 began to decline after the third week of provision (Figure 4). This suggests that certain interventions
304 may require longer intervals between provisions to maintain motivation in the long term. This will
305 require further exploration

306 Usage score assigned by keepers after the intervention had been removed from the enclosures
307 was a useful proxy for the amount of time the RTBC, as a group, spent foraging during the provision
308 period. However, the usage score was not significantly related to the proportion of time that the RTBC
309 spent performing oral stereotypies, though the trend was in the predicted negative direction. The results
310 suggest that this rapid assessment (keeper score) method is a reliable indicator of whether interventions
311 are successful based on their ability to promote a specific behavior, in this case foraging. However,
312 restrictions may apply in group-housing situations, where one or more individuals may ‘guard’ or
313 otherwise prevent access to the foraging resources. In the present study, one individual (the youngest
314 female) was observed antagonizing the other RTBC for their cucumber slices. Another male was
315 observed biting and chasing other RTBC when utilizing the grass intervention. Despite this, we suggest
316 that this method can be integrated into future management practices where similar interventions are
317 provided; such that they can be ‘used up’ or would bear some other indication of the amount of time
318 the RTBC spent interacting with the object. It is important to note however, that this method would
319 only be effective for interventions that take a significant amount of time to be used up. For example, an
320 intervention that could be consumed quickly would result in a high keeper score, but would not equate
321 to a high duration of interaction. This method may only also be effective to a maximum group size
322 where individual variability (i.e. individual preferences and use of different interventions) may be
323 increased, and this would need to be investigated further.

324 It is important to determine whether there are daily patterns in behavior, particularly in the exhibition
325 of ‘abnormal behaviors’, to develop an effective enrichment schedule that targets those problem
326 periods. While observation times in this study were constrained by husbandry practices, it was clear
327 that the RTBC would have benefited from foraging interventions after 16:00 when observations ended.
328 Since the conclusion of this study, foraging interventions are now presented to the RTBC following
329 their allocated feeding times, as this study indicated that the times following 13:00 and 15:30 were the

330 greatest problem periods for the expression of oral repetitive behavior. Cucumber, baffle cages, grass
331 and a modified millet disc (millet and gelatin disc) are still utilized, among a larger variety of enrichment
332 items designed to encourage physical and oral manipulation, cognitive stimulation, sensory stimulation,
333 and extended food extraction. A modified keeper scoring system has been successfully integrated,
334 which allows keepers to record enrichment item usage and duration of interaction. Further studies which
335 aim to determine the optimal intervals between repeated enrichment presentation (for example, weekly,
336 fortnightly or other) should be performed to maintain maximal motivation for the RTBC to interact with
337 each of the foraging interventions in the long term.

338 **Conclusion**

339 Overall, this study demonstrated that providing foraging interventions can effectively decrease the
340 amount of time spent performing oral repetitive behavior in a captive population of RTBC,
341 corresponding with an increase in overall time spent foraging. Here, two foraging interventions, grass
342 and millet discs, were successful in both promoting foraging behavior and reducing oral repetitive
343 behavior when compared to control conditions. Moreover, usage scores assigned by keepers effectively
344 predicted the duration of interaction and time spent foraging when the interventions were present.

345

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354 **References**

- 355 Appleby, M. C., & Lawrence, A. B. (1987). Food restriction as a cause of stereotypic behavior in
356 tethered gilts. *Animal Science*, 45(1), 103-110.
- 357 Chapman, T. F., & Paton, D. C. (2005). The glossy black-cockatoo (*Calyptorhynchus lathami*
358 *halmaturinus*) spends little time and energy foraging on Kangaroo Island, South Australia. *Australian*
359 *Journal of Zoology*, 53(3), 177-183.
- 360 Claxton, A. M. (2011). The potential of the human–animal relationship as an environmental
361 enrichment for the welfare of zoo-housed animals. *Applied Animal Behaviour Science*, 133(1), 1-10.
- 362 Dantzer, R. (1991). Stress, stereotypies and welfare. *Behavioural processes*, 25(2-3), 95-102.
- 363 Emery, N. J. (2006). Cognitive ornithology: the evolution of avian intelligence. *Philosophical*
364 *Transactions of the Royal Society of London B: Biological Sciences*, 361(1465), 23-43.
- 365 Emery, N. J., & Clayton, N. S. (2004). Comparing the complex cognition of birds and primates. In
366 *Comparative vertebrate cognition* (pp. 3-55). Springer US.
- 367 Emery, N. J., & Clayton, N. S. (2015). Do birds have the capacity for fun? *Current Biology*, 25(1),
368 R16-R20.
- 369 Fàbregas, M. C., Guillén-Salazar, F., & Garcés-Narro, C. (2012). Do naturalistic enclosures
370 provide suitable environments for zoo animals? *Zoo biology*, 31(3), 362-373.
- 371 Fernandez, L. T., Bashaw, M. J., Sartor, R. L., Bouwens, N. R., & Maki, T. S. (2008). Tongue
372 twisters: feeding enrichment to reduce oral stereotypy in giraffe. *Zoo biology*, 27(3), 200-212.
- 373 Field, D. A., & Thomas, R. (2000). Environmental enrichment for psittacines at Edinburgh zoo.
374 *International Zoo Yearbook*, 37(1), 232-237.
- 375 Garner, J. P. (2008). Systems-level Insights from Clinical Psychology. *Stereotypic animal*
376 *behavior: fundamentals and applications to welfare*, 121.
- 377 Hill, S. P., & Broom, D. M. (2009). Measuring zoo animal welfare: theory and practice. *Zoo*
378 *biology*, 28(6), 531-544.
- 379 Hosey, G., Melfi, V., Pankhurst, S. (2013). *Zoo animals: behavior, management, and welfare*.
380 Oxford University Press.
- 381 Hoy, J. M., Murrat, P. J., Tribe, A. (2010). Thirty years later: enrichment practices for captive
382 mammals. *Zoo Biology*, 29, 303-316.
- 383 King, C. E. (1993). Environmental enrichment: is it for the birds? *Zoo Biology*, 12(6), 509-512.
- 384 Lewis, M. H., Presti, M. F., Lewis, J. B., & Turner, C. A. (2006). The neurobiology of stereotypy
385 I. environmental complexity. *Stereotypic animal behavior: fundamentals and applications to welfare*,
386 190-226.
- 387 Lumeij, J.T. and Hommers, C.J. (2008). Foraging ‘enrichment’ as treatment for pterotillomania.
388 *Applied Animal Behaviour Science*, 111, 85-94.
- 389 Martin, P., Bateson, P. P. G., & Bateson, P. (1993). *Measuring behavior: an introductory guide*.
390 Cambridge University Press.
- 391 Masefield, W. (1999). Forage preferences and enrichment in a group of captive Livingstone's fruit
392 bats *Pteropus livingstonii*. *Dodo*, 35, 48-56.

- 393 Mason, G., & Rushen, J. (Eds.). (2008). *Stereotypic animal behavior: fundamentals and*
394 *applications to welfare*. Cabi.
- 395 Mason, G.J. (1993). Forms of stereotypic behavior. In A.B. Lawrence, & J. Rushen (Eds.),
396 *Stereotypic animal behavior: fundamentals and applications to welfare* (pp. 8-40). Wallingford,
397 Oxon, UK: CAB International.
- 398 Meehan, C. L., & Mench, J. A. (2002). Environmental enrichment affects the fear and exploratory
399 responses to novelty of young Amazon parrots. *Applied Animal Behaviour Science*, 79(1), 75-88.
- 400 Meehan, C. L., Garner, J. P., & Mench, J. A. (2004). Environmental enrichment and development
401 of cage stereotypy in Orange-winged Amazon parrots (*Amazona amazonica*). *Developmental*
402 *Psychobiology*, 44(4), 209-218.
- 403 Meehan, C. L., Millam, J. R., & Mench, J. A. (2003). Foraging opportunity and increased physical
404 complexity both prevent and reduce psychogenic feather picking by young Amazon parrots. *Applied*
405 *Animal Behaviour Science*, 80(1), 71-85.
- 406 Meehan, C., & Mench, J. (2006). Captive parrot welfare. *Manual of parrot behavior*, 301-318.
- 407 Mellen, J., MacPhee, M. S. (2001). Philosophy of environmental enrichment: past, present, and
408 future. *Zoo Biology*, 20, 211-226.
- 409 Mulawka, E. J. (2014). *The Cockatoos: A Complete Guide to the 21 Species*. McFarland.
- 410 Polverino, G., Manciooco, A., Vitale, A., & Alleva, E. (2015). Stereotypic behaviours in
411 *Melopsittacus undulatus*: Behavioural consequences of social and spatial limitations. *Applied Animal*
412 *Behaviour Science*, 165, 143-155.
- 413 R Core Team. (2015). R: a language and environment for statistical computing. R Foundation for
414 Statistical Computing, Vienna, Austria <https://www.R-project.org/>.
- 415 Reimer, J., Maia, C. M., & Santos, E. F. (2016). Environmental Enrichments for a Group of
416 Captive Macaws: Low Interaction Does Not Mean Low Behavioral Changes. *Journal of Applied*
417 *Animal Welfare Science*, 19(4), 385-395.
- 418 Robert, S., Bergeron, R., Farmer, C., & Meunier-Salaün, M. C. (2002). Does the number of daily
419 meals affect feeding motivation and behavior of gilts fed high-fibre diets? *Applied Animal Behaviour*
420 *Science*, 76(2), 105-117.
- 421 Rodríguez-López, R. (2016). Environmental enrichment for parrot species: Are we squawking up
422 the wrong tree? *Applied Animal Behaviour Science*, 180, 1-10.
- 423 Rozek, J. C., & Millam, J. R. (2011). Preference and motivation for different diet forms and their
424 effect on motivation for a foraging enrichment in captive Orange-winged Amazon parrots (*Amazona*
425 *amazonica*). *Applied animal behavior science*, 129(2), 153-161.
- 426 Rozek, J. C., Danner, L. M., Stucky, P. A., & Millam, J. R. (2010). Over-sized pellets naturalize
427 foraging time of captive Orange-winged Amazon parrots (*Amazona amazonica*). *Applied animal*
428 *behavior science*, 125(1), 80-87.
- 429 Schneider, E. R., Gracheva, E. O., & Bagriantsev, S. N. (2016). Evolutionary specialization of
430 tactile perception in vertebrates. *Physiology*, 31(3), 193-200.
- 431 Shepherdson, D. J. (2001). *A Guide to Improving Animal Husbandry Through Environmental*
432 *Enrichment* (June 2001).

- 433 Stock, W. D., Finn, H., Parker, J., & Dods, K. (2013). Pine as fast food: foraging ecology of an
434 endangered cockatoo in a forestry landscape. *PLoS One*, 8(4), e61145.
- 435 Stoinski, T. S., Daniel, E., Maple, T. L. (2000). A preliminary study of the behavioral effects of
436 feeding enrichment on African elephants. *Zoo Biology*, 19, 485-493.
- 437 Styche, A. (2000). Distribution and behavioural ecology of the Sulphur-crested cockatoo (*Cacatua*
438 *galerita* L.) in New Zealand.
- 439 Swaisgood, R. R., White, A. M., Zhou, X., Zhang, H., Zhang, G., Wei, R., Hare, V.J., Tepper,
440 E.M., & Lindburg, D. G. (2001). A quantitative assessment of the efficacy of an environmental
441 enrichment programme for giant pandas. *Animal Behaviour*, 61(2), 447-457.
- 442 Tennessen, T. (1989). Coping with confinement—features of the environment that influence
443 animals' ability to adapt. *Applied Animal Behaviour Science*, 22(2), 139-149.
- 444 Tribe, A., & Booth, R. (2003). Assessing the role of zoos in wildlife conservation. *Human*
445 *Dimensions of Wildlife*, 8(1), 65-74.
- 446 van Hoek, C. S., & King, C. E. (1997). Causation and influence of environmental enrichment on
447 feather picking of the crimson-bellied conure (*Pyrrhura perlata perlata*). *Zoo Biology*, 16(2), 161-172.
- 448 van Zeeland, Y. R., Schoemaker, N. J., Ravesteijn, M. M., Mol, M., & Lumeij, J. T. (2013).
449 Efficacy of foraging enrichments to increase foraging time in Grey parrots (*Psittacus erithacus*
450 *erithacus*). *Applied animal behavior science*, 149(1), 87-102.
- 451 van Zeeland, Y. R., Spruit, B. M., Rodenburg, T. B., Riedstra, B., Van Hierden, Y. M., Buitenhuis,
452 B., Korte, S.M., & Lumeij, J. T. (2009). Feather damaging behavior in parrots: a review with
453 consideration of comparative aspects. *Applied Animal Behaviour Science*, 121(2), 75-95.
- 454 Waitt, C., & Buchanan-Smith, H. M. (2001). What time is feeding?: How delays and anticipation
455 of feeding schedules affect stump-tailed macaque behavior. *Applied animal behavior science*, 75(1),
456 75-85.
- 457 Webber, S., Carter, M., Smith, W., & Vetere, F. (2017). Interactive technology and human–animal
458 encounters at the zoo. *International Journal of Human-Computer Studies*, 98, 150-168.
- 459 Young, R. J. (2003). Environmental enrichment for captive animals. Oxford: Blackwell
460 Publishing.

461 **Tables**462 **Table 1:** Ethogram of recorded state behaviors

Category	Behavior	Description
<i>Resting</i>	Stationary	Sitting on a branch with the eyes open, or hanging from the enclosure walls
	Sleep	Perching with the eyes closed and the head turned back between the wings or hanging forward
	Ground	Sitting on the ground of the enclosure
<i>Foraging</i>	Environment directed foraging	Picking at edible feed on the ground, stripping bark from branches, stripping and chewing leaves and nuts from supplied browse
	Intervention directed foraging	Directly interacting with a foraging intervention, including; holding and eating cucumber slices, extracting feed from baffle cages, digging through soil and roots attached to grass, or manipulating millet pancakes and extracting millet seed
<i>Locomotion</i>	Fly/Flutter	Moving through the air or hopping between branches using wings
	Climb	Using the beak and feet to ascend or descend along branches/enclosure walls
	Walk	Moving along the ground or across perches using feet
<i>Maintenance</i>	Autopreen	Self-grooming, including: wiping their bill along a branch, moving their bill and tongue along their feathers, rubbing powder down, scratching head with foot or nibbling on feet
	Allopreen	Grooming of another bird
<i>Oral repetitive</i>	Self-directed	Oral behavior performed for at least 5-seconds without variation, including: beak grinding, tongue rolling or foot licking
	Metal-directed	Chewing, licking and manipulating the metal parts of the aviary, including the aviary walls, door frames and locks.

463

464 **Table 2:** Explanation of the keeper score (KS) for usage of the foraging intervention

Score	Definition
1	The forage had not been touched
2	The forage had been used minimally OR less than 1/3 of the provided forage had been consumed
3	The forage had been used moderately OR 1/3-2/3 of the provided forage had been consumed
4	The forage had been used substantially OR greater than 2/3 of the provided forage had been consumed
5	The forage had been used to its maximum potential OR all of the forage had been consumed

465

466 **Figure Legends**

467 **Figure 1:** Oral stereotypies were primarily self-directed in the form of repetitive foot licking (a). Four
468 foraging interventions were provided to alleviate this; b) sliced cucumber, c) grass grown in pots and
469 provided in clumps (also shown are fresh turf squares provided post-study in a similar manner), d) baffle
470 cages, and e) millet discs.

471 **Figure 2:** Proportion of time spent performing a) resting and maintenance behaviors, and b) oral
472 repetitive and foraging behaviors in RTBC across the day during baseline conditions. Five of the six
473 birds were removed from their aviaries twice daily at 11:30 and 14:30 for performance in the free-flight
474 bird show and/or feeding, and were returned at approximately 12:30 and 15:30 respectively; during
475 these times observations were stopped. Data are presented as the median time spent performing
476 behaviors at each point in time, arrows represent the difference between the first and third quartile (n =
477 6). Vertical dashed lines indicate timing of the bird show.

478 **Figure 3:** Proportion of time spent performing oral repetitive and foraging behavior in RTBC under
479 baseline conditions (n = 10), and five foraging intervention conditions; no enrichment (control; n = 5),
480 grass (n = 5), millet discs (n = 5), baffle cages (n = 5) and cucumber (n = 5). Data are presented as the
481 daily median. Arrows represent the difference between the first and third quartile. Bars to the left of
482 the vertical dotted line indicate no enrichment conditions. Asterisks represent values that are
483 significantly different from the 'no enrichment' conditions.

484 **Figure 4:** Time spent interacting with a foraging intervention period under four foraging conditions; a)
485 grass, b) millet discs, c) baffle cages, d) cucumber. Data are presented as the median duration of
486 interaction of six RTBC over two 90-minute provision periods per day. Arrows represent the difference
487 between the first and third quartile. The mean usage/consumption score for those provision periods is
488 overlaid.

489 **Figure 5:** The relationship between the usage score and time spent; a) interacting with enrichment, b)
490 performing foraging behavior, and c) performing oral repetitive behavior, per provision period for all
491 foraging interventions at times where interventions were present (10:00-11:30 and 13:00-14:30).

492 **Supplementary Figure Legends**

493 **Figures S1-S6:** Proportion of time spent performing oral repetitive and foraging behaviors in individual
494 RTBC across the day. Conditions are baseline (S1), control (S2), baffle cages (S3), cucumber (S4),
495 grass (S5) and millet discs (S6). Individuals are three females (Diyara, Iranda and Nangari) and three
496 males (Korridge, Noko and Tali). Data are presented as the median time spent performing behaviors at
497 each point in time (n = 6). Vertical dashed lines indicate timing of the bird shows. Arrows indicate
498 timing of foraging intervention provision (10:00 and 13:00 for 90-minute provision periods).

499 **Table S1:** Candidate models explaining behaviour ranked based on Akaike information criterion
500 corrected to effective sample size (AICc) values calculated using the R package ‘MuMIn’. Change in
501 AICc, relative model weight, log likelihood (log (L)) and degrees of freedom are also included. The
502 models include 150 observations of 6 individuals.

503 **Table S2:** Candidate models explaining behaviour ranked based on Akaike information criterion
504 corrected to effective sample size (AICc) values calculated using the R package ‘MuMIn’. Change in
505 AICc, relative model weight, log likelihood (log (L)) and degrees of freedom are also included. The
506 models include 150 observations of 6 individuals.

507 **Table S3:** Latency (minutes) to interact with each foraging intervention over five days of provision.
508 Data is presented as the median latency of six RTBC to interact with the foraging interventions over
509 two provision periods per day, and then the range (min,max) (n=12).

510