The challenge of regurgitation and re-ingestion in orang-utans at Auckland Zoo

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Regurgitation and re-ingestion (R/R) is a behaviour seen in captive non-human primates to describe forceful and voluntary ejection of vomitus material out of the stomach which is then re-ingested. It differs from vomiting as the action is controlled and voluntary and not caused by a stomach reflex. As well, it differs from rumination in herbivores with compartmentalised stomachs because primate anatomy does not include R/R as a part of normal digestion (Hill, 2009). R/R is described widely in the literature as an abnormal and undesirable behaviour and is only seen in captive apes, although anecdotally it has recently been observed in released orang-utans in Sumatra. Hill (2009) describes an abnormal behaviour as "differing in pattern and frequency than would be expected in an environment allowing full behavioural range". Because it is abnormal, assumptions can be made of decreased welfare due to disruption of natural behavioural repertoires, or, a limiting ability to cope with the environment (Mellen, Singleton, & Sodaro 2007). There are also potential health issues. R/R is most often described in captive gorillas and chimpanzees but recent research demonstrates the prevalence of R/R in captive orang-utans in North America. R/R is said to occur as part of a post prandial expression of feeding frustration (Lukas et al. 1999), with numerous interlinked variables related to diet and inactivity stated widely in the literature.

Auckland Zoo in New Zealand houses five Bornean orang-utans and one hybrid orang-utan of varying ages, housed in two separate groups, of which four animals have a high frequency of R/R compared to those in North America. They spend 22% of their daily activity budget engaged in the behaviour with R/R bouts occurring after nearly every meal, multiple times a day. Some training sessions are interrupted with the animals stopping to R/R in the middle of a session.

A study within captive North American populations demonstrated Bornean orang-utans to have a higher prevalence of R/R (45%) than Sumatran (18%) and hybrid orang-utans (42%) (Cassella, 2012). There are various speculations as to the root cause of R/R and these are well known: feeding sweet foods, feeding out produce grown for human consumption that is high in sugar and low in fibre; low levels of high fibre items in the diet such as browse; lack of foraging and feeding behaviour opportunities and boredom, stress and anxiety. In gorillas and chimpanzees, potential causes of R/R have been attributed to social deficits in early development (Gould & Bres, 1986), boredom, restricted living areas, feeding frustration, or lack of control (Ruempler, 1992; Lukas, 1999). A disease in humans called Human Rumination Syndrome (HRS) has been compared to R/R in captive apes. Although there is no evidence available describing health issues associated with R/R in orang-utans, humans with HRS often suffer from dental erosion, oesophageal dysfunctions, ulcers and pulmonary aspiration, from repetitive regurgitation of stomach acid. Hill (2009) found regurgitated material from gorillas to be more acidic than the food consumed therefore there may be similar risks with HRS for animals who practice R/R.

Why did we care? As a progressive zoo that prides itself on achieving best practice standards in animal welfare, we are not comfortable with the levels of R/R we see in our orang-utans despite husbandry and animal management changes we have made in recent years. Combined with potential health consequences this behaviour may be indicative of sub-optimal welfare. We have a female who suffers from air sacculitis at times and frequent R/R may exacerbate her condition. A reduction in feeding behaviour in comparison to the wild is a welfare concern because ultimately their behavioural repertoire is reduced therefore limiting opportunities to exhibit behaviours that would typically be displayed by a wild orang-utan. We aim to provide as many opportunities as possible to display natural

behaviour both for welfare reasons and visitor education. Negative or misunderstood visitor perceptions of R/R are an additional concern as we aim for our visitors to have a positive experience of zoos. You only have to look at YouTube to clearly see the misunderstood nature of R/R and how it appears to zoo visitors.

Many of Auckland Zoo's orang-utans have a higher prevalence of R/R compared to those surveyed in North America. We have been able to identify a number of causative factors that we continue to work through. Literature suggests females are more prone to R/R but we find the males the worst. This behaviour has been taught to our youngest animal, a 9 year old male, through observational learning along with very specific pre-R/R behaviour.

Keepers noticed a relationship between the amount of browse and the types of food fed to the orangutans in relation to the prevalence of R/R. We commissioned a student to undertake a research project to measure the effects of different browse availability regimes on regurgitation behaviour in four of the orang-utans held at Auckland Zoo. These included normal browse days (control) where browse supplemented the fruit and vegetable diet, usually twice per day; browse free days where no browse was offered, increased browse days where browse was offered immediately after every meal and browse only days where no other foods were offered except browse. Twenty hours of data for each regime were collected.

In this study the mean number of R/R bouts in the group was 125 per day under control conditions, or 22% of their activity budget. This reduced to an average of 10 bouts per day or 1% frequency, with browse only days. All four individuals studied were observed performing R/R with frequencies ranging from 0 bouts to 80 bouts per thirty minute observation period for the group, across all regimes.

Prior to the commencement of the study various interventions/deterrents were trialled such as adding unpalatable ingredients like hot sauce to the regurgitated material and washing it away with water, but this had no long term effect as the orang-utans got increasingly clever with where they would do it and some even enjoyed the taste of hot sauce. We are working to identify food items most associated with R/R and modify the diet accordingly by reducing or eliminating these items and providing opportunities for post-prandial activity that override R/R.

We believe a combination of diet manipulation and increased browse availability as well as provision of an appropriate arboreal environment will result in a reduction and eventual elimination of R/R behaviour and therefore improve the welfare of our orang-utans. Wherever possible we avoid having the orang-utans in areas that encourage R/R for prolonged periods – this includes access to certain areas of their indoor facility with clean, flat surfaces, without activities such as behavioural enrichment or browse to occupy them. There is evidence to suggest a higher occurrence of R/R whilst in indoor enclosures.

This slide is representative of a typical orangutan's diet at Auckland Zoo. It is complex and changes each day and season but we recognise it contains excessive sugar, with a large proportion of the diet being fruit with the addition of vegetables, legumes and leafy greens. The orangutans receive a form of protein most days – either: nuts, cooked egg, cooked chicken or tinned salmon.

Wild primates spend much of their day foraging for high-energy food (Oates, 1987; Strier, 2003). Wild orang-utans spend around 60% of their daily activity budget foraging with the remainder of their time spent moving almost entirely arboreally between feeding sites and resting. Foraging involves finding, processing and consuming food which requires both

manipulative and intellectual skill. Because of the boom or bust, variable environment orang-utans live in, food availability differs throughout the year. Thus, calorie and nutrient content of food also changes and orang-utans must spend most of their day searching for, processing, and consuming food to meet energy requirements. (Cassella, 2012.) Orangutans have evolved to handle this changeable food availability whereas captive environments differ dramatically. Food fed out in zoos is high in energy and eaten quickly with little to no skill necessary to acquire it. Calorie and nutrient composition do not often fluctuate in a zoo environment (Cassella 2012, Jaeggi et al., 2010.)

An orang-utan's natural diet is at least half fruit, with leaves and bark the next most commonly consumed items (Morrogh-Bernard 2009.) Knott (1998) proposed that during fruiting season, orang-utans store excess energy for times of low fruiting. This was based on the presence of ketones, which are products of fat metabolism found in wild orang-utan urine during the non-fruiting season. This suggests an adaptive ability to gorge to excess when food is plentiful and efficiently store fat thereafter. This is beneficial for a wild orang-utan in times of hardship but could easily facilitate obesity in captivity. In addition, orang-utans have a very slow metabolism that may make them more susceptible to weight gain (Pontzer et. al 2010.)

Browse

A lack of species-typical feeding opportunities may be expressed through frustrated feeding behaviour, such as R/R but can be minimised by prolonging feeding time through provision of browse (Casella et. al 2012). Browse mimics prolonged and continual access to food as would happen in the wild and is any consumable plant material that includes bark, pulp, leaves and stems. The majority of our orangutans' regurgitation cycle is spent on re-ingestion, which may suggest an attempt to prolong feeding time. This is consistent with findings from Loeffler (1982) and Lukas (1999.)

The usefulness of browse in gorilla and chimpanzee diets to mitigate the frequency of R/R is well documented. Browse acts as a deterrent by increasing feeding time, replicating more closely what wild conspecifics would eat. This has been well documented (Gould & Bres, 1986; Ruempler 1991, 1992; Wiard 1992; Baker & Easley 1996; Baker 1997; Hill, 2004; Struck et. al 2007; Fogarty et al, 2008; Less, 2012). Fritz et al (2007) increased orangutan feeding time by 43% with the addition of browse and Cassella, Mills and Lukas (2012) increased feeding time by 13% in a group of orangutans.

In our study there was a 38% increase in feeding behaviours during the browse only regime where the animals spent 80% of their time feeding, compared to the control at 42%. There was also very little change in R/R frequency between the control and no browse regimes. Providing continuous access to browse is beneficial: it increases feeding and foraging behaviours similar to wild orang-utans which in turn reduces R/R behaviour. It also provides them with more control over their environment, which improves welfare. Using browse-only days can offer a break from continuous regurgitation behaviour.

Observations throughout our study noted a preference for different browse species and the provision of some types had no effect in delaying or minimising R/R. If a desirable species was offered with a less desirable, the favourite would be consumed immediately after fruit and vegetables and the less favoured would sometimes not be consumed at all, so R/R became more preferable. This suggests that if insufficient fibre was the underlying cause of R/R they would have consumed all browse provided and it is likely they were trying to re-consume desirable food or increase satiation.

R/R may also occur as a way to increase satiety. Fibre maximises satiety and lack of it may be a contributing factor to R/R. In the non-fruiting season, bark and leaves which are high in fibre, make up a significant proportion of a wild orangutan's diet, perhaps to help them

feel full. A fibrolytic bacterial process converts the fibre into usable sugars which are then absorbed as energy. Bark can be up to 74% fibre and leaves up to 70% (Knott, 1998) which is higher than fruit and vegetables (Schmidt 2007). Captive orang-utan diets may be lacking sufficient fibre compared to that of a wild orang-utan (Cassella 2012). Evidence suggests that orang-utans evolved to consume a high fibre diet outside the fruiting season. They store excess energy during the fruiting season when they gorge, for use in times of hardship so they are able to maintain a positive energy balance (Knott, 1998). Neutral detergent fibre is the most commonly used measure of fibre in food and is the fibrous parts of plants left behind from a process using a neutral detergent to dissolve plant pectins, proteins, sugars and lipids (www.wikipdedia.org). Knott (1998) reported that neutral detergent fibre comprised 24 – 61% of a wild orang-utan's diet. It is incredibly difficult to meet the average fibre content consumed by wild orang-utans when feeding their captive counterparts commercial produce and biscuits. The addition of browse increases the fibre content in the diet and plays a vital role in not only the physical health of the animal but the psychological aspects of feeding and foraging which if adequately met, should mitigate the occurrence of R/R. Because of this we expected the no browse regime to increase regurgitation through removal of a feeding opportunity and lowering of fibre content, as evident in similar studies. As I've previously mentioned, our study showed no significant difference in regurgitation behaviour when browse was decreased. High fibre diets may also be associated with reduced obesity levels which in turn promotes good health of captive orangutans.

Meal spacing

Cousins (2015) suggests that providing orang-utans with an ongoing source of edible material may have an impact on the reduction of R/R because they aren't compensating for

an absence of feeding opportunities between meals that may be widely spaced. There is evidence demonstrating a correlation between R/R rates and time since the previous meal in captive chimpanzees (Baker 1996**)**. Therefore, increasing meal frequency or providing a constant supply of edible material could be more beneficial than adjusting diet composition (Baker and Easley 1996). We have trialled providing more frequent fruit and vegetable meals by feeding small amounts often but found it caused frustration and anxiety as the adult males in particular were never fully satisfied. It did not reduce R/R. This may be relevant to Charlie, our adult male who practices the highest levels of R/R, who, with a larger body size may have little satiety and increased feeding frustration compared to the others. This may also help explain why he was the only orangutan to have a reduced R/R frequency during the increased browse regime.

Sweet foods

The high desirability of sweet food means R/R is likely to occur to prolong consumption. The types of food that captive orang-utans regurgitate most frequently is similar to what wild orang-utans prefer to eat. Wild orangutans prefer fruit over more fibrous food like browse (Hamilton & Galdikas 1994; Bastian et al., 2010; Kanamori et al. 2010) and will consume a diet that is entirely fruit if it is available (Kanamori et. al, 2010; Knott, 1998.) Orangutans can taste sweet compounds at a lower threshold than other great apes (Simmen & Charlot 2003), so this would lead us to believe that captive orangutans have similar preferences. All available literature on R/R in orang-utans most commonly identifies fruit and sweet foods as triggers. Fruit contains the simple sugar fructose, which is among the sweetest of the sugars. Given the incredibly high sugar content of commercial produce (Schmidt 2007) that is made for human taste this makes orang-utans want to re-consume these items more

often. Simple sugars are quickly absorbed by the body to produce energy. They are broken down into glucose, which is either used for energy or stored for later use. These foods are typically referred to as “empty calories” because they provide a lot of energy but very few nutrients like essential vitamins, minerals, fibre and fatty acids. Simple sugars aren’t readily available in the wild, but preferred by orangutans as an energy resource (Hladik & Simmen 1997.) Cooked vegetables have increased sugar concentration of up to three times that of raw vegetables so it is advisable to omit cooked vegetables from captive orang-utan diets.

Our study also focussed on measuring a correlation between sweet foods and R/R. Sweet foods that showed high R/R bouts were items such as kiwi, corn, grapes, sweet potato, apple and even tinned salmon. R/R significantly increased when sweet food was present over all regimes measured. During control observations, the group increased from 17 bouts per 30 min observation in the absence of sweet food, to 210 bouts with sweet food present - a 93% increase. Our study showed that days with browse only significantly decreased R/R to less than 1% compared to the control at 22% (Andrews 2015). This was accompanied by a significant increase in feeding time.

Sweet food will mitigate the effect of browse if available, which was proven in our increased browse regime in three out of four orangutans. Browse was offered to each orangutan after every meal of fruit and vegetables. The expectations were that R/R would decrease as both produce and browse material were on offer allowing increased feeding opportunities. There was no significant statistical difference in regurgitation behaviour when comparing the two regimes at just under 5%. Although browse may help to reduce R/R by prolonging feeding time, it is likely R/R still occurred in response to desirable food items being fed prior to browse. The orangutans may have preferred to R/R fruit as a way to prolong feeding

behaviour with a desirable food item rather than to prolong feeding in general by consuming browse. (Andrew 2015.**)** The results of the study indicate sweet food is a main trigger for R/R in this group of orang-utans, the presence of which mitigates the effect of increased browse availability. There is scope for further research here as different types of browse can significantly mitigate R/R if they are favoured species. Adult male Charlie was the only animal to show a change in R/R frequency with a decrease of 17% - this is similar to expected results and indicates R/R occurs as a group and individually (Andrew 2015.).

Captive orang-utan diets are often similar to wild diets at face value but not necessarily nutritionally balanced. Schmidt recommends a captive daily diet of 60% leafy greens, 30% vegetables, and 10% fruit to sustain a nutritional balance with appropriate fibre and sugar content. She compared sugar concentration and fibre content in captive orang-utan diets between different food groups to establish ratio. Fruit had 40% sugar concentration and 13% fibre concentration, vegetables had 26% sugar and 19% fibre, and leafy greens had 18% sugar and 19% fibre.

Eliminating fruit entirely from orang-utan diets may not be feasible due to their frugivorous nature however a reduction combined with an increase in vegetables, leafy greens and browse may help reduce R/R. We are undergoing trials to determine which vegetables elicit R/R. We tested this with days when our orang-utans were only offered a variety of green vegetables and legumes such as peas, beans and sprouts as well as browse. We did not analyse the data statistically but R/R was seen on only one occasion over the day. We are further testing the extent of trigger foods by offering greens and browse only days with the addition of one high fibre vegetable. There was an additional benefit that correlated with our greens only days – the day after one of the trials one of the males was scheduled for an anaesthetic. Charlie displays the highest levels of R/R and we have issues with orang-utans regurgitating during anaesthetics despite a starve period prior. Whether or not it was a

coincidence, we did not have any regurgitation issues during this anaesthetic compared to the previous few.

Activity level

As is obvious so far, there is a link between increased foraging and reduced abnormal behaviour in captivity. Lukas et al (1999) found a negative correlation between R/R and activity level in a group of captive gorillas. This suggests that reduced activity levels in comparison to wild counterparts may also be a contributing factor to R/R prevalence.

The benefits of providing an increase in browse is two-fold: not only does it allow for prolonged activity including natural processing and manipulation skills, it increases activity levels. Studies have found that orangutans with reduced R/R levels become more active which has obvious health benefits. Orangutans are known to be reasonably inactive in zoos (Wright, 1995) and spend an unnaturally large proportion of time on the ground, often in a state of inactivity which in turn promotes R/R. When we increase species typical behaviour in captivity we reduce abnormal behaviour and improve welfare.

Various enrichment feeder devices have been used successfully to lengthen foraging time and deter or delay R/R through increased activity.

AZ's orang-utans have an extensive behavioural and environmental enrichment program and we have found arboreal feeders lengthen the time between R/R and even prevent it if suitable browse is used. We would like to further investigate seasonal differences too. This study was conducted in summer when the orang-utans spend the majority of their time outdoors. Orangutans are less active in winter and spend a lot of time inside at Auckland Zoo because of high rainfall. Lukas et al. (1999) found a higher incidence of R/R in the winter compared with summer when the gorillas ate more hay and engaged in more R/R.

An interesting observation keepers noticed recently is the provision of shredded paper bedding at the end of the day prevents R/R from occurring despite the evening meal

containing sweet food items. The orang-utans engage in nest building for 30 minutes or more before sleep, so the paper had a mitigating effect on R/R. This has been found in a previous study with gorillas by Gould and Bres (1986) and chimpanzees by Baker (1996) where the provision of bedding reduced R/R frequency.

R/R is the only abnormal behaviour displayed by our orang-utans and not all our orang-utans practice R/R. We recognise there are aspects lacking in our enclosure to enable them to display their full range of natural behaviour which may impact on the levels of R/R we see. This will be remedied in the next two years with the redevelopment of the orang-utan facilities which will provide extensive opportunities to travel, rest and feed arboreally. Our orangutan collection is about to be halved next month with the transfer of three of our animals to North America. We plan to continue to utilise the browse provision for six orangutans for the remaining three animals to help reduce the prevalence of R/R. Our ultimate goal is to eliminate R/R completely from the orang-utan's activity budgets. We plan to achieve this through a combination of diet manipulation by providing appropriate browse and incorporating browse only days into their management. This will be coupled with a review of diet content to significantly reduce the sugar component and increase leafy greens as well as make improvements to their environment to allow a wider range of species-typical behaviour. We are confident that the current levels of R/R will be significantly reduced and eventually eliminated and therefore improve the welfare of Auckland Zoo's orang-utans. The overall conclusions of our research backed up by the available literature show this is a complex issue with numerous interlinked variables that contribute to R/R, the most important being the availability of browse and the reduction of fruit.

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