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A behavioural study of Drill monkeys (*Mandrillus leucophaeus)* at Fota Wildlife Park

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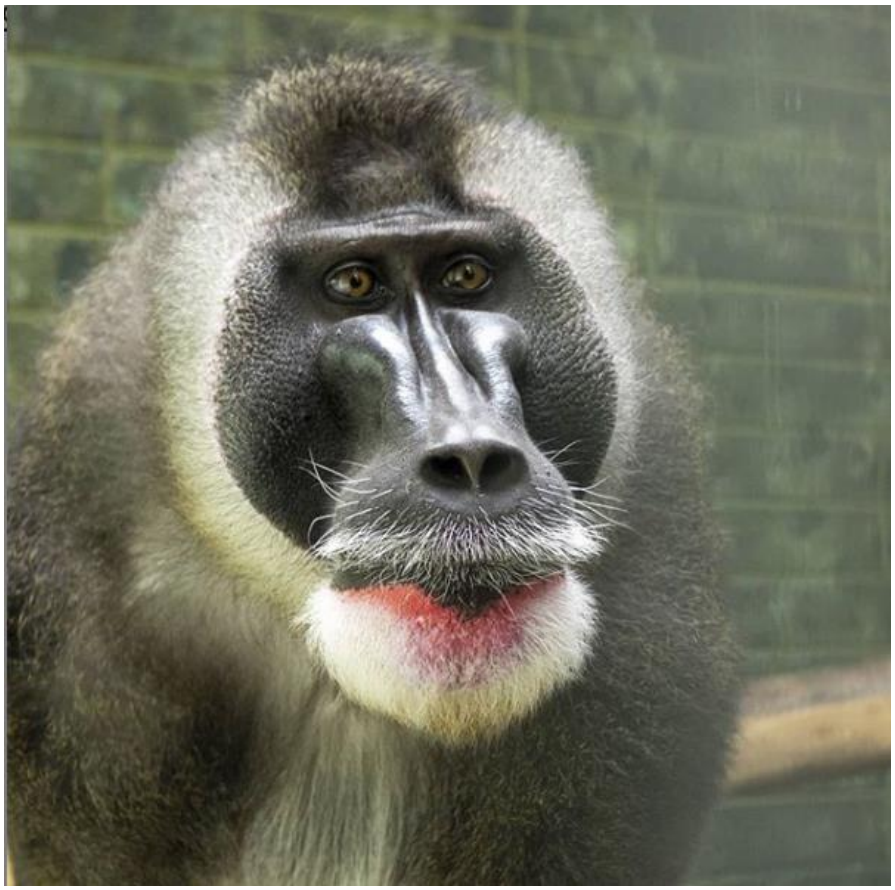

Photography: Sinead Donnachie, Fota Wildlife Park

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FOTA
WILDLIFE PARK

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Abstract

The drill monkey, *Mandrillus leucophaeus*, is considered among the top priorities for conservation of African primates due to an extremely small and decreasing population caused by hunting and habitat loss. This study follows the relocation and integration of five captive drills at Fota Wildlife Park. The aim of the study was to improve understanding on drill behaviour, as currently little is known about this shy species. Behaviour of the group was observed using scan and focal samples, which were then analysed with the non-parametric Kruskal Wallis, Wilcoxon Signed Rank, and Chi-square test. Behaviour was not found to be significantly different between individuals or to change overtime. Visitors also had no significant effect on behaviour, likely due to low visitor numbers. Enclosure usage was recorded using points on a map and through Spatial Participation Index (SPI). This showed that both as individuals and as a group the drills had quite an even usage of the enclosure and had a preference for particular areas, mainly the house. It can be concluded during the course of this study that the relocation and integration was successful. Species typical behaviours such as foraging, grooming and play in juveniles indicate good welfare while low levels of autogrooming indicate low levels of stress. Vigilance decreased overtime as animals habituated to one another. Although no physical contact has been witnessed between the two unfamiliar groups, sexual displaying from two females towards the alpha male give promising signs that the group may produce offspring in the future.

WC: 248

Introduction

The role of zoos

Zoos and wildlife parks have become a necessity to the conservation of endangered species due to increased habitat destruction and fragmentation caused by human activities (Kaumanns *et al.*, 2008). Until these habitats are returned to their former state, ex-situ conservation sites provide a safe environment to conserve gene pools of endangered species with the aim to releasing them back into the wild. The Golden Lion Tamarin (*Leontopithecus*

*rosalia**came)*** close to extinction in the wild, however 140 zoos worldwide devised a reintroduction programme, which brought the status from critically endangered to endangered (Kierulff *et al.*, 2008). As of 2019, a third of wild Golden Lion Tamarins have originated from the ex-situ programme (www.Savetheliontamarin.org). The Korup National Park in Cameroon is the only existing in-situ conservation for endangered drills and has stated that the park would not be able to function without the financial support from foreign governments and NGOs, such as the Frankfurt Zoological Society (www.Tengwood.org).

Animal welfare in the zoo

Risk management of factors which may cause a captive animal stress is a vital part of zoo management, especially for highly intelligent and social primate species who are particularly susceptible to stress (Searl, 2002; Rommeck *et al.*, 2009; Birkett and Newton-Fisher, 2011). Without using invasive measures, it is difficult to detect physiological signs of stress such as heightened heart rate, blood pressure and cortisol levels (Thoerell, 2003; Honess and Martin, 2006), so keepers often rely on abnormal behaviours to identify stress (Honess *et al.*, 2004).

Stereotypical behaviours are a form of abnormal behaviour classified as repetitive and apparently purposeless motor behaviours, such as rocking, excessive autogrooming, and digit sucking (Mason, 2006). Although these behaviours may not be harmful to the individual, if they occur excessively this can be detrimental to essential natural behaviours like eating, breeding and parental care (Bayne and Novak, 1998). Rhesus macaques (*Macaca mulatta*) display many stereotypical behaviours (motor, postural, self-stimulation) in single housing and when isolated for extended periods of time, such as pacing (Lutz *et al.*, 2003), high inactivity, aggression and hair-pulling (Bayne *et al.*, 1991). Backflipping in single housed Rhesus macaques was thought to replace natural locomotory behaviour that could not be expressed in confined conditions (Draper and Bernstein, 1963). Zoos will often introduce environmental enrichment to stimulate animals and encourage them to display skills they would typically use in the wild (Hosey *et al.*, 2013) such as toys that encourage foraging and grooming in Rhesus macaques (Bayne *et al.*, 1991). Naturalistic and complex enclosure design reduced the amount of autogrooming and increased activity in in Lion tailed macaques (Mallapur *et al*., 2005). A review by Hoesy and Skyner, 2007 on several captive primate

species, found multiple social factors that may induce stress, including: the presence of male conspecifics, approaches by or aggression from an unfamiliar individual, changes in the group composition, and removal from the group. Rhesus macaques were more prone to developing abnormal behaviours if nursery reared or if they experienced extreme or frequent stress as an infant (Novak, 2003). A survey of North American Zoos found abnormal behaviour in 497 individuals of 68 different species, giving an overall average rate of 14% (Bollen and Novak, 2000).

One non-social factor which has recently grown in popularity within the animal behaviour community is the effect of visitors on animals. A study on gorillas *(Gorilla gorilla*) found a direct positive correlation between high visitor numbers and agonistic behaviour and Self Injurious Behaviour (self-biting), while a relaxed manner was associated with low visitor numbers (Wells, 2005). An association between large crowds and increased self-biting was found in captive pleated gibbons (*Hylobates pileatus*) (Skyner *et al.*, 2004). Although there are more reported cases of negative effects by visitors, there are also cases of neutral effects where siamang gibbons (*Hylobates syndactylus*) ignored visitors and maintained normal behaviour (Nimon and Daziel, 1992), and positive effects including a study on Squirrel monkeys (*Saimiri sciureus*) that found visitors to be enriching for certain individuals who chose to repeatedly interact with visitors (Polgár *et al.*, 2017).

Dufour *et al.* (2011) notes that there are few studies on how ex-situ primates cope with relocation to new enclosures. The moving process and a change of environment can be stressful for animals and may elicit decreased foraging, increased inactivity and elevated stress hormones. Most research on relocation of captive primates is centred around laboratories and not the zoo setting (Bayne and Novak, 1998; Lutz *et al.*, 2003; Rommeck *et al.*, 2009). Papers focused on zoo relocation tend to describe increased activity, decreased SIBs, and overall greater behavioural diversity when moved to a more complex and naturalistic enclosure (e.g. Pan troglodytes, Clarke *et al.*, 1982). However if the relocation also includes introduction to unfamiliar individuals this can result in lower basal cortisol levels and subsequent decreased longevity (Capitanio *et al.*, 1998) increased cortisol levels (Gust *et al.*, 1991), and extreme aggression and sexual behaviour (Bernstein and Mason, 1963) as seen in several species of macaques. Deaths caused by increased stress can be devasting to

populations as currently 63% of primate species are threatened with extinction (Estrada *et al.*, 2017).

Drills background

Drills (*Mandrillus leucophaeus)* are semi-terrestrial forest dwelling Old World Monkeys with a limited range in Cross River in Nigeria to the Sanaga River in Cameroon. These primates belong to the family Cercopithecidae and were only recently classified into the genus *Mandrillus*, along with the Mandrill (*Mandrillus sphinx*) by Robert Groves in 1989 (Oates and Butynski, 2008). *M. leucophaeus* has 2 subspecies: *M. I. leucophaeus*, from the mainland, and *M. I. poensis* from Bioko island. It is difficult to distinguish the subspecies from each other by looks alone, however they are separated by a substantial body of water, keeping the populations isolated (Grubb *et al.*, 2003). Male drills are characterised by an extreme sexual dimorphism, weighing three times as much as females, and bright colouration surrounding the genitalia and a red mark on the chin (Oates and Butynski, 2008). Females are a drab brown and both sexes possess enlarged rounded incisors designed to crush hard nuts and seeds from the forest floor (Fleagle and McGraw, 1999).

These primates have been listed as endangered by the IUCN since the first record of the population status in 1986. The most recent assessment of the species was in 2008 and needs updating, according to the IUCN themselves. The reasoning for the need on updating the status is due to a population decline exceeding 50% over the past 30 years (Oates and Butynski, 2008). This has led to drills being recognised as the highest priority in the conservation of African primates. However very little information is available on the species due to their dense forest habitat, incredibly shy nature due to hunting, and difficulty in habituating making long term studies on wild populations rare (Gadsby *et al.*, 1994; Oates and Butynski, 2008). Captive drill populations provide an opportunity to study this shy species, however many of these animals have poor welfare due to sub-standard living conditions and small group sizes (Gadsby *et al.*, 1994). Drills have a history of poor breeding in captivity and poor social skills, with cases of drills not being able to recognise conspecifics (Gadsby *et al.*, 1994).

Fota and drills

According to their website (www.Fotawildlife.ie), Fota Wildlife Park is located in the south of Ireland and receives over 465,000 visitors per year. The park was founded in 1984 by the Zoological Society of Ireland and was built upon 100 acres of land owned by University Cork College (UCC). Their main objectives are conservation and education. The strong ties with UCC have led to extensive research by students on captive animals within the park. As well as research, Fota have an education programme that provides talks on endangered species daily and tours for school children. Many reintroduction programmes for species previously extinct in the wild such as, the Scimitar horned Oryx, European Bison and the native Irish corncrake have been highly successful. This NGO also contributes to in-situ conservation projects such as the Wildcat Conservation Alliance. High standards for animal welfare are regulated by conforming to international laws, such as no buying or selling of animals and meeting regulations for enclosure standards. Zoos and wildlife parks across Europe work together as a cohesive unit, swapping breeding animals regularly to maintain genetically diverse populations. Fota participates in the European Endangered Species Programme (EEP), which helps manage animal populations kept in European Association of Zoos and Aquaria (EAZA) zoos.

As part of an EEP initiative to conserve the endangered drill species, Fota accepted a group of 5 drills. These are the only captive drills in Ireland. Drills are notoriously difficult to breed in captivity, meaning that the captive drill population is equally as endangered as the wild population. Worldwide roughly 76 individuals make up the captive population, with 16 drills in 4 North American zoos, Africa, and 60 drills in 12 European zoos. German zoos have the highest breeding success in drills, which is where Fota received one adult male and female from (www.Tengwood.org). Fota intend to contribute new offspring to the drill population, however currently the biggest priority for the group is slowly integrating the unfamiliar individuals, with the aim of forming strong bonds with minimal aggression. Monitoring the welfare of all animals during this process will give an indication as to whether a long-term successful integration is possible.

Objectives

The overall aim of the study was to gain a better understanding of captive drill behaviour, monitor the integration process and evaluate the welfare of the drill group at Fota Wildlife Park. To achieve this, the four objectives identified were:

Objective 1. Drill behaviour in November 2019.

Objective 2. Drill behaviour in January 2020.

Objective 3. The visitor effect on drill behaviour.

Objective 4. Drill enclosure use.

WC: 1620

Materials and methods

Study location and subjects

The study took place at Fota Wildlife Park, Carrigtwohill, Cork, Ireland with GPS coordinates 51.8914° N, 8.3074° W (Fig. 1A). The study subjects were a group of five captive drill monkeys (*Mandrillus leucophaeus).* The drills can be categorised into the Stuttgart group (one adult male and female), and the Bristol group (one mother and her two immature daughters). See table 1 for details of the group.

Table 1. Profile of study subjects at Fota Wildlife Park.

Name	Previous zoo	Sex	Date of Birth	Rank
Julian	Stuttgart	M	16/03/1997	Alpha male
Buddy	Stuttgart	F	28/10/1991	Mature female
Inneke	Bristol	F	26/06/2010	Mature female
Lewa	Bristol	F	01/10/2016	Immature female
Banni	Bristol	F	03/08/2017	Immature female

Julian, the alpha male, and his adult female partner, Buddy, came from the same zoo in Stuttgart, Germany (Table 1) and arrived at Fota in March 2019. In Stuttgart Zoo they were housed together indoors with a glass display for 20 years. One offspring was born, however soon died while still an infant. The Bristol group arrived at Fota in July 2019, the breeding female, Inneke, and her 2 juvenile daughters, Lewa and Banni. Inneke was born in Bristol Zoo where she also gave birth to Lewa and Banni with a gap of 10months between births.

Fota Wildlife Park purpose built the drill enclosure which consisted of an indoor house, roughly 104m^2, and an outdoor island, roughly 578.24m^2 (Fig 2B). The house was divided into two sections by a metal grate to keep the Bristol and Stuttgart group separate. In each section there was a larger area with one glass wall to act as a display for visitors, and a smaller area separated by a concrete wall where animals were not visible to visitors. In both sections of the building, large logs, wooden planks and metal grates encourage natural behaviours such as climbing. The concrete floor was covered in wood chip. The island was accessible from both sections of the house by a log, mesh tunnel and black plastic tunnel. The island was westward facing and surrounded by sea water in the 'Monkey Island' section of the park. Other animals inhabiting surrounding islands include Roloway monkeys with a distance of 7m and Siamang gibbons at 15m. Features of the island include grass and naturally growing weeds, stones, tree species (Sweet chestnut, willow, sycamore, eucalyptus, bog alder), a dirt mound with a tunnel, and climbing structures (i.e. Wooden poles, ropes, and platforms ranging from 2-8m) (Fig. 1B and C). The access to the island was restricted at certain times of the day to aid cleaning of the indoor housing and to control the potential for physical contact between certain individuals. Their diet consisted of mixed salads made of fruits and vegetables. This was provided through scatter feeding three times daily.

Figure 1A. Fota Wildlife Park located in the south of Ireland, Carrigtwohill, County Cork (51.8914° N, 8.3074° W). Image: Google Earth Pro.

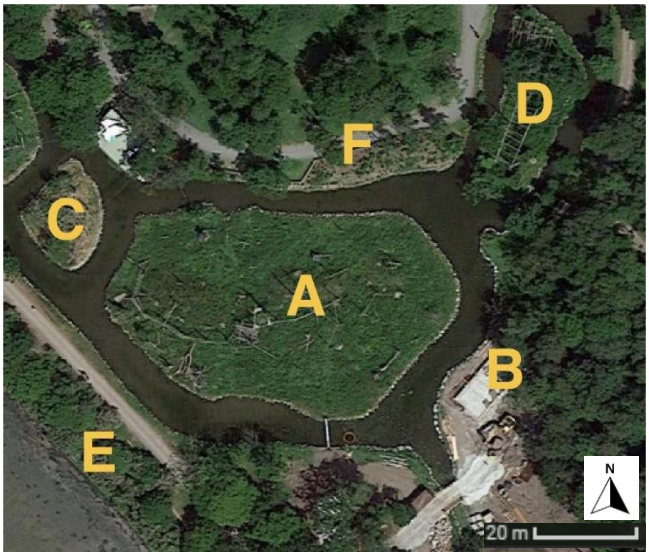

Figure 1B. Image taken from google earth Pro before the construction of structures on the drill monkey, Mandrillus leucophaeus, enclosures at Fota Wildlife Park with surrounding areas. A= drill island, B= drill house, C= Roloway island, D= Siamang gibbon island, E= public walkway, F= public walkway.

Figure 1C. The completed drill monkey island at Fota Wildlife Park. Taken by the author from the public walkway closest to the left side of the island ('E' in Fig. 2).

Animal identification

Identification of the animals was done through a mixture of each animal's anatomic distinctions, varying personalities and particular behaviours (Martin and Bateson, 2007), which became apparent after *ad libitum* sampling. Julian, the only male was much larger than the females and had blue and red colouration on his sexual organs and a red patch under his chin (see Fig. 2A).

Buddy, Julian's female partner, had a scar on her head and as described by the head primate keeper, carried a stuffed teddy for comfort, due to her being hand reared (T. Power, pers. comm., August 2019) (see Fig. 2A). Buddy remained separate from the other females for the entirety of the study which simplified identification.

Inneke's left leg was much thinner than the right, which was caused by an aggressive male in her previous zoo (See Fig. 2B). Lewa, the oldest daughter, was slightly smaller than her mother, Inneke, and had a white spot between her nostrils (See Fig. 2C). This white spot was difficult to see from a distance so size difference, personality, and unique behaviour was used for identification. Lewa was more active and playful than Inneke who spent more time sitting still and scanning the area. Lewa was less dominant than her mother and was usually seen looking at Inneke and following behind her. Banni was the smallest individual and displayed very active behaviour (See Fig. 2D).

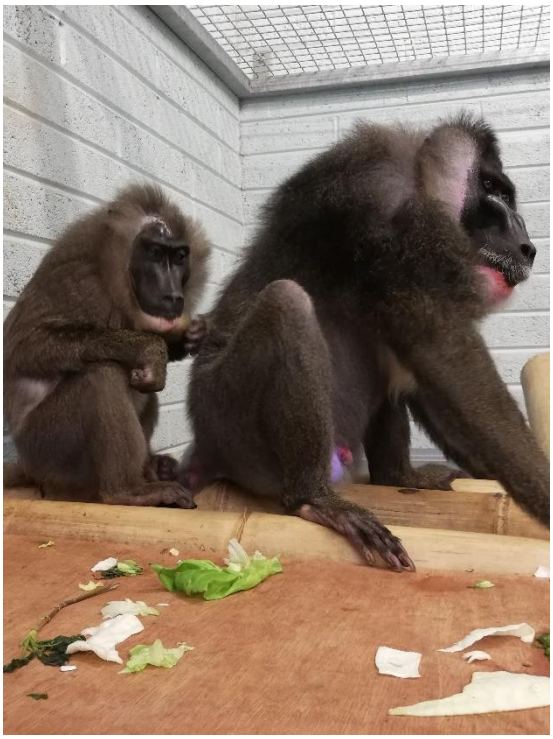

Figure 2A. Buddy (left) and Julian (right). Photography: T. Power.

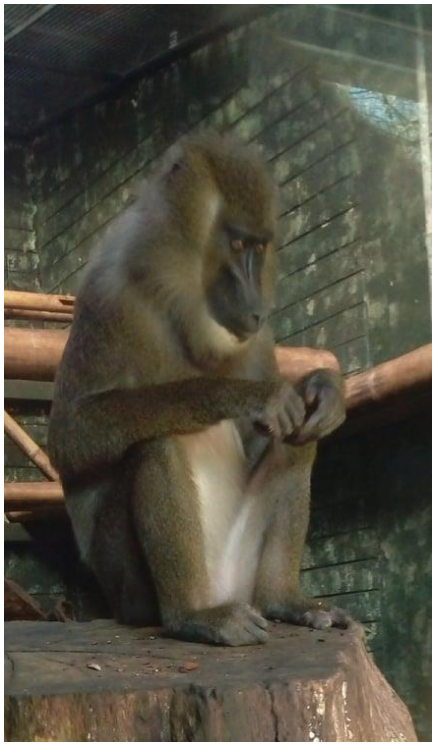

Figure 2B. Inneke. Photography: author

Figure 2C. Banni. Photography: T. Power.

Figure 2D. Lewa. Photography: T. Power.

Observation methods

Observations were recorded during normal viewing hours (10.00am – 6.00pm) on the 5th, 9th, 12th, and 17th of November 2019 and on the 10th, 14th, 18th and 23rd of January 2020. Days of mild, dry weather were selected for data collection. The indoor enclosure was observed from the glass display and the outdoor enclosure was observed from walkways on either side of the island (Fig 1B). Sampling methods used in this study were focal sampling, instantaneous scan sampling, and *ad libitum* sampling (Altmann, 1974).

Focal samples record all instances of behaviour of one individual for a specific length of time (Altmann, 1974). This sampling method was used to test hypothesis 1 and 2 as Altmann (1974) described this sampling technique as being particularly relevant to behavioural studies based on specific individuals within a group. This technique is useful for observing both states and events, giving unbiased data for many questions. States are defined as behavioural patterns of long duration, such as prolonged activities i.e. resting or foraging. Events are behavioural patterns of short duration, which can be measured as points in time and calculated by the frequency of occurrence.

Scan sampling records an instant of behaviour of one or more individuals at regular predetermined intervals for a select amount of time. States rather than events are recorded. Hypothesis 1, 2, and 3 were measured using scan samples as this method represents the overall behaviours of the group and can be used to calculate times and frequencies of behavioural states. Hypothesis 4 was not measured using sampling techniques, but with enclosure maps and a modified Spread of Participation Index (SPI).

Ad libitum sampling was used throughout the study to take note of any behaviours occurring outside of the other more restrictive sampling techniques.

A limitation of scan and focal sampling is the portion of time where animals move out of the observer's line of sight. This may create a bias in behaviour recorded, as many animals will perform behaviours such as eating or mating in private, therefor behaviour recorded while visible to the observer may not be representative of their behaviour as a whole (Martin and Bateson, 2007). Results obtained from scan sampling may not be representative of the overall behaviour in the individual or group as rare or inconspicuous behaviours are likely to

go unrecorded. Focal sampling when animals are constantly in view, avoids this bias. However, animals not visible to the observer during focal samples are also liable to this bias (Martin and Bateson, 2007).

Procedure

An ethogram was created from preliminary data collected on the 9th and 10th of July 2019 through *ad libitum* sampling (table 2). Behaviours were categorised as Out of Sight, Inactive, Active and Social, and had a list of codes for each behaviour. This acted as a template for behaviours recorded in focal and scan samples.

During preliminary data collection, several focal and scan samples were trialled at 5, 10, 15 and 20 minutes. A time of 15 minutes was chosen when no new behaviours were recorded after this time and behaviours were not repeated. Behaviour was recorded continually for 15 minutes in focal samples and for 15 minutes with a one-minute sample interval in scan samples. The 15 minutes allowed for replication of at least two focal and two scan samples for each individual per study day and was an appropriate amount of time to ensure no observer fatigue occurred (Altmann, 1974).

Randomisation of the order in which the animals were observed was necessary to reduce bias. This was attained using an online random number sequence generator called Random.org. The generator did not contain duplicates. Each animal was assigned a number from 1-5 (Julian= 1, Buddy= 2, Inneke= 3, Lewa= 4, Banni= 5). On each observation day the range of 1-5 was selected on the website and the resulting random sequence order was followed for recording focal samples, with a separate order for scan samples.

Following the randomised orders, focal and scan samples were taken alternately until each individual had been recorded by both sampling methods at least twice per study day. During focal and scan samples, the presence or absence of visitors was noted, excluding the observer. If the animal being recorded was inside during the sample, visitors close to the glass display would be counted, whereas if the animal was outside then any visitors along the walkway would be counted.

Table 2. Ethogram of behaviours displayed by a group of 5 drills at Fota Wildlife Park.

	Code	**Behaviour**	**Behaviour definition**
Out of sight	OOS	Out of sight	Animal cannot be seen by observer.
Inactive	RS	Rest	Sitting or laying down motionless with eyes open or closed.
Active	L	Locomotion	Moving at any speed on all four legs from one area to another along the same height gradient.
	F	Foraging	Looking for food with hands and eyes, finding food and eating food.
	V	Vigilance	Alert and focused, looking at surrounding area, other animals or people.
	AT	Autogroom	Individual picks through own fur or skin with hands or teeth.
Social	P	Play	Non-aggressive interaction with object or another individual in a spontaneous, apparently non goal-oriented manner. Behaviours include chasing, wrestling, lunging, spinning in circles, throwing and catching sticks. During these behaviours there was no aggressive body language or vocalisations and generally a play face would be used while interacting with another individual.
	ALG	Allogroom	Picking through another individual's fur or skin with hands or mouth. Also includes similar behaviour towards teddy held by Buddy.
	AG	Aggression	Threatening display or stance, chasing, biting or scratching, short aggressive calls.
	SX	Sexual	Male and female displaying to each other, touching or sniffing of genitals, mounting.

Before and after each focal sample, the enclosure use was recorded by marking the position of each drill in one of 5 identical maps (Appendix Fig. A1). November observations were marked in blue and January in red. Each study day resulted in a total of 20 data points per drill marked on the five enclosure maps. This gave 160 data points of enclosure use per drill after 8 days.

To assess drill personality, a survey was sent to the head primate keeper at Fota Wildlife Park, Teresa Power. The survey included 13 personality traits (Appendix Table A1), that would be rated on a scale of 1-7 of how accurately the strength of each behaviour was seen in each drill (1= hardly ever seen, 7= seen near constantly). Teresa completed this survey with no outside input.

Data analysis

Analysis was preformed using a variety of statistical tests with IBM SPSS Statistics 26. Both numerically and visually, Shapiro-Wilk normality tests and histograms suggested the data were non-normal. The non-parametric tests: Kruskal Wallis, Wilcoxon, and chi-squared tests were used in SPSS. Standard deviation was used to explain the variability for each of these tests. An alpha level of α=0.05 was used for all non-parametric tests. The Bonferroni correction was applied to Kruskal Wallis and Ci-square tests so as to account for multiple comparisons. Objectives 1 and 3 tested the four group behaviours (Out of sight, inactive, active, social), therefore the modified Bonferroni correction alpha level is α=0.0125.

Objective 1: The Kruskal Wallis test was selected for its ability to compare a specific behaviour amongst several individuals. This was carried out on scan data from November 2019. The mean frequency of each behaviour category (Out of Sight, Inactive, Active, Social) was calculated per study day. A histogram was produced to asses visually the variation in behaviour between all drills. Descriptive statistics were produced using Microsoft excel from November 2019 focal data in the form of pie charts showing the mean frequency of behaviours for each drill.

Objective 2: The Wilcoxon test was chosen to assess if there was a difference in drill behaviour between November 2019 and January 2020. For each grouped behaviour, the frequency of each observation preformed at the individual level was compared between scan data from November 2019 against January 2020. Pie charts were produced using Microsoft Excel based on focal data for January 2020. The pie charts allowed comparison of behaviour in a temporal context, and also a comparison of individuals within the group.

Objective 3: The Chi-square test was used to determine the association between visitor presence and drill behaviour. Visitor presence was split into two categories, present or absent. This was due to very low visitor numbers, commonly with no visitors present. The maximum visitors recorded on any day was eight and minimum was zero. The frequency for each grouped behaviour was run against visitor presence to determine if any association was statistically significant.

Objective 4: Enclosure use was measured using the modified Spread of Participation Index (SPI) (Plowman, 2003) at the individual and group level. SPI was also calculated separately for November 2019, January 2020 data and using pooled data from both months. SPI gives the potential to assess animal welfare if animals are not using a diverse range of their enclosure through enrichment or a change to enclosure design (Garry, 2012; Rose *et al.*, 2018).

To calculate the modified SPI, first the enclosure was divided into 8 uneven zones (Appendix Fig. A1). The area of each zone and of total enclosure were measured in m^2 using the Google Earth Pro measuring tool.

The equation used was:

$$\mathrm{SPI} = \frac{\sum |f_o - f_e|}{2(N - f_{e\,\min})}$$

Where f_o is the observed frequency of drill observations in a zone and f_e is the expected frequency of drill observations within a zone; this is based on zone size when enclosure use is assumed to be even. Enclosure area was measured in m^2 using the Google Earth Pro measuring tool. The absolute value is the difference between f_o and f_e and can be seen in the equation as: $|f_o-f_e|$, which is summed for all zones by $\sum$. N represents the total number of drill observations in all zones and $f_{e\,min}$ is the expected number of drill observations in the smallest zone (Plowman, 2003). The resulting SPI score ranges from 1 to 0, with scores closer to 0 indicating the drill has an uneven use of the entire enclosure and uses a wide range of zones, whereas scores close to 1 show that the drill has an even use of one preferred area within the enclosure.

WC: 2140

Results

Objective 1. Drill behaviour in November.

H_0: There was no difference in mean behaviour between drills.

H_1: There was a difference in mean behaviour between drills.

In November 2019 the drills spent most of their time active, with Inneke being the most active (91% ± 0.1179) and Buddy the least active (55% ±=0.2461) (Fig. 4A, C, E, G, I). Of these active behaviours (foraging, locomotion, vigilance, autogroom) foraging took up a large portion of the time at roughly 49% ± 0.1854 for the Bristol group, 74% ± 0.2281 for Julian and 26% ± 0.2289 for Buddy. Buddy was much more inactive than any other drill 34% ± 0.2953. The two adult females, Buddy 27% ± 0.2127 and Inneke 49%, ± 0.1862, showed the highest vigilance in the group. Social behaviours (play, allogroom, aggression, sexual) were displayed between 9-17% of the time in the females, however no social behaviour was shown by Julian during November 2019. Play was seen only in the two immature females, Lewa 2% ± 0.0225 and Banni 6% ± 0.0674.

Although the trends in data would suggest that there were differences in behaviour between drills (Fig. 3A,B,C) the Kruskal Wallis test found no significant differences in the mean grouped behaviours: Social (H= 5.087, df=4, P= 0.311), Active (H=6.087, df= 4, P= 0.278), Inactive (H= 6.018, df= 4, P= 0.198), Out of Sight (H= 0, df= 4, P= 1).

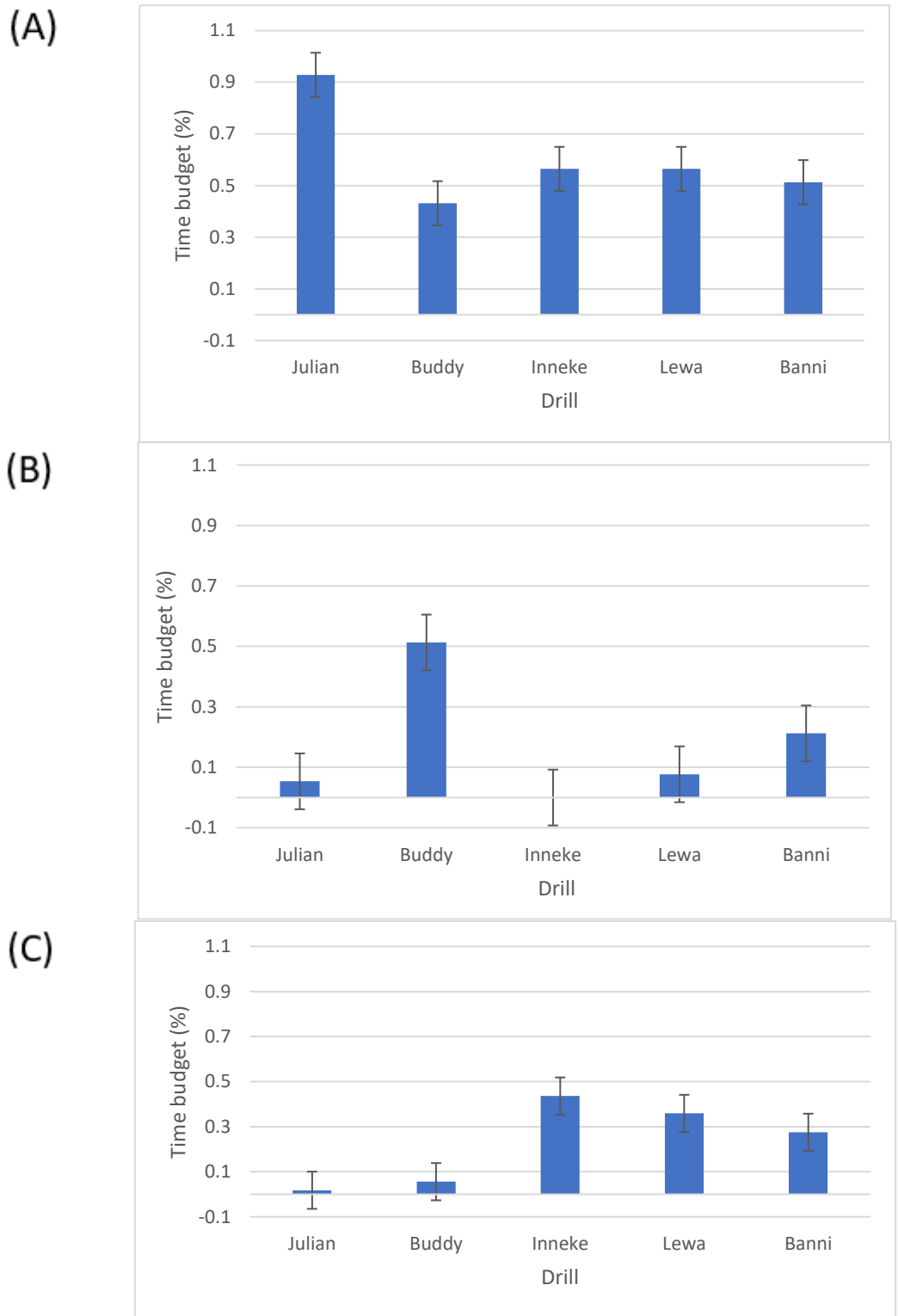

Figure 3. The frequency which each drill spent in active (A), inactive (B), and social (C) behaviour based on scan data from November 2019.

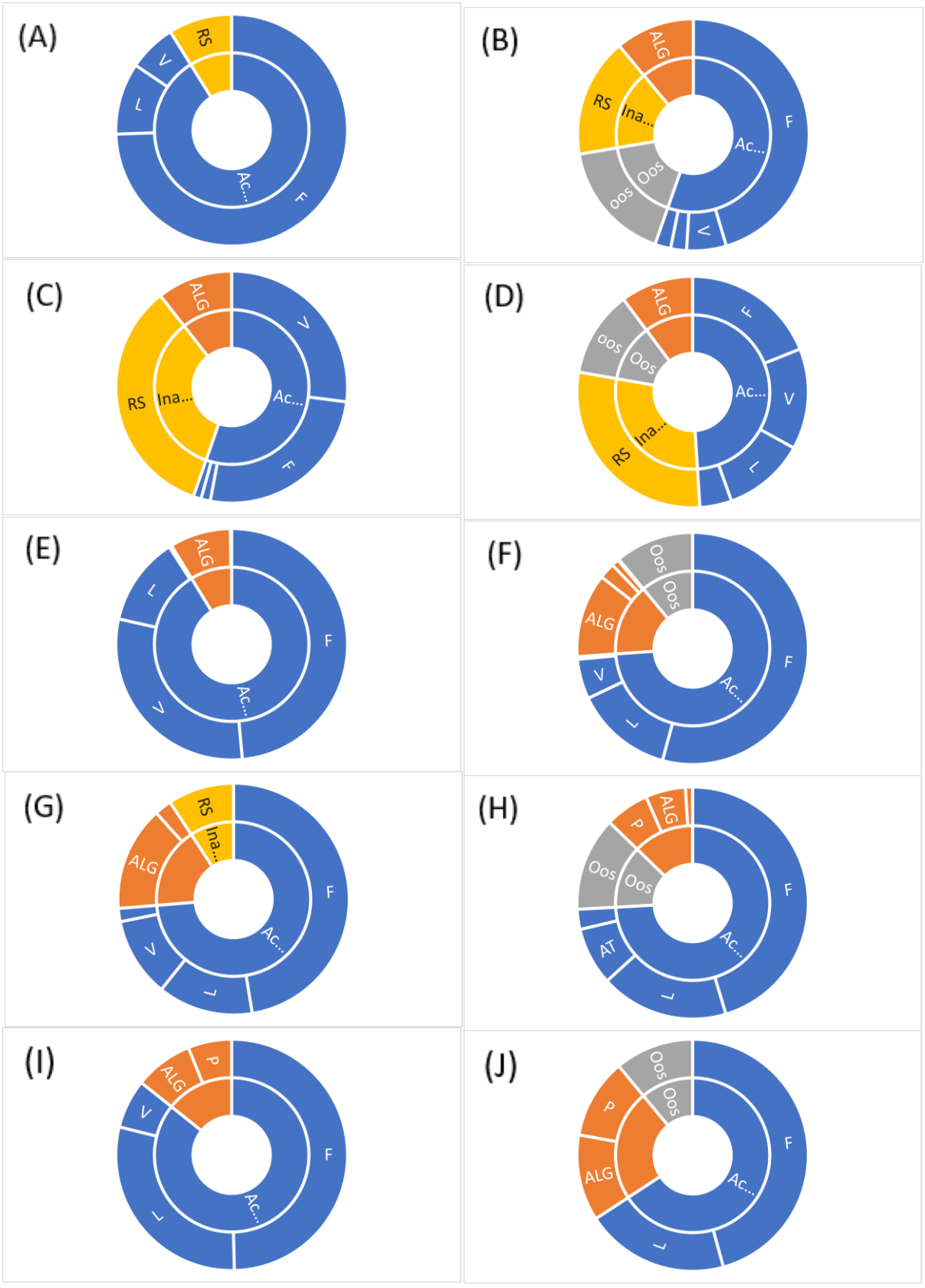

Figure 4. The mean behaviour of each drill based on focals at Fota Wildlife Park in November 2019 (left) and January 2020 (right). A+B= Julian, C+D= Buddy, E+F= Inneke, G+H= Lewa, I+J= Banni. See Table 1 for ethogram codes.

Objective 2. Drill Behaviour in January

H_0: There was no difference in mean drill behaviour between November 2019 and January 2020.

H_1: There was a difference in mean drill behaviour between November 2019 and January 2020.

Comparing January behaviour to November, the group still spends a large portion of their time in active behaviours, however a decrease was seen over time in Julian from 90% ± 0.1461 to 55.56% ± 0.0509 and Inneke from 91.30% ± 0.1179 to 73.70% ± 0.1686, but no change was seen in the other three drills (Fig. 4B, D, F, H, J). Buddy is still the most inactive individual at 29% ± 0.1432, however this was a decrease from November at 34% ± 0.2953, while Julian's inactivity increased from 9% ± 0.154 to 17% ± 0.1528.

Julian decreased in locomotion from 10% ± 0.095 to 2% ± 0.0385 and Banni decreased from 29% ± 0.0725 to 20% ± 0.2082 but was still the most active. Julian decreased in foraging from 74% ± 0.2281 to 46% ± 0.077, Buddy decreased from 26% ± 0.2289 to 19% ± 0.1018 and female group remained at roughly 50% ± 0.1133. There was decreased vigilance in each drill, Buddy was the most vigilant (14% ± 0.037) and Banni the least (0% ± 0).

Play was still only seen in the younger drills, with an increase in Lewa from November to January from 2.41% ± 0.0225 to 6% ± 0.0585 and Banni from 6.11% ± 0.0674 to 11.11% ± 0.0771. Allogrooming was roughly 10% of time spent in all drills, Lewa the least (5.56% ± 0.1125), Inneke (11.67% ± 0.1063) and Banni (12% ± 0.0979) the most, no allogrooming was seen by Julian in November and 11% ± 0.1171 was seen in January. Out of sight, aggression or sexual behaviours were not seen in November, but were present in January. Aggression was shown by Inneke at a low level of 2.22% ± 0.0192. Sexual behaviour in Inneke and Lewa ± 0.0085 was seen in both at 1% ± 0.0257. Out of sight was a similar level among drills with Julian having the highest percentage (16.67% ± 0.2887) and Inneke and Banni the lowest percentage (11% ± 0.058).

The Wilcoxon test found significant differences in out of sight behaviour between November 2019 and January 2020 (Table 3) in Inneke (z= -2, p= 0.046) and Lewa (z= -2.251, p=0.024).

Table 3. The significance of differences in mean behaviour between November 2019 and January 2020 for each drill.

		Julian	Buddy	Inneke	Lewa	Banni
Out of Sight	Z=	-1.857	-1.857	-2	-2.251	-1.732
	P=	0.063	0.063	0.046	0.024	0.083
Inactive	Z=	-0.68	-1.483	0	-0.447	-1
	P=	0.448	0.138	1	0.655	0.317
Active	Z=	-0.679	-1.782	-0.135	-0.314	-0.405
	P=	0.497	0.075	0.893	0.753	0.686
Social	Z=	-0.108	0	-0.734	-0.943	-1.363
	P=	0.914	1	0.463	0.345	0.173

Objective 3. The visitor effect on drill Behaviour

H_0: There was no association between drill behaviour and visitor presence or absence.

H_1: There was an association between drill behaviour and visitor presence or absence.

Visually the data shows an increase in active behaviours and a decrease in social, out of sight and inactive behaviours in the presence of visitors (Fig 5). The Chi-square test found that the association between visitor levels and drill behaviour was not statistically significant ($\chi^2(4) = 9.475$, p = 0.024). However there were trends between active and social behaviours in the presence and absence of visitors. Active behaviours seemed positively associated with visitor presence (z= 1.7) and negatively associated with visitor absence (z= -0.9). Opposingly, social (z= -1.8), out of sight (z= -0.4), and inactive (z= -0.9) behaviours seemed negatively associated with visitor presence and positively associated with visitor absence (social: z= 1; out of sight: z=0.2; inactive: z= 0.5).

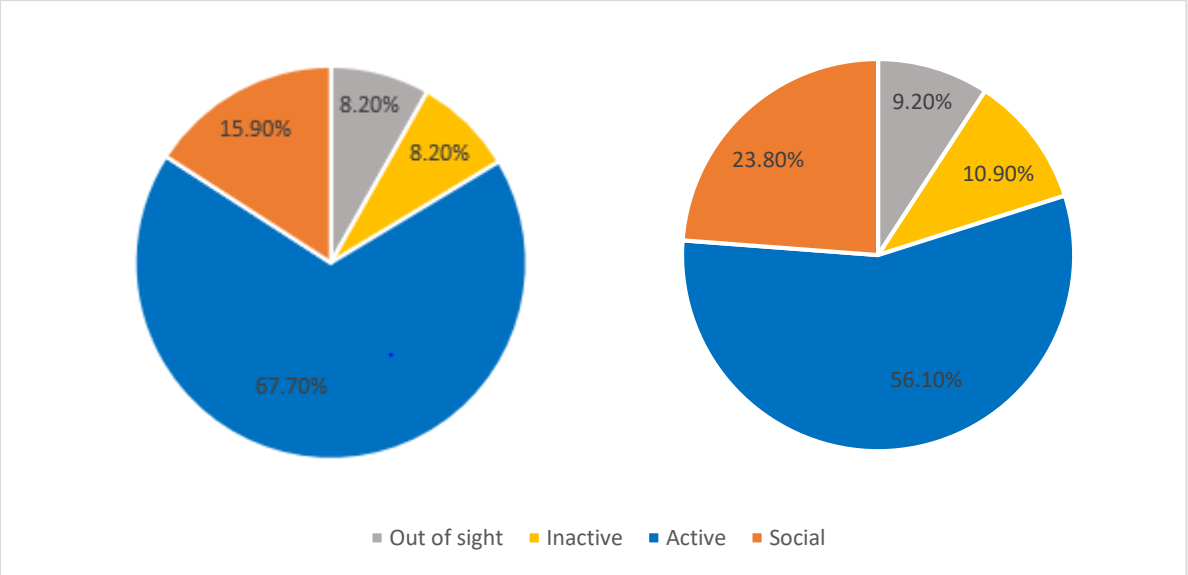

Figure 5. Mean grouped behaviours of the drill group at Fota Wildlife Park in the presence (left) and absence (right) of visitors. .

Objective 4. Drill enclosure usage

H_0: Drills used their enclosure evenly.

H_1: Drills did not use their enclosure evenly.

Table 4. SPI scores at the individual and group level in November 2019, January 2020 and an average of both months.

	November	January	Average
Julian	0.68	1	0.79
Buddy	1	1	1
Inneke	0.76	0.74	0.69
Lewa	0.76	0.69	0.7
Banni	0.76	0.72	0.69
Group	0.79	0.83	0.77

SPI scores and the enclosure maps show that Buddy had the most even use of the enclosure with a constant score of one. From ad libitum she was never seen leaving the house by the observer or by keepers, which aligns with the map observations (Fig 6B).

Julian had the most uneven usage of all drills in November (0.68), showing high exploration of all zones, except for zone 6 which none of the drills used during November (Fig. 6A). In January, Julian had an equally high preference for the house similar to Buddy (1).

The Bristol group have the most uneven usage overall with Inneke and Banni having an SPI score of 0.69 and Lewa 0.7. In November, all 3 females had a score of 0.76 and showed very similar use of zones (Fig. 6C-E). They had a clear preference for zone 2 which is located nearest the house and were not seen using zone 6 or 8 for the month of November. Opposingly, Julian showed very high use of zone 8, which was located closest to the Roloway monkey island (Fig. 1B). The Bristol group had slightly differing SPI in January and were seen using zones more independently of each other (Fig. 6C-E). Zone 5 showed a high usage due to keepers throwing food from the walkway onto this zone (*Ad libitum*). No females were seen using zone 8, however all females used zone 6 in January, with Banni showing the highest use.

Ad libitum sampling

Ad libitum sampling recorded more aggression and sexual behaviour than focal and scan sampling results show. These brief events occurred more in January than in November. Aggression was only seen by Inneke towards Lewa when Lewa was initiated in play with Banni. Sexual displaying was observed by Inneke and Lewa towards Julian. This would usually be initiated from a distance of 2m, with a metal grate between the male and females, or the female would stay close to the island exit as she displayed. Buddy and Banni were seen gently touching each other briefly through the metal grate.

The enclosure use inside of the house (zone 1) became more varied as the study went on. Even though all animals had open access inside the house in January, the Bristol group would spend most of their time in the left side of the house and the Stuttgart group stayed in the right side. All animals except Inneke were seen foraging for brief periods of time in the half of the opposing group. When Banni, Lewa or Buddy were present the members of the opposing group showed no reaction. However, when Julian entered the area with the Bristol group, all members of the group would increase in locomotion, vigilance and stay near to the tunnel entrance to the island for a quick escape. WC: 1292

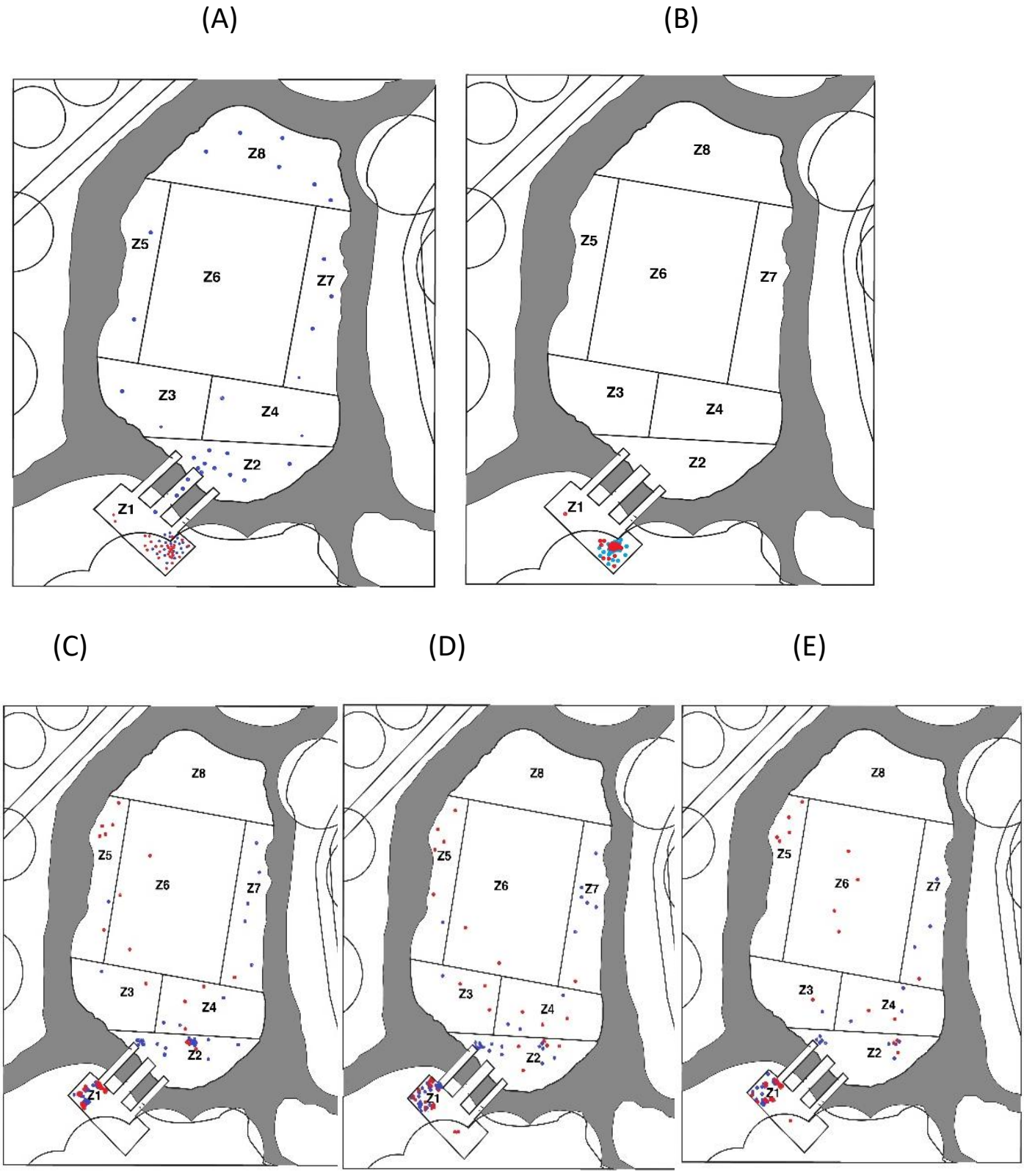

Figure 6. Enclosure map usage for each drill in November 2019 (blue) and January 2020 (red). A= Julian, B= Buddy, C=Inneke, D= Lewa, E= Banni.

Discussion

The drill group at Fota Wildlife Park displayed many species typical behaviours including high levels of foraging, which takes up two thirds of the day in wild population (www.Tengwood.org), and social behaviours such as grooming which forms an integral part of drill ecology (www.Tengwood.org). The female drills displayed more social behaviour than the male, which is a common finding among rhesus macaques (Kulik *et al.*, 2015), Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*: Wang *et al.*, 2007), and baboons (Young *et al.*, 1982). This is likely due to females being the natal sex, therefore forming strong bond within matrilines and using social behaviours to reinforce hierarchies and co-operative behaviour (Roney and Maestripieri, 2003). The play behaviour seen by juveniles Lewa and Banni are instrumental in learning practical behaviours such as fighting (Lonsdorf *et al.*, 2014) or parental care, which was seen in young chimpanzees cradling sticks to mimic carrying an infant (Kahlenberg and Wrangham, 2010). The behavioural results may have been impacted by time of day as data was recorded randomly between 10am-6pm.

Bayne *et al.* (1991) suggest that high rates of inactivity can be an indicator of poor welfare, as was seen consistently in Buddy. However, this may be due to her being hand reared as an infant, which would agree with studies on rhesus macaques. It was found that nursery-reared infants are more prone to developing high rates of inactivity and stereotypical behaviours such as abnormally high autogrooming or Self Injurious Behaviours (SIBs) more frequently than mother-reared infants (Erwin *et al.*, 1973; Rommeck *et al.*, 2009).

Although the group was closely monitored for aggressive behaviour to prevent injuries, De Wall notes that aggression is a normal component of primate social systems (De Wall, 1992; De Waal, 1997; De Waal, 2000**)**. A study on adult Rhesus monkeys found extremely high levels of aggression towards kin, especially juvenile kin. **T**his is a natural socialization process to prevent young from developing undesirable behaviour patterns (De Waal, 1992). These findings directly mirror the aggression displayed by Inneke towards Lewa and Banni. Further research could see if an expected decreased aggression from the matriline occurs as the juveniles mature (Bernstein and Ehardt, 1986).

Many captive primate species are affected by visitor numbers with studies describing increased abnormal behaviour in lion tailed macaques (*Macaca Silenus)* (Mallapur *et al.*, 2005), decreased allogrooming, play and foraging in chimpanzees (Wood, 1998), and increased aggression in gorillas (Wells, 2005). However, Polgár *et al.* (2017) found visitors to increase behavioural diversity of captive squirrel monkeys. The group at Fota Wildlife Park were found to have increased activity but decreased social behaviour. A closely related species, the mandrill, showed similar decrease in time spent engaged in affiliative behaviour with high visitor numbers, however the same study by Chamove *et al.* (1998) also found mandrills to spend more time watching and threatening visitors which were not present in the drill group. Low rates of social behaviour can reduce the rate of reproductive success within the group, particularly for females (Sterck *et al.*, 1997) so future studies should ensure the group behaviour is not negatively impacted further by visitors. Currently out of sight areas give the animals an opportunity to escape stress cause by visitors and signs ask visitors not to bang on the glass, which are potential methods to increase animal welfare (Anderson *et al.*, 2002; Birke, 2002; Kuhar, 2008; Smith & Kuhar, 2010; Bonnie *et al.*, 2016). The winter season typically has very low visitor numbers so the effects the public have on behaviour may increase during the summer with larger crowds.

The enclosure use varied throughout the study with less use of the island than expected. The group all display high caution to novel experience, which is expected of such a shy species and may be an explanation of limited exploration of the island. It is possible that the Roloway monkeys close to zone 8 may have affected enclosure use, causing Julian to use this area in a territorial manner, while the Bristol group avoided this area completely. The Bristol group showed high vigilance and stayed very close together during November, however in January vigilance decreased and the group began exploring the enclosure more independently of each other. Squirrel monkeys and capuchin monkeys were found to remain close to individuals within their original groups when relocated to a new zoo (Dufour *et al.*, 2001), while Chimpanzees increased affiliative behaviour within their original group (Schel *et al.*, 2012). Potentially these close bonds with familiar individuals are a coping mechanism for the stress caused by an unfamiliar physical or social environment (Schel *et al.*, 2012).

An interest to further studies would be to see if use of the island and of the climbing structures increases overtime as the group habituate to the enclosure. The average temperature during the study was 9°C, which is much colder than the typical 20-30°C a wild drill would experience in Cameroon during the winter (www.Tengwood.org). Increasing summer temperatures at Fota (average 13-20°C) may encourage more even use of the outside enclosure. Langur monkeys and Chimpanzees increased their use of climbing structures, platforms and foliage as the diurnal temperature increased due to the microclimates they provided (Little and Sommer, 2002; Duncan and Pillay, 2013).

Enclosure design is vital to animal welfare, especially during an integration. Commonly behavioural diversity increases with enclosure complexity (Abou-Ismail & Mendl, 2016), often the rate of active behaviours increases (Perkins, 1992; Jensvold *et al.*, 2001; Irving-Lewis, 2004). It cannot be said as to whether this applies to the drill group in this study due to a lack of information on their behaviour prior to their relocation. Future behavioural analysis of the group as they increase exploration of the island may provide similar results to the aforementioned studies.

The drill enclosure was designed specifically to support the relocation and slow integration of the drills in this study and played a vital role in the currently successful adaptation to their new environment. The slow integration approach has been an effective model for (Westergaard *et al.*, 1999; Winslow *et al.*, 1992; Cooper *et al.*, 2001) and has much lower rates of injury caused by aggressive attacks and increased likelihood of long-term success. This involves giving animals visual access to each other with a physical barrier that prevents contact, in turn creating a sense of safety while adapting to the presence of new individuals (Westergaard *et al.*, 1999; Winslow *et al.*, 1992; Cooper *et al.*, 2001). Having different height levels and access between indoor and outdoor enclosures gives individuals the option to avoid aggressive attacks from within the group (Novak & Suomi, 1989; Westergaard *et al.*, 1999; Herrelko *et al.*, 2015). Areas within the enclosure that are hidden from the view of the public reduce stress and abnormal behaviours (Owen *et al.*, 2005; Kaumanns *et al.*, 2006; Chosy *et al.*, 2014). Animals who have control over their environment through enclosure complexity and choice of indoor and outdoor environment experience less stress, as was seen in marmosets (Badihi, 2006)

In conclusion, the group is thought to have good welfare as many species typical behaviours were present and very little stereotypic behaviours were seen. This gives reinforcement that the drills are adjusting well to their new enclosure and to the new individuals within the group. The integration process to date can be deemed successful as no agonistic behaviour occurred between the two groups. Some groups of primates take long periods of time to integrate into one functioning group and to begin showing affiliative behaviour. Schel *et al.* (2013) found that a year after integration, a group of chimpanzees were still very distinct in their original groups. Considering this, displaying from females Inneke and Lewa towards the alpha male gives a promising potential for breeding in the future, which would contribute to the currently endangered captive population.

WC: 1274

Total WC: 6574

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WC: 104

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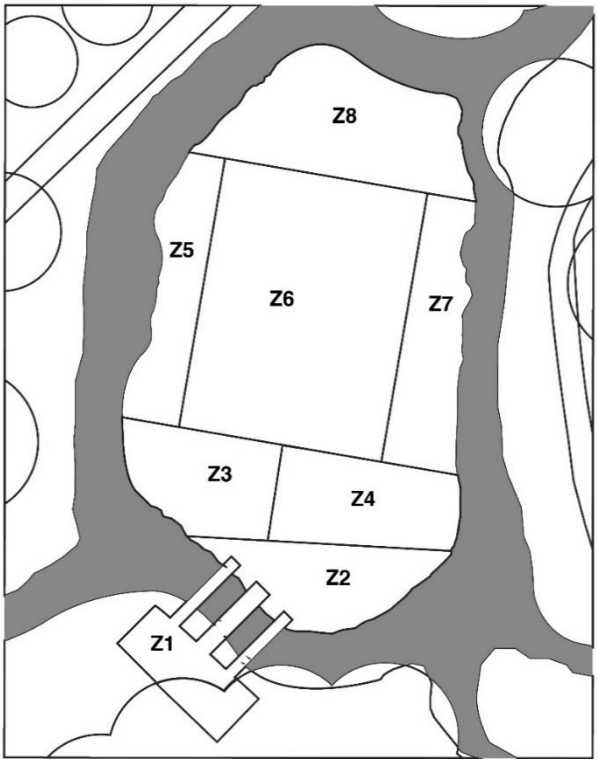
Appendix

Appendix: A1. Zoned map of drill monkey enclosures at Fota Wildlife Park. Created by Aaron Moroney.



Appendix: A2. Personality traits described for personality survey.

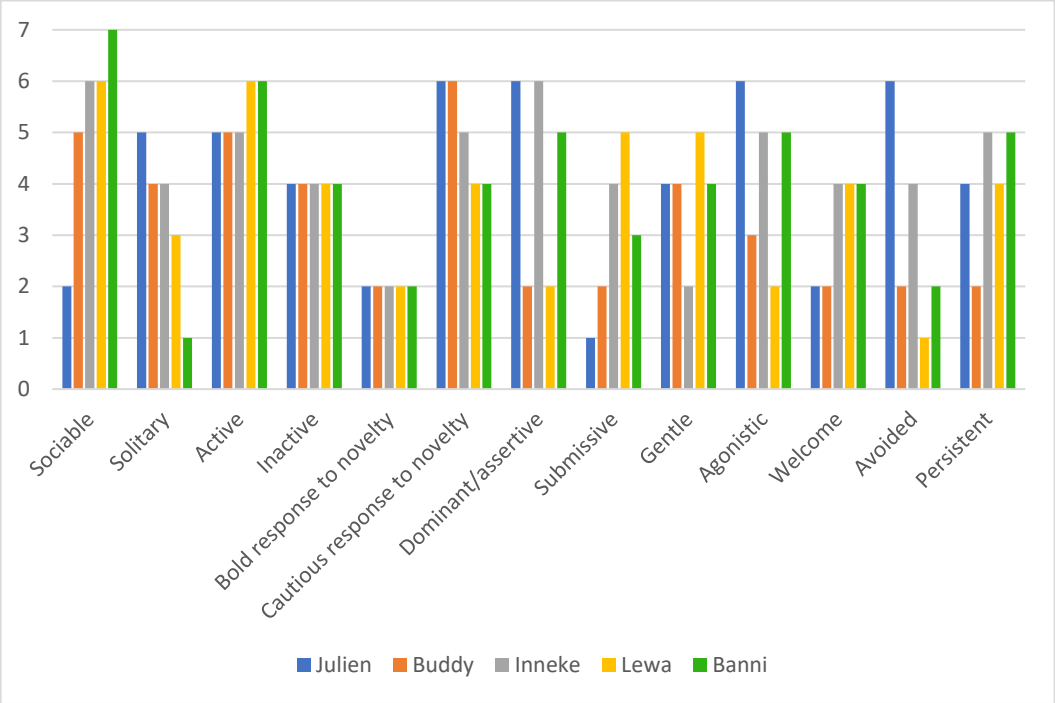
Personality Trait	Description
Sociable	*Spends a lot of time with other, allogrooming, playing*
Solitary	*Out on own*
Active	*Engages in active behaviour*
Inactive	*Predominantly resting behaviours*
Bold response to novelty	*Shows interest, not afraid*
Cautious response to novelty	*May show interest but does not approach quickly*
Assertive (Dominant)	*Displaces others without aggression*
Submissive	*Yields place, food or affiliative relationship to another*
Gentle	*No threat/aggression when others interact*
Agonistic	*Threatens others*
Welcome	*Others allow individual to approach*
Avoided	*Others move away when individual approaches*
Persistent	*Will try repeatedly to gain an item; re-approaches individual after aggressive rebuff*

Limitations of the study

One day, November 9th, deviated from the control of mild dry weather when occasional brief showers occurred in the morning. Observations continued as normal due to all animals being inside the house both before and after the shower. This may have impacted upon results.

Another factor which was out of the observer's control was when the keepers would enter the drill house. The presence of the keeper changed the behaviour of the group by increasing activity and causing animals to flee outside occasionally.

Appendix: A3. Personality score for each drill on a scale of 1-7 (1= never seen, 7=always seen) based on personality surveys filled out by keeper T. Power.



WC: 87