A PILOT STUDY INVESTIGATING THE BEHAVIOUR OF HORSES MANAGED INDIVIDUALLY IN SMALL PADDOCKS AND EFFECTS OF A SLOW-FEEDING DEVICE

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science
in
Zoology

at Massey University
Palmerston North, New Zealand

Jamie Corkill
2020

Abstract

This thesis discusses an observational pilot study, which explores the time budget of four horses kept individually in small paddocks. The horse (*Equus caballus*) evolved as a highly social, cursorial grazing mammal that roamed open grasslands in herds. Current research indicates domestic horses experience better physical and mental health outcomes when kept under similar conditions. Thus, through the lens of horse welfare, keeping horses at pasture is preferred to stabling or yarding. In New Zealand, most horses are kept at pasture year-round. However, the way horses are managed at pasture can vary significantly. Few studies have investigated how the size of a paddock or whether horses are kept alone or in company, affect a horse's welfare. This thesis begins to fill in the gap by characterising the behavioural time budget of horses kept alone in small paddocks. The findings are contextualised through a literature review of the time budgets of horses kept under different management conditions. This information could aid horse owners in making informed paddock management decisions that aim to improve horse welfare.

Although the horses in this study could graze, the restrictions imposed by small, socially isolated paddocks were similar to that of stables. As seen in time budgets of stabled horses, I hypothesised that the horses would spend a large proportion of their time standing. Slow-feeding devices, such as 'foodballs', have been found to significantly increase the time horses spent eating concentrated feeds in stables and yards, and often reduced the time spent standing. As there has been no published research examining the use of foodballs when horses are on grass, this thesis also investigated whether horses will be motivated to use the device, and if so, how effective it is at slowing concentrate consumption and altering the overall time budget of paddocked horses.

For the first part of the study, the behaviour of four privately-owned horses managed in their usual 132m^2 paddocks at the Massey University Equestrian Centre, Palmerston North, was monitored through video recordings. Horses were filmed continuously during four, one-hour observation periods (7-8AM, 11AM-12PM, 4-5PM, 5-6PM) during daylight hours for three baseline days. A total 38 hours and 23 minutes of recordings were used in the baseline data analysis, 9 hours 48 minutes each for three horses, 8 hours 59 minutes for one horse. The proportion of time all horses spent in each behaviour during these four-hour time periods a day, was used to form a daily time budget. Horses spent a median (IQR) 75.4% (50.9%-94.5%) of their time grazing, 14.3% (2.9%-36.1%) standing and resting, 2.1% (1.1%-3.9%) in locomotion, and 0% (0%-0.2%) grooming. The data was then grouped into observation periods and analysed for time of day effects. Only the time spent in locomotion varied significantly with time of day ($p=0.01$), peaking at a median 5% during the evening period in which the horses received a concentrated feed, compared to median 1-3% for all other times of day.

For the second part of this study, the horses were taught to use a foodball and a portion of their normal concentrated feed was supplied in the device for three days, before being filmed again on the fourth day. A total 11 hours 26 minutes of recordings were used in the data analysis, 3 hours 16 minutes each for two horses and 2 hours 27 minutes each for the other two horses. During the foodball condition, horses would use the device until empty, interspersing the activity with eating the concentrated feed supplied in a bucket and grazing. The time spent eating concentrates increased significantly from that of the baseline condition ($p=0.045$). However, the percentage of time spent in each other state behaviour during the evening periods was not found to be significantly different between conditions, and in both conditions horses spent most of the evening grazing (around 72%).

In summary, the four horses were observed to spend most of their time grazing, similar to what is reported for feral horses and horses in large paddocks. However, these horses spent comparably very little time in locomotion or grooming, and had no physical social interactions. Providing a foodball slowed down concentrate consumption significantly, though did not significantly affect the time spent in other states. In a practical context, the results of this study suggest that keeping a horse in a small paddock does not reduce the time spent grazing compared to studies of horses kept in larger enclosures. Additionally, as this was the first study to use a foodball on grass, it was useful to find that the horses were motivated to use the device until empty.

Acknowledgements

I would like to acknowledge a number of people, whose input and support were integral to the completion of this thesis.

To my supervisors, Dr. Ngaio Beausoleil and Dr. Charlotte Bolwell, thank you for your guidance and expertise. You were quick to adapt and support me during the year's public health crisis, and we all learned to love Zoom.

To Anna Palmer, thank you for facilitating my contact with members of the Massey University Equestrian Centre, and helping me initially secure eight horses for the study.

To Anna Palmer, Sophie Jansonius, and Grace van Cingel, thank you so much for letting me film your horses, and for your willingness to teach your horses to use a foodball, and feed from the device for several days.

To Neil Ward, your help with preparing the video files was much appreciated.

I would also like to express my gratitude to those who selected me to be a Heseltine Ecology Bursary recipient this year.

Ethical statement

Ethical approval was granted by the Massey University Animal Ethics Committee (approval no. 19/132). Animal husbandry and care were under the management of the respective owners. Owners were asked to complete a short survey regarding the management and feeding of their horse. The project was evaluated by peer review and judged to be low risk by the Massey University Human Ethics Committee (ethics notification no. 4000022025).

Table of contents

List of figures

List of tables

1. General introduction

In natural settings, horses are highly social herd animals that spend most of their time grazing. However, most forms of captive management present some degree of social, dietary and/or spatial restriction. In general, captive management has been demonstrated to influence horse behaviour by limiting the distance horses travel and time spent grazing, restricting the expression of natural behaviours, and producing stereotypical behaviours (Hampson et al, 2010b; McGreevy et al, 1995; Sarrafchi & Blokhuis, 2013; Werhahn et al, 2011). There are different ways of managing horses, such as stabling and paddocking, and they are likely to have different impacts on behaviour and welfare. The effects of stabling on the horse has received much attention in the literature, no doubt because it is a common practice in European countries, and considered to be far removed from natural living conditions (Kiley-Worthington, 1990; Nover, 2013; Werhahn et al, 2011). Although paddocking is generally recommended as the superior form of captive management for horse behaviour and welfare, it has received comparatively little scientific attention.

One way to mitigate the effects of social and/or spatial restriction in captive environments on horse behaviour is to provide behavioural enrichment. Horses have been found to be most motivated to engage with enrichment when it involves food (Jørgensen et al, 2011). However, all studies on feeding enrichment in horses have been conducted in stables and bare dirt yards in European countries. Horses are managed differently in New Zealand, with the temperate climate allowing many horses to be kept on pasture year-round. The need for, and effectiveness of, feeding enrichment when horses are managed on grass is so far unknown.

In New Zealand, it is not uncommon to keep non-commercial horses in small paddocks, and it is so far unknown how horses behave under this form of management. Many non-commercial horses in New Zealand are kept on pasture originally intended for dairy, beef, or sheep (Fernandes et al, 2014). These pastures are characterised by grasses far richer than the low-energy fibrous forage horses evolved eating (Sneddon & Argenzio, 1998; Watts, 2010).

Unrestricted access to New Zealand pasture is often more than enough for the maintenance of an adult horse, and during periods of grass growth the feeding value of quality pasture can be high enough to lead to obesity (Hoskin & Gee, 2004). Three-quarters of New Zealand Pony Club horses are kept on pasture year-round, according to a survey, and half of a studied population had a body condition score that identified them as fat (Fernandes et al, 2015). To mitigate obesity and other grass-related issues, such as laminitis and high-energy behaviour, horse owners often restrict the size of the paddock (Geor & Harris, 2009). To date, there has been little research into the behaviour of horses kept on very small paddocks (Maisonpierre et al, 2019).

This thesis consists of a literature view and an observational study. The literature review firstly provides an overview of the behaviour and ecology of free-ranging horses and the effects of captive management on horse behaviour. It then reviews the relevant literature surrounding the effects of providing feeding enrichment to horses. Lastly, the literature review evaluates the current knowledge surrounding how non-commercial horses are kept in New Zealand, and also highlights the areas which require further research. The observational study explores the behaviour of non-commercial horses kept in small paddocks and the effect of a slow-feeding device on behaviour, then discusses the findings of this thesis.

2. Literature review

The following literature review firstly provides an overview of the behaviour and ecology of free-ranging horses and the effects of captive management on horse behaviour. The relevant literature surrounding the effects of providing feeding enrichment to horses is then reviewed. Lastly, the literature review evaluates the current knowledge surrounding how non-commercial horses are kept in New Zealand, highlighting the areas which require further research

2.1 Behaviour and ecology of free ranging horses

Observations of feral horses influence our understanding of natural horse behaviour
The horse (*Equus ferus caballus*) is an odd-toed ungulate of the taxonomic family Equidae. *Equus* is the only extant genus of Equidae, and is comprised by seven extant species, including horses, donkeys and zebra. The only other extant member of the *Equus ferus* species is the Przewalski's horse (*Equus ferus przewalskii*). This sub-species is widely considered to be the only extant wild horse, however, recent genomic studies have discovered domesticated contribution to the breed ~5500 years ago (Gaunitz et al, 2018). Aside from Przewalski's horses, most free-ranging horse populations are descended from escaped or released stock and thereby considered feral. Wild and feral horse populations from around the world are studied in order to gain an understanding of many aspects of adaptive equine behaviour, such as social behaviour and foraging choice. (Goodwin, 2002). Thus, feral horse behaviour can be used as a reference point for natural behaviour.

2.1.1 Time budgets

The time budget of feral horses represents the characteristics of the species and the environment. Time budgets convey how animals divide their time between behaviours that satisfy their basic needs, such as food, movement and rest (Boy, 1979). Time budgets can vary within feral horses according to age, sex, and season (Duncan, 1980; Kaseda, 1983). For example, foals have been found to spend more time resting each day than adult horses (Duncan, 1980), and males have been found to spend more time in motion and exhibit greater numbers of behaviours per hour (Boyd, 1988). The time budget of a free-living horse could loosely be considered the blueprint for natural behaviour, representing a way of living that the horse is evolutionarily well-adapted for (Kiley-Worthington, 1990; Veasey et al, 1996).

2.1.2 Grazing behaviour

Feral horses are commonly reported to spend over half to three-quarters of their time grazing, and there is some seasonal and temporal pattern to this behaviour. For example, feral horses of the western United States were found to graze for 58% of the daylight time observed (Ransom et al , 2010). Feral horses in western Alberta were found to graze for 75% of the time during winter and spring, which sometimes involved foraging in snow, and somewhat less time during summer and autumn (Salter & Hudson, 1979). Likewise, adult Camargue ponies in Southern France were found to graze on grasslands and marsh for 60% of the 24-hour period for which they were observed during spring and summer, and 63% during autumn and winter (Duncan, 1980). These ponies were observed to graze at every hour, though preferentially grazed during the day for all seasons except summer (Mayes & Duncan, 1986). Japanese Misaki horses displayed a different seasonal trend, and were found to graze for 71% of the 24-hour period for which they were observed during winter, and 76% during summer (Kaseda, 1983). Misaki horses were also observed to spend more time grazing at night during summer than winter (Kaseda, 1983). Regardless of season, major grazing periods were commonly observed at dawn and dusk (Kaseda, 1983; Keiper & Keenan, 1980; Mayes & Duncan, 1986). Grazing tended to be lowest during the midday period, especially in summer, during which horses in warmer climates would spend more time grazing at night (Arnold, 1984; Kaseda, 1983). The observed differences in time spent grazing could be related to seasonal and environmental food availability and distribution.

As a hind-gut fermenter, grazing is expected to comprise most of a horse's time budget. This digestive strategy is characterised by high voluntary food intake and rate of passage of digesta, and has allowed horses to be more successful at utilising low-quality grasses than fore-gut fermenters (Sneddon & Argenzio, 1998; Van Soest, 1996). For example, a feral horse will graze for 14-18 hours a day with a mean retention time (MRT) of feed residues of 35 hours (Pearson et al, 2006). A cow fed the same grass-hay diet will graze for 6–10 hours a day, and spend 6–8 hours in rumination, with an MRT of 60 hours (Pearson et al, 2006; Smith, 1999). The digestive strategy of horses is therefore advantageous in low-quality systems with plenty of dry, fibrous foliage (Pearson et al, 2006; Sneddon & Argenzio, 1998). When food is of higher quality and restricted, the slower fore-gut fermentation of ruminants is the more effective strategy for gaining nutrients (Pearson et al, 2006).

2.1.3 Standing and resting behaviour

After grazing, feral horses tend to spend most of their time standing. Horses will stand for a quarter to a third of their time, either in an awake, drowsy, or slow-wave sleep state (Carson & Wood-Gush, 1983; Duncan, 1980; Kaseda, 1983; Ransom et al, 2010; Zeitler-Feicht, 2003). A passive stay apparatus, the patella lock mechanism, allows horses to stand with limited muscle activity and even achieve slow-wave sleep (Schuurman et al, 2003). Horses need to lie down for the fourth stage of sleep, rapid eye movement (REM) sleep to occur (Carson & Wood-Gush, 1983). REM sleep tends to make up a quarter of total sleep time, approximately 45-minutes in each 24-hour period (Belling, 1990). Horses spend far less time in lying down rest, either lateral (lying flat on one side) or sternal recumbence (lying with legs tucked underneath), than in standing rest (Boyd et al, 1988; Duncan, 1985). This is attributed to the comparatively short time spent in REM sleep, the vulnerability of the horse to predation while in this position and depth of sleep, and a physical incapability for maintaining the position (Belling, 1990; Carson & Wood-Gush, 1983). During lateral recumbence, the weight on the thorax of a mature horse eventually blocks respiration, thereby limiting the comfort of the position to bouts of 15-minutes (Fraser, 1980 in Carson & Wood-Gush, 1983). Lying has been found to occur mostly at night and makes up 4-5% of the feral horse time budget, with lateral recumbence constituting approximately 1% of this duration (Boyd et al, 1988; Duncan, 1985).

2.1.4 Social behaviour

Horses are highly social animals that form bands and display high levels of behavioural synchronicity. Feral equids tend to form family or bachelor groups of 2-35 individuals (Ransom & Kaczensky, 2016). Family groups are generally comprised of a single stallion and a harem of mares, including a lead mare, and their young. The horse social structure is matriarchal, and the stallion tends to neither be the most dominant nor most aggressive member of the band (Goodwin, 1999). Feral horses and captive horses managed in groups tend to display high levels of behavioural synchronicity, which is considered to be a behavioural adaptation that functions to keep the herd together (Rifa, 1990). Bands tend to be most synchronous during feeding behaviour, and are generally only partially synchronous for rest. It is hypothesised that this partial synchronicity when members are non-alert functions to reduce vulnerability to predation (Rifa, 1990).

Feral horses reportedly spend around 7% of their time directly engaging in social behaviours, such as allogrooming, nursing, agonism, herding behaviour, and reproductive behaviour (Ransom et al, 2010). These moments of physical contact are often how social behaviour is quantified in time budget studies (Boyd et al, 1988; Duncan, 1980; Ransom et al, 2010). However, most social interactions between horses are conducted from a distance (Heitor & Vicente, 2010; Rifa, 1985, 1990). As herd animals, horses are well attuned to body language and personal space. Horses use escalating cues to communicate for example, aggression, that only if ignored may lead to a physical altercation (Goodwin, 1999). As this communication can occur while the horse is engaged in other activities, such as standing or grazing, traditional classification of social interaction likely understates the scale of social behaviour occurring.

2.1.5 Locomotion

Feral horses tend to cover many kilometres each day and spend up to a tenth of their time in locomotion not related to grazing. For example, three Australian brumbies fitted with GPS collars were found to cover an average of 17.9km per day, and a subsequent study by the same research team found 12 brumbies to cover 15.9 ± 1.9km (range 8.1–28.3 km) per day (Hampson et al, 2010a; Ransom & Kaczensky, 2016). In feral horse bands, this non-grazing locomotion reflects travel on regular routes between key resources, such as water and grazing, within a home range (Miller, 1983). Home ranges have been found to range from 7-303 square kilometres (Berger, 1986; Hampson et al, 2010a; Miller, 1983; Ransom & Kaczensky, 2016), though the size can be highly seasonal and vary greatly with the productivity of the system and number of members. Feral bands have been observed to arrive at certain locations within their home range at the same times year after year, mirroring something of a rotational grazing system (Miller, 1983). Time budget studies have reported that feral horses spend 7-10% of their time in locomotion not related to grazing (Duncan, 1980, 1985; Ransom et al, 2010; Rifa, 1985). Where specified, walking was the main pace observed, constituting at least 90% of locomotion across studies (Duncan, 1980, 1985). Season had some influence on locomotion in feral Camargue ponies, with walking shifted primarily to daylight hours during summer (Duncan, 1985). This pattern was hypothesised to be a response to attacks from biting flies (Duncan, 1985).

2.1.6 Summary

In summary, feral horses are highly social grazing animals that travel over home ranges that range from several to hundreds of square kilometres in size. Feral horses spend the majority of their time grazing, and their digestive system has evolved to specialise on low-energy, high-fibre forage.

2.2 Captive management

Horses are managed in captivity for a variety of commercial and non-commercial purposes, and although the characteristics of enclosures can vary greatly, captivity always presents some degree of social, spatial, and/or dietary restriction. Previous attempts to evaluate the effects of captive management on horse behaviour have compared the time budgets of horses in various enclosure types to that of feral horses (Kiley-Worthington, 1987; Winskill et al, 1996). The main categories of horse enclosure are stables, yards and paddocks.

2.2.1 Stables

Stables represent the most intensive form of horse housing, and are characterised by indoor and often individual stalls. Stables are commonly reported to range from 9-14m^2 (Sweeting et al, 1985; Thompson et al, 2017; Werhahn et al, 2010; Werhahn et al, 2011), though guidelines can differ between countries. The substrate is either porous and drains urine and water (topsoil, clay mix, gravel, wood, grid mats), or impervious and drains wetness via a slope (concrete, asphalt, solid rubber mats) (Wheeler & Smith Zajaczkowski, 2016). Bedding is applied on top of the substrate to absorb excrement, provide insulation, improve skid resistance, and make standing and lying more comfortable (Werhahn et al, 2010). Stable blocks often have some form of artificial lighting. Within each stall, horses may or may not be able to look out a window or a half door, and may or may not have the opportunity for physical or at least visual contact with other horses while confined (Sweeting et al, 1985). Indoor housing is useful for sheltering horses from extreme weather, and managing thermo-regulation in cold environments. For instance, in many European countries, space and climate often dictate that horses are kept in stables for at least part of the day, at least part of the year (Werhahn et al, 2010). A survey on the demographics of captive horses in Great Britain reported that stabling was overwhelmingly the most common form of horse management, with horses kept in stables for all or part of the day in 70–90% of cases, except in summer, when this dropped to about 50% (Hotchkiss, 2007).

Time budgets of stabled horses are commonly characterised by higher proportions of standing and lying, and lower proportions of grazing and locomotion than that of feral horses. For instance, four Warmblood mares, of which two were stabled with their foals, were found to stand for 37%, lie for 27% and eat for 16% of their time between 6pm and 11am (Werhahn et al, 2010). Furthermore, the horses spent 10% of their time eating or investigating their bedding, and 10% in other short-lived behaviours such as rolling, grooming and locomotion (Werhahn et al, 2010). Likewise, five Standardbred horses individually housed in $16m^2$ loose boxes were found to stand for 39%, lie for 20% , eat for 31%, and move for 3.6% of the 24-hour period over which they were observed (Winskill et al, 1996). Three horses in single stables also observed over a 24-hour period were found to stand for 40%, lie for 10%, and eat for 47% of the time (Kiley-Worthington, 1987). Stables are widely considered to be far removed from the horse's natural environment and restrict the expression of many natural behaviours, such as social behaviours, movement, and selecting and grazing on growing forage (Hoffmann et al, 2012).

2.2.2 Yards

Yards are characterised as outdoor, bare dirt enclosures, where horses are either kept separately or in groups. The minimum day yard size recommended by the New South Wales Department of Primary Industries is $20m^2$, and Equestrian Sports New Zealand recommend $9m^2$ as the minimum size for portable yards at events. Horses kept in yards do not tend to have the same shelter as those in stables, or freedom of movement as those in open paddocks, and are more susceptible to the weather (Committee, 2018). In both stables and yards, food must be provided to horses. This should consist mostly of forage, either fresh or conserved, and concentrated feeds if required to maintain body condition and/or nutritional balance of the horse (Committee, 2018).

The time budget studies of horses in yards have generally found standing and resting behaviour to be less prevalent than in stabled horses, and locomotion to be higher than that of feral horses. For example, Przewalski horses kept in groups on >0.6ha yards in zoos were found to stand for 42%, lie for 0%, eat for 39% and move for 17% of the daylight hours over which they were observed (Boyd, 1988). In the same study, Przewalski horses kept in yards <0.4ha were found to stand for 25%, lie for 1%, eat for 55%, and move for 13% of the time (Boyd, 1988). The high proportion of locomotion observed was expected to be a result of managing the groups in close confines. The minimal lying behaviour observed in this study was attributed to the presence of the public and level of noise that occurred during the day (Boyd, 1988). Another study found 50 Arabian breeding mares turned out to the same 0.4ha yard for 6-hours each day to stand for 17%, move for 12%, and eat for 65% of the time when provided ad lib hay, and stand for 43%, move for 24%, and eat for 30% of the time when provided limited forage (Benhajali et al, 2009). A study that observed behaviour over a 24-hour period found eight yarded horses with ad lib hay to stand for 23%, lie for 10%, and eat for 57% of the time (Kiley-Worthington, 1987).

2.2.3 Paddocks

Paddocks are outdoor enclosures with growing grass where horses are either kept separately or in groups. While New Zealand uses the term paddock as a catch-all for management on grass, the term varies internationally. For example, the American and Norwegian definition of a paddock is similar to the New Zealand definition of a yard, or can refer to a grazing cell of a larger pasture (Jørgensen et al, 2007). A good paddock has some form of man-made or natural shelter, such as trees, or horses are at least covered in adverse weather (Committee, 2018). Grazing on pasture alone is often enough to maintain body condition, though horses in restricted or poor paddocks, or in moderate to heavy work may require supplementary feeding (Committee, 2018; Hoskin & Gee, 2004).

Of all the enclosures, the time budget of horses in paddocks is generally reported to be the closest to that of feral horses. For instance, Przewalski horses kept in groups on >0.6ha paddocks in zoos were found to stand for 29%, lie for 0.5%, move for 7.5%, and graze for 65% of the daylight hours observed (Boyd, 1988). Similarly, a group of Thoroughbred horses on a large, 15ha paddock were found to stand for 43% and graze for 57% of a 24-hour period (Arnold, 1984). A study that used accelerometers to track the activity of horses kept alone in paddocks of 0.06ha and 0.24ha, found horses to stand for 45% and 40%, move for 3% and 4%, and graze for 52% and 56% of a 24-hour period, respectively (Maisonpierre et al, 2019).

Captive horse management may consist of one or a combination of enclosures each day, and may change with the season and workload of the horse. Combined systems are becoming popular in Europe because of their positive influence of health, welfare and social behaviour compared with traditional stable management (Hoffmann et al, 2012). One such 'active stable' system in Iceland consists of indoor and outdoor spaces with automatic hay feeders and a central water trough that eight horses could move between freely and maintain their social group (Hoffmann et al, 2012). In addition, these horses had access to pasture for three-hours a day. In many parts of Europe, it is also common for sport horses to be partly or wholly in stables during the competition season then turned out to pasture for the off-season. In New Zealand, where horses are predominantly kept on pasture, it is common to spell horses in paddocks larger than what they are managed in during the competition season (Bolwell, 2015).

2.3 Effects of captive management on horse behaviour

Many forms of captive management have been found to restrict the expression of natural behaviours, increase standing behaviour, and even lead to the development of stereotypical behaviours. Stereotypical behaviours are repetitive and seemingly functionless behaviours that are only observed in captive members of a species (Mason, 1990). By presenting some degree of social, spatial and/or dietary restriction, captive environments restrict the expression of natural behaviours to varying degrees.

2.3.1 Social restriction

When horses are kept individually they are generally incapable of performing social behaviours, and tend spend less time eating, and are less trainable and more aggressive than group-housed horses. Activities that involve physical contact, such as a mutual grooming, fighting, herding behaviour, and reproductive behaviour are not possible when horses are isolated. Feral horses spend 7-10% of their time in such behaviours (Duncan, 1980; Ransom et al, 2010), and spend

10-81% of the time in synchronisation with the behaviour state of the group (Rifa, 1990). When the visual barriers between a sample of stabled ponies were removed, the ponies were found to become highly synchronous in their feeding behaviour and spent significantly longer eating hay than when visually isolated (Sweeting et al, 1985). Likewise, visual contact with other horses was found to effect the trainability of stabled riding school horses. Horses were scored to be significantly more difficult to handle when kept in fully isolated stalls than when kept in stalls that allowed visual contact with neighbouring horses (Yarnell et al, 2015). Solitary housing has also been associated with increased aggression when the horse is reintroduced to other horses, and decreased trainability compared with socially housed conspecifics (Kiley-Worthington, 1990; Rivera et al, 2002; Sondergaard, 2003).

2.3.2 Spatial restriction

Spatial restriction has been found to affect how often horses lie down, and to be directly related to the distance horses travel each day and adverse health consequences. Horses housed in single stables have been found to spend 10-27% of their time budget lying down, whereas group-housed and feral horses have been observed to lie for 0.5-5% of their time (Boyd et al, 1988; Boyd, 1988; Duncan, 1985; Heleski et al, 2002; Kiley-Worthington, 1990; Werhahn et al, 2010; Winskill et al, 1996). This has been hypothesised to relate to a familiarity and security stabled horses may have with their indoor surroundings, and a lack of ability or need to spend time in other behaviours, such as moving and foraging (Belling, 1990). A review of 800 cases of behavioural problems linked excessive lying to restricted physical environments, monotonous environments, monotonous food, high or low temperatures, low light, and pain (Kiley-Worthington, 1987). The increase in lying behaviour in many spatially restricted horses often comes with a decrease in movement. A study which compared distance travelled by horses in stables and in paddocks of 0.8ha, 4ha and 16ha, found that the distance travelled each day increased with enclosure size (Hampson et al, 2010a). When kept in stables, horses would travel less than 1km a day, and this distance increased logarithmically to the 16ha paddock, in which the horses would travel 7km a day. Longer distances travelled per day, especially when on firm ground, have been shown to produce short hoof walls with minimal flaring (Hampson et al, 2013). Although there is some debate to the optimal model for hoof health, maintaining a hoof height that is short enough to allow the frog, bars, and sole of the foot to have contact with the ground promotes circulation in the legs, provides traction, and maintains exfoliation of the growing tissue (Jackson, 1997; Thomason, 2007). High levels of daily movement are also important to for musculoskeletal development in young horses (Rogers et al, 2012), and obesity prevention in all horses (Robin et al, 2015).

2.3.3 Dietary restriction

Most captive environments limit the ability of horses to select a wide range of forage types, and are generally associated with provision of higher energy foods than the horse has evolved to process. At the extreme, all of the horse's feed is provided to it by its carer and generally consists of forage, fresh or preserved, and often a concentrated feed to provide nutritional balance and additional calories (Committee, 2018). Concentrated feeds often consist of preserved forage, cereals, oils, minerals and salt (Fernandes et al, 2014). Providing a sizeable proportion of a horse's caloric needs in concentrated feeds can reduce the need to forage, and alter the time budget of the horse by often increasing the time spent standing (Winskill et al, 1996) and performing stereotypical behaviours (McGreevy et al, 1995). When horses receive a large proportion of their diet in concentre form, and/or do not have ad libitum access to forage, as can be the case when owners are trying to manage horse weight (Argo et al, 2012), horses have been found to consume the forage on offer and spend periods of the day fasting (Ellis et al, 2015). Fasting can cause problems in horses, as the digestive system has rather evolved to cope with large quantities of low energy forage (Sneddon & Argenzio, 1998). Continuous grazing produces a flow of saliva and ingesta that buffers stomach acid and aids digestion (Andrews et al, 2005). Stomach acid pH drops six hours after feeding, as the saliva and ingesta clears the system, making horses especially vulnerable to gastric ulceration (Nadeau et al, 2000). Horses will rarely voluntarily fast for longer than 2-4 hours (Harris, 2006), and so it is important that horses are provided with sufficient quantities of forage delivered in a way that cannot be consumed so quickly as to cause prolonged fasting.

2.3.4 Stereotypical behaviours

Stereotypical behaviours are defined by Mason (1990, p1015) as 'repetitive, invariant behaviour patterns with no obvious goal or function'. Stereotypical behaviours are often considered abnormal as they do not occur in free-living animals (Mason, 1990). They are widely considered signs of poor welfare (Hemsworth et al, 2015; Henderson & Waran, 2001; Jørgensen et al, 2011; McGreevy et al, 1995), although this relationship is not certain (Mason, 1990; Newberry, 1995). The development of stereotypical behaviours is linked to sub-optimal environments that are monotonous, a lack of exercise, chronic stress, and frustration due to an inability to express desired behaviours (Mason, 1990). Common horse stereotypies include weaving, pacing, pawing, box-walking, windsucking, and cribbing (Sarrafchi & Blokhuis, 2013). Although stereotypical behaviour is far more commonly observed in stabled horses, some forms have also been observed in paddocked horses (Heleski et al, 2002; Monk, 2006).

2.4 Providing enrichment

2.4.1 Environmental enrichment

One approach to ameliorating the effects of captivity on domestic horses is to provide environmental enrichment. This aims to satisfy the behavioural needs of the horse rather than restrain the symptoms of adverse behaviour (Sarrafchi & Blokhuis, 2013). Environmental enrichment has been defined as 'an improvement in the biological functioning of captive animals resulting from modifications to their environment' (Newberry, 1995, p229). Potential methods to achieve enrichment can involve presenting food in ways that invoke natural foraging behaviour, providing opportunities for social contact, increasing opportunities for exercise, increasing the complexity of the enclosure, or promoting new sensory experiences (Bloomsmith et al, 1991; Newberry, 1995).

Individual horses may respond differently to stimuli based on their environment and individual preferences. For example, a study on the relative effects of enrichment items found that individually managed horses spent more time scratching themselves on a brush pole than group-managed horses (Jørgensen et al, 2011). Additionally, hanging stable toys provided to cribbing horses were found to engage some horses and be of no interest to other horses (Whisher et al, 2011). Therefore, alterations to an animal's environment should not be presumed to be enriching until it is demonstrated that they improve the biological function of the animal (Newberry, 1995; Young, 2003).

2.4.2 Feeding enrichment

Environmental enrichment involving feed (feeding enrichment) is the process of providing forage in ways that are physically and mentally stimulating for the animal. This can involve providing a variety of forage types (Thorne et al, 2005), or delivering food in ways that the horse must work to access, and are within its natural behavioural repertoire (Jørgensen et al, 2011). Such behaviours include digging, reaching for, manipulating with their mouth, and pawing to access food (Young, 2003).

Feeding enrichment has been shown to be the most effective form of enrichment at capturing the interest of the horse. For example, one study provided horses kept individually in barren yards one of three non-edible items, a cone, ball, and scratching pole, or one of four edible items, peat soil, straw, branches, and a foodball (Jørgensen et al, 2011). Horses spent significantly more of the time observed engaging with edible items (13.2%) than non-edible items (0.9%). Another study that placed foodballs, a plastic ball with a small opening for concentrated feed to fall out when pushed, in stables found foodball use was highly reinforcement dependant, meaning horses would rarely interact with the ball once it became empty (Henderson & Waran, 2001).

2.4.3 Application to horses in restricted paddocks

Currently, all studies on the effects of environmental enrichment on behaviour have been conducted on horses managed in stables or yards. Horses in these management systems generally spend less time grazing than their paddocked and feral counterparts, and are often socially isolated (Boyd et al , 1988; Kiley-Worthington, 1990; Werhahn et al, 2010; Yarnell et al, 2015). However, it is not uncommon for paddocked horses to be kept individually and in very small enclosures (Fernandes et al, 2014; Maisonpierre et al, 2019). Thus, it is possible that enrichment could be of some benefit to such horses. The findings of this review suggest that feeding enrichment is likely to be more successful at engaging the horse than other forms of environmental enrichment. Given that paddocked horses have access to grass, and have been found to preferentially seek high-quality diets, an effective form of feeding enrichment may need to offer variation additional to the horse's current forage, or provide a high-quality reward (Pearson et al, 2006; Thorne et al, 2005).

2.5 Requirement for New Zealand specific studies

In New Zealand, it is not uncommon to keep non-commercial horses in small paddocks, and it is so far unknown how horses behave under this form of management. Unlike in many parts of the world, the temperature climate of New Zealand is suitable for producing more than adequate grass growth, and managing horses on pasture year-round (Hoskin & Gee, 2004). A survey of endurance riders found 80% of mounts were kept on pasture 12-24 hours a day, year-round (Bolwell et al, 2015). Similarly, 80% of New Zealand Pony Club members answered that their horse had access to pasture for 24-hours a day, year-round (Fernandes et al, 2014). Of these Pony Club horses, 66% were kept on pasture originally intended for dairy, beef, or sheep. These pastures are characterised by grasses far richer than the low-energy fibrous forage horses evolved eating (Sneddon & Argenzio, 1998; Watts, 2010). Unrestricted access to New Zealand pasture is often more than enough for the maintenance of an adult horse, and in spring the feeding value of quality pasture can be high enough to lead to obesity (Hoskin & Gee, 2004). A separate study on New Zealand Pony Club horses found that 76% of horses were kept on pasture year-round, and half had a body condition score that identified them as fat (Fernandes et al, 2015). To mitigate obesity and other grass-related issues, such as laminitis and high-energy behaviour, horse owners often restrict the size of the paddock (Geor & Harris, 2009), and there has so far been little research into the behaviour of horses kept on very small paddocks (Maisonpierre et al, 2019). Given the differences in climate and horse management in New Zealand compared to other parts of the world, there is a need for New Zealand specific studies to evaluate the time budget of horses kept in small paddocks, and the effects of providing feeding enrichment to such horses.

3. Objectives

This study seeks first to characterize the behavioural time budget of non-commercial horses housed individually in small paddocks (132m^2) in New Zealand.

We will then evaluate the effects of providing a slow feeding device (a foodball) on the horses' behavioural time budget, and rate of concentrated feed consumption. Specifically, we will evaluate the effect of the intervention on behaviour after horses have become familiar with the device over a period of days to account for the effects of novelty alone.

4. Methods

4.1 Horses and management

The study population consisted of privately-owned horses kept at the Equestrian Centre at Massey University, Palmerston North. Horses were eligible for inclusion in the study based on the following criteria:

- Aside from when being worked, the horse is kept in a paddock full time (not stabled)
- Horse receives a concentrate feed between one and two times a day
- Horse is not in very heavy work, and will not be taken out of the paddock for >4 hrs/day during the study period and the week prior
- Are normally* kept in a small paddock (<0.1 hectare)
- Are normally* grazed without company
- Are at least four years old
- Is not pregnant

* normally refers to a consistent management practice lasting at least the last two months

This study had organised to collect data from eight horses in total. However, the government mandated lockdown in response to the COVID-19 pandemic came into effect before the last four horses could be filmed. Table 1 shows the details of the four horses included in the study.

Table 1. Owner reported height, weight, sex, age, breed and feed weights of study horses.

Horse	Height (HH)	Weight (kg)	Sex	Age	Breed	Level of work	Concentrated feed dry-weight (kg)
1	15.2	540	Mare	16	TB	Spelling	0.7
2	16.0	600	Gelding	13	Clydesdale x TB	Spelling	0.6
3	16.0	500	Mare	6	NZ Sport Horse	Light	~1.6
4	16.3	590	Mare	9	Dutch Warmblood x TB	Moderate	~2.3

TB: thoroughbred; HH: hands high

Three mares and one gelding were kept individually behind electric tape on grass paddocks of 132m^2, as per their usual management. Three of the four horses had their electric tape moved to allow a strip of new grass morning and/or evening (the evening shift to new grass was typically caught on camera during this study). The fourth horse did not have access to new grass each day, and instead the entire paddock area was moved to a fresh grass plot each week. Horses had free access to water. The horses used in this study had visual contact with other horses grazing at the facility at all times. Two horses shared a fence with another horse and two were did not have physical contact with other horses. Horses were cared for by their owners, and received hay in the morning and/or evening, and a concentrated feed in the evening (Table 2). In order to record feeding behaviour, concentrated feed was supplied between 5 - 5:30PM for the week leading up to, and the week of the study.

Table 2. Owner reported usual feeding schedule and details.

Horse	Morning		Evening		Concentrated feed
1	5:30AM	1-2 slices soaked hay, grass	8:00PM	Concentrated feed, grass, 1-2 slices soaked hay	500g NRM Equine Balancer (pellets), 125g meadow chaff, 50mL flax-seed oil, electrolytes
2	5:30AM	1-2 slices soaked hay, grass	8:00PM	Concentrated feed, grass, 1-2 slices soaked hay	550g NRM Equine Balancer (pellets), 125g lucerne chaff, 50mL flax-seed oil, electrolytes
3	7:00AM	1 slice of hay	4 – 7:00PM	Concentrated feed, grass	500g Dunstan Maxim low GI (pellet), 850g Equifibre meadow, 250g dry weight beta-beet, 2Tb salt, 1.5Tb Epsom salt
4	7:00AM	1 slice of hay	4 – 7:00PM	Concentrated feed	500g Dunstan betabeet (dry weight – soaked in 3L water), 500g NRM Low GI (nuts), 500g CopRice Rice Bran, 800g meadow chaff, 60mL Duwell liquid magnesium, 60mL linseed oil, 20g Duwell toxin binder, 25g Duwell vitamins and minerals, 1Tb coarse salt

4.2 Study design

The study period lasted seven days (Fig. 1) from the 11th-17th March 2020. This study was conducted in early autumn and temperatures were mild, with a low of 7°C and a high of 24°C over the study period. Sunrise was at 7:12 AM, and sunset at 7:40 PM.

For the first three days (Baseline), horses (n=4) were filmed in their paddocks. Video cameras were mounted on tripods set outside of the paddock (Fig. 2) during the morning (6:50-8:05am), midday (10:50-12:05pm) and evening (4:50-7:05pm) observation windows on Days 1-3 (Fig. 1). Horses were left uninterrupted during these windows, except between 5 – 5:30PM when owners delivered the horse's evening feed (Table 2). On the morning of Day 4 the owners trained their horses to use the foodball (process detailed below). For Days 4-7 (Foodball), 120g of the concentrate (pellet/nut) ration of the horse's usual feed was supplied in the foodball, and both the foodball and bucket feed were presented to the horse during the evening feeding period. Horses were not filmed on Days 4-6 to give them time to become accustomed to using the foodball. On Day 7, horses were filmed as on Days 1-3.

Figure 1. Experimental condition breakdown (left) and observation periods for data collection (right).


Figure 2. Tripod and camera setup outside of the horse's paddock, keeping the entire paddock in frame

4.2.1 Slow-feeding device and training

The slow-feeding device used in this study is known as a ‘ball feeder’ or ‘foodball’. The plastic device is approximately the size of a soccer ball with an opening on one side for filling and dispensing food (Fig. 3). On the morning of Day 4, owners trained their horses to use the foodball using the method described by Winskill et al, (1996) with guidance from the researcher. On initial presentation, an additional handful of pellets/nuts was shown to the horse and placed underneath the foodball, encouraging the horse to push the ball to receive the food reward. This process was continued until the horse began to learn that feed fell out when the horse pushed the ball, and was concluded when the horse pushed the ball without assistance to receive four consecutive food rewards.

Figure 3. The 'foodball', a plastic, equine slow-feeding device.

4.2.2 Behavioural observations

Footage from each of the evening filming windows (4:50- 7:05PM) were split into two clips (evening_a and evening_b), to be comparable to the morning and midday clips. Due to batteries dying and the occasional gust toppling a tripod, not all cameras recorded for the full duration of each observation window. To limit loss of data, video clips were cut to 49 mins (the length of the shortest clip). Behaviours were scored from the video clips according to an ethogram of 38 mutually exclusive behaviours developed from (Guinnefollau, 2019; Rochais et al, 2018; Winskill et al, 1996) (Table 3). Continuous sampling was used to record all behaviours for each horse in order to measure their frequencies and durations.

Table 3. Ethogram of mutually exclusive behaviours

■ (black)	State behaviours	Record duration. Each behaviour must last at least five seconds to be recorded (with the exception of locomotive behaviours, which must last at least 4 strides)
■ (grey)	Event behaviours	Record no. of occurrences

Feeding			
G	Grazing		Bites off and ingests hay, grasses and forbs close to the ground. Horses move as they graze; therefore, as long as the horse is feeding while it is moving, it should be considered as feeding rather than locomotion. Bout starts when horse first bites off forage, and ends when horse stops masticating or engages in another behaviour
D	Drinking		Lowers head and put lips in water trough or pond in posture typical of ingesting water in horses, and then raises head again
Bf	Bucket feed		Ingests concentrated feed from bucket or ground if spilled. Bout ends when horse stops masticating or engages in another behaviour
F	Foodball		Engages with foodball; includes Pushes directed at Foodball, using either the nose or foreleg, whilst standing or moving and investigation and ingestion of fallen substrates from the Foodball, whilst standing or moving.
Pff	Pushes for food		The number of pushes directed at the foodball, separated by a break in contact with the device
Standing/Resting			

S	Standing	Legs are generally still, positioned either straight or cocked. Small movements backwards/ forwards/ weight shifting or turning may occur. Horse is not masticating. Poll is above wither height (standing is still be scored when briefly interrupted by event behaviours such as drinking or sniffing that involve dropping the head below this height), ears are generally forward and focused
R	Resting	Generally standing still with poll at or below withers height, eyes may be partly or fully closed, legs straight or with one cocked, ears are not pricked forward (showing a general lack of attention). Bout ends when the head comes up and/or to the side, and ears are pricked, or other purposeful, non-reflex movement
Sr	Sternal recumbence	Lying with legs tucked under and neck off the ground
Lr	Lateral recumbence	Lying flat on one side, legs extended along the ground
Locomotion		
W	Walking	Moves forward with a slow, four beat gait, with head higher than chest (not seeking to immediately graze) for at least four steps. Bout ends when horse stops, changes gait, or engages in another behaviour for at least five seconds.
Tr	Trotting	Moves forward with a two-beat gait for at least four steps. Bout ends when horse stops, changes gait, or engages in another behaviour for at least five seconds.
Ct	Cantering	Moves forward with a three-beat gait for at least four steps. Bout ends when horse stops, changes gait, or engages in another behaviour for at least five seconds.
Gl	Galloping	Moves forward with a fast, four-beat gait for at least four steps. Bout ends when horse stops, changes gait, or engages in another behaviour for at least five seconds.

B	Bucking		Horse lifts hind end into the air, either kicking out hind legs or not, and then brings it back down again
P	Pacing		Horse moves back and forth along a fence line. Bout ends when horse leaves the fence line
Grooming			
Gr	Grooming		Nibbling or licking on self, rolling and rubbing lasting at least five seconds
Bg	Brief grooming		A brief but deliberate action of full body shaking, itching, nibbling or scratching oneself, lasting less than five seconds.
Social (over the fence interactions as horses are paddock alone)			
So	Social		Social interactions among neighbouring horses, such as allogrooming or threats. Bout ends when horse engages in another activity
V	Vocalisations		The horse expresses nicker or whinny
T	Threats		Laterally pinned back ears and/or arched neck, and movement of the head or hind toward the opposing horse, but with no physical contact
B	Bites		Bites another horse; involves physical contact, then releases hold
K	Kicks		Kicks another horse with the fore- or hind legs; involves physical contact, before legs return to ground

Re	Rears		Lifts its forelegs off the ground and elevates its body into a more vertical position, before returning to the ground
A	Avoids		Turns head away because of another horse
Ra	Runs away		Moves away because of another horse
Other			
E	Elimination		Urination (elimination of fluid waste) or defecation (elimination of solid waste)
Td	Threatens ducks		Kicks, chases, or otherwise threatens ducks in their paddock
Pw	Pawing		Uses foreleg to strike at the ground. Bout consists of a front hoof extending forward of the shoulder, and coming down towards the ground. Contact may or may not be made with the ground.
Pb	Paws bucket		Uses foreleg to strike at their bucket. Bout consists of a front hoof extending forward of the shoulder, and coming down towards the ground. Contact may or may not be made with the bucket.
Ph	Paws hay		Uses foreleg to strike at their hay. Bout consists of a front hoof extending forward of the shoulder, and coming down towards the ground. Contact may or may not be made with the hay.
Hm	Head movement		Shaking (head is shaken side to side. Bout consists of the head shaking, then becoming still), tossing (head is tossed up and down. Bout consists of head going up and coming down once) or circling (head is circled on a mostly horizontal plane. Bout consists of one full circle) of the head, either while standing or locomoting.

Cb	Checks bucket		Lowers head into their bucket, may sniff, but does not eat from the bucket. Bout ends when horse raises head back up or begins grazing
Y	Yawning		Horse opens jaw and lifts head in typical yawn posture, then closes jaw again
Fl	Flehmen		Horse extends its neck, raises its head, and inhales as it rolls its upper lip back displaying front teeth. Bout ends when the horse closes lips and lowers its head again
Rs	Receives shock		Horse makes contact with the electric fence and demonstrates a sudden reflex away from the fence
Sp	Spooks		Horse demonstrates a sudden reflex away from an external stimulus. Ears are pricked in the direction of stimulus, and horse may move away from it

4.2.3 Foodball use

As the 49-minute videos used for behavioural observations were often cut from a video of greater length, the uncut evening videos were viewed to determine how long horses took to finish their feed (total time), and how long they spent actually eating from the bucket and/or foodball (net time) so that this could be compared between the Baseline and Foodball conditions.

4.3 Statistical analysis

There were a total of 47 videos (38 hours and 23 minutes) analysed from the baseline condition (four horses, four times a day, for three days ~one data point missing), and 14 videos (11 hours 26 minutes from the foodball condition (four horses, four times a day, for one day ~two data points missing). During the baseline condition there was 9 hours 48 minutes of data analysed each for three horses, and 8 hours 59 minutes for one horse. During the foodball condition there was 3 hours 16 minutes of data analysed each for two horses, and 2 hours 27 minutes each for the other two horses. As previously stated, each video was cut to 49 minutes (2940 seconds) long for analysis.

To evaluate the intra-rater agreement at scoring behaviours across videos, a random sample of three videos was selected (one video where a foodball was present, and two non-foodball videos). Videos were duplicated and randomly labelled, then the behaviour in these six videos was scored for the periods 0-5mins, 22-27mins, and 44-49mins, resulting in the same 15 minutes from the three selected videos being scored twice. Intraclass correlation (ICC) estimates and their 95% confidence intervals were calculated for the state behaviours scored using SPSS statistical package version 26 (SPSS Inc., Chicago, IL) based on a single measurement, absolute agreement, 2-way mixed-effects model.

Videos were scored in a randomised order in an effort to reduce any bias regarding time of day or condition. Data were entered into Microsoft excel (2016) and exported to the statistical programme R (version 1.1.423). The total seconds per state behaviour and total occurrences of event behaviours were calculated per video.

Baseline time budget

Time budget values were created by calculating the median seconds spent in each state behaviour across morning, midday and evening periods of all three days of the baseline condition. For analysis, state behaviours were collapsed into five categories: Grazing, Concentrates, Standing/Resting, Locomotion, and Grooming. This was due to the rarity of which some behaviours were performed, and similarity of function. For example, walking, trotting, cantering, galloping and pacing were collapsed into the category 'locomotion'. Walking was observed in every video clip, while the other paces were observed rarely. Standing and resting were combined for analysis because these behaviours often appeared to share a similar function or purpose, and the line drawn between these activities felt rather contrived. Finally, ‘concentrates’ combined both bucket feed and foodball behaviours as the horses were consuming the same concentrated food in each, and it allowed time spent feeding to be compared between baseline and foodball conditions. The time budget value for concentrates was reported using data from the evening periods only, as this was the only time concentrates were available to the horses.

State behaviours were then transformed into percentage of time (no. seconds per state behaviour divided by 2940 seconds). Event behaviours were transformed (divided by 49 then multiplied by 60) to produce event behaviours per hour, the more common formats of presenting such data. The level of significance was set at P=.05.

The number of times a horse changed between state behaviours in a video was calculated, and these data were called ‘transitions’. Transitions can be roughly used as an index of activity (Boyd et al, 1988), with a high number of transitions per hour indicating an active period for a horse (it is of course possible that a horse may walk through an entire video and be very active, though present a low transition rate. However, such a scenario was not observed). Transitions data were transformed like the event behaviours to produce transitions per hour (divided by 49 then multiplied by 60).

A Shapiro-Wilk test found the time spent in each behaviour state, and the number of event behaviours to be not normally distributed. Therefore, a Freidman Test was used to compare the time spent in behavioural states and event behaviours at different times of day (morning, midday, evening_a, and evening_b), and during the baseline and foodball conditions. Medians and interquartile ranges are presented for non parametric data.

Effect of a slow-feeding device on the time taken to consume concentrates

To compare the time horses spent eating concentrates between the baseline and foodball conditions, uncut videos of the total evening period were analysed in order to view the entire feeding period. The total time it took horses took to finish their concentrated feed (from the start of the first feeding bout to the end of the last feeding bout), and the net time horses spent eating (total time minus non-feeding intervals) were recorded for each of the three baseline condition and one foodball condition evenings. A Friedmans test was used to analyse the difference in total and net feeding times between the conditions. Due to there being three evenings worth of baseline data and only one evening of data from the foodball condition, the Friedmans test was blocked by each horse, and compared across the treatments (median value from baseline condition, and only value from foodball condition).

Effect of providing a slow-feeding device on evening time budget

To evaluate if a foodball affects the horse's time budget (and if so, how), time budgets were constructed from evening period data only and compared between conditions using a Friedmans test (the test was blocked by horse, as above).

5. Results

5.1 Baseline time budget

5.1.1 Intra-class correlation estimates

A high degree of intra-rater reliability was found between the three paired measurements. The average measure ICC was 1.000 with a 95% confidence interval from 0.999 to 1.000 ($F(4,4)= 98075.4$, $P<.001$).

5.1.2 State behaviours

Table 4 gives the median time spent in various behaviour states by the horses over the three baseline days, and for each of the four periods of the day. Grazing was the most commonly recorded behaviour, accounting for a median 75.4% of the horses' time budget. Grazing activity was recorded in every observation. Standing was the second most commonly performed behaviour, constituting a median 14.3% of the daily time budget. Resting was rarely observed, with bouts lasting between six seconds and seven minutes 51 seconds in a 49-minute period. No lateral or sternal recumbence was observed during the baseline period. Locomotion constituted a median 2.1% of the horses' daily time budget, and walking constituted almost the entirety of locomotion. No cantering was observed during the baseline condition, and trotting was very rare. Only two horses exhibited pacing during the baseline condition and both instances were during the evening period shortly prior to receiving their hard feed. Very little grooming behaviour was observed, with bouts lasting between five and 49 seconds.

The Friedman's test indicated that there was little difference in the median percentage time horses spent grazing, standing/resting and grooming between the sampled periods of the day in (all P >.05). However, locomotion varied significantly with time of day (P =.01, Table 1). The sample size was too small to run post-hoc tests to determine between which periods the significant difference lay, though Table 4 and Figure 4 illustrate that the time spent in locomotion was lowest during the midday period and highest during the first evening period (median 1.1% and 5.1% of time spent in locomotion respectively, Table 4).

*Table 4. Percentage of time horses spent performing each state behaviour and median number of event behaviours performed per hour, across the three days of the baseline condition (with 1st and 3rd quartile values). Followed by a break down of state behaviours (%) and event behaviours (per hour) during the morning (7-8am), midday (11-12pm), evening_a (4-5pm) and evening_b (5-6pm) periods of the baseline condition. Analysis of Variance (Friedman test) for the effect of time of day on the proportion or rate of each behaviour. A P-value of <.05 indicates that there was a significant difference in the proportion or rate of a behaviour at different times of the day. *<.05, **<.01*

	Baseline time budget			Morning			Midday			Evening_a			Evening_b			
Behaviour *(% of time)*	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	Friedman test *P*-value
Grazing	**75.4**	50.9	94.5	**90.7**	61.2	96.7	**52.9**	27.3	88.3	**63.1**	50.1	74	**85.4**	65.1	96.6	.39
Standing/Resting	**14.3**	2.9	36.1	**6.7**	1.7	36.5	**45.4**	10.8	71.6	**17.7**	7.7	26.3	**3.4**	1.2	19.8	.18
Locomotion	**2.1**	1.1	3.9	**1.4**	1.1	2	**1.1**	0.7	1.3	**5.1**	3.4	6	**3.2**	1.5	4.2	.01*
Grooming	**0**	0	0.2	**0**	0	0.2	**0**	0	0.2	**0**	0	0.4	**0**	0	0.2	.44
Concentrates†	**7.3**	0	19.5	**-**	-	-	**-**	-	-	**10.9**	6.5	18.2	**0**	0	19.5	NA
Behaviour *(per hour)*	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	**Med**	Q1	Q3	Friedman test *P*-value
Brief groom	**3.7**	2.4	11.6	**3.7**	2.1	4	**3.7**	2.4	6.1	**7.3**	2.1	15.9	**10.4**	2.4	12.6	.18
Head tossing	**2.4**	0.6	6.1	**0.6**	0	1.5	**2.4**	1.2	6.1	**6.1**	3.4	14.7	**1.8**	0	4	.009**
Eliminations	**1.2**	0	1.2	**1.2**	0	1.5	**1.2**	0	1.2	**1.2**	0	1.2	**1.2**	0.9	1.2	.31
Drinks	**0**	0	2.4	**0**	0	0	**3.7**	2.4	3.7	**0**	0	1.2	**1.2**	0	2.8	.02*
Agonistic	**0**	0	0.5	**0**	0	0.3	**0**	0	0	**0**	0	1.2	**0**	0	0	.26
Paws	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	2.8	.71
Vocalisations	**0**	0	0	**0**	0	0	**0**	0	0	**1.2**	0	4.3	**0**	0	0	.11
Yawns	**0**	0	0	**0**	0	0	**0**	0	3.1	**0**	0	0	**0**	0	0	.39
Transitions‡	**29.4**	14.7	40.4	**18.7**	11.3	32.1	**18.4**	14.7	41.6	**38.6**	31.8	46.2	**29.4**	14.7	40.1	

†concentrates were available in the evening periods only, and so analysed for the evening periods only
‡median transitions between behaviour states per hour

5.1.3 Event behaviours

Table 4 gives the events performed per hour by the horses over the three baseline days, and for each of the four periods of the day. The only events that were recorded in at least half of the baseline observation periods were brief grooms, head tossing, and eliminations. Brief grooms were recorded in 91% of observations, at a median rate of 3.7 grooms per hour. Head tossing occurred in 74% of observations. The rate of head tossing peaked during the first evening period, preceding the arrival of the horses' evening feed. There was one exception when a rate of 22 head tosses per hour was recorded from one horse during a midday observation. During this period, the horse also yawned 58 times per hour. Eliminations (urinations and defecations) were the most regular event, occurring once or twice in 64% of observations. All other event behaviours were observed rarely (median 0 times per hour, Table 4). The event behaviours 'spooks', 'receives shock' and 'Flehmen' occurred four, three, and two times over the 2303 minutes of the Baseline condition, respectively. These behaviours are not reported in the tables due to their infrequency.

The Friedman test indicated that time of day had a significant effect on the median number of head tosses (P = .009) and drinks (P = .02) performed per hour during the baseline condition (Table 4). The sample size was too small to run post-hoc tests to determine between which periods the difference lay, though Table 4 indicates that the rate of head tossing was highest during the first evening period, and the rate of drinking was highest during the midday period. There was no time-of-day effect on any other event behaviours, or on the number of transitions between behaviour states performed per hour (all P >.05).

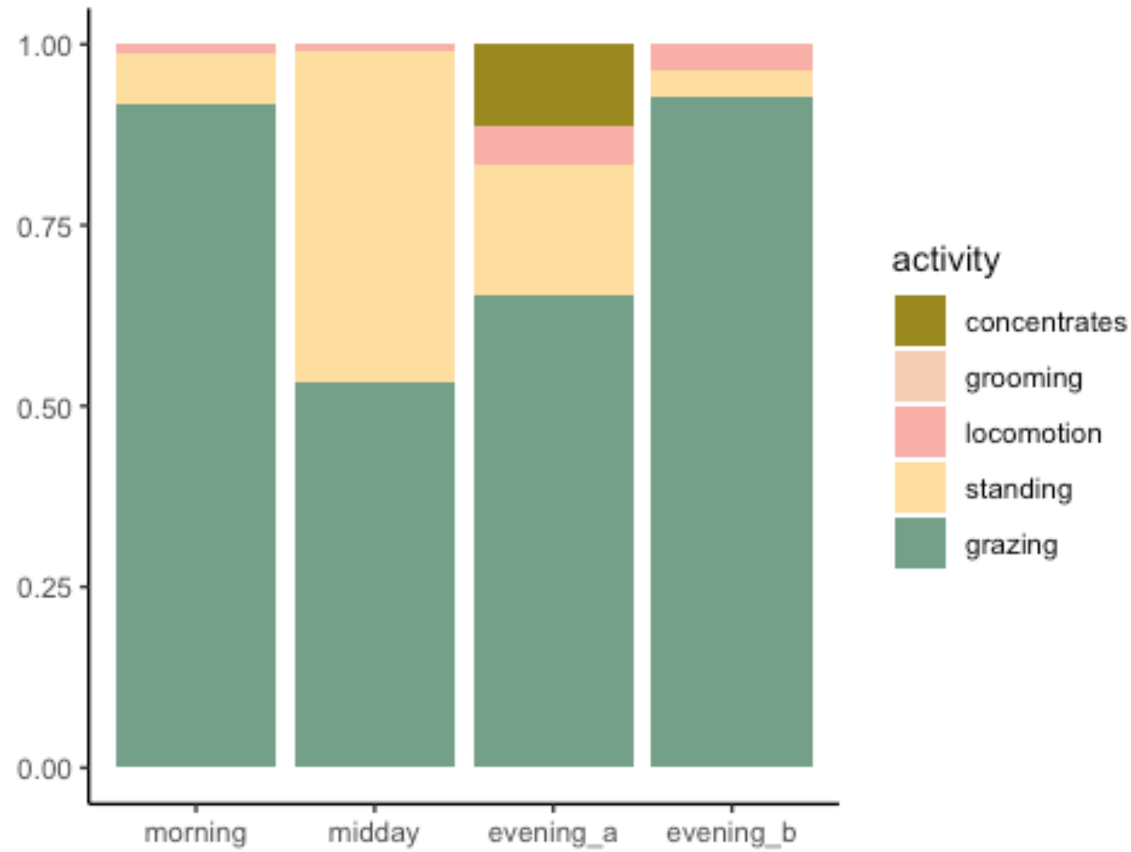

Figure 4. Median proportion of time spent in five behaviours throughout the day during the baseline condition. Morning (7-8am), midday (11-12pm), evening_a (4-5pm) and evening_b (5-6pm). Concentrates were available during the evening periods only. Refer to Table 1 for median and quartile values.

5.2 Effect of a slow-feeding device on the time taken to consume concentrates

Table 5 gives the median time horses took to finish their concentrated feed (total time), and net time horses spent eating (total time minus non-feeding intervals) for the baseline and foodball conditions. There are no quartile values for the foodball condition as observations were only made on one day.

During the baseline condition, the two horse that received <1kg of feed always consumed it in one sitting, giving the same total time as net time. During the foodball condition, no horses consumed all of their feed in one sitting, and the time it took horses to finish their feed was significantly longer in the foodball compared to the baseline condition (Friedman test $\chi^2(1) = 4$, $P = .045$), an increase of 7-2031%. There was also a statistically significant difference in the net time spent eating concentrates depending on condition (Friedman test $\chi^2(1) = 4$, $P = .045$), an increase of 13-192%, indicating that the horses spent longer actually eating concentrates during the foodball condition than the baseline condition.

Table 5. Time between first presentation of concentrated feed and finishing feed (total time), and the net time horses spent eating the concentrated feed during the baseline (median, 1st and 3rd quartile) and foodball conditions. There are no quartile values for the foodball condition as observations were only made on one day. Dry weight of hard feed and weight of concentrates are included to give context to the differences in time spent eating concentrates among horses.

Horse	Condition	Time to finish concentrates (mm:ss)			Net time eating concentrates (mm:ss)			Dry-weight of hard feed (kg)
		Med	Q1	Q3	**Med**	Q1	Q3	
Horse 1	Baseline	**61:02**	50:12	69:53	**27:42**	26:15	32:03	~2.3
	Foodball	**65:33**	-	-	**39:25**	-	-	
Horse 2	Baseline	**30:26**	18:54	35:47	**26:04**	17:39	31:25	~1.6
	Foodball	**126:20**	-	-	**29:23**	-	-	
Horse 3	Baseline	**3:29**	2:17	5:36	**3:29**	2:17	5:36	0.7
	Foodball	**74:10**	-	-	**7:07**	-	-	
Horse 4	Baseline	**7:07**	3:43	7:07	**7:07**	3:43	7:07	0.6
	Foodball	**81:42**	-	-	**20:41**	-	-	

5.3 Effect of providing a slow-feeding device on evening time budget

Table 6 gives the median time horses spent in various behaviours during the evening periods (4-5pm and 5-6pm) of the baseline and foodball conditions. Presenting half the concentrate ration in the foodball had no significant effect on the time spent grazing, standing/resting, locomoting or grooming during the evening periods. Horses spent a median 7.3% and 11.3% of the evening time budget eating concentrated feed in the baseline and foodball conditions respectively, and this difference was statistically significant (*P* =.045). Out of 24 evening observation during the baseline condition, there were 10 observations in which horses spent no time eating concentrates (Horse 1: once, Horses 2,3,4: three times). This was because the horses would sometimes finish their concentrates within one evening period, hence the Q1 value of 0 (Table 6). During the foodball condition, all horses consumed concentrates during both periods.

Brief grooms were performed at a median rate of 10.4 and 1.2 grooms per hour during the evening periods of the baseline condition and foodball condition, respectively. The Friedman test indicated that condition had a significant effect on the rate of grooms per hour during the evening periods (P = .045). None of the other event behaviours differed between the conditions for the evening periods.

*Table 6. Percentage of time horses spent performing each state behaviour, and number of event behaviours per hour (median, 1st and 3rd quartile) during the baseline and foodball conditions for the evening periods only (4-5pm, 5-6pm). Analysis of variance (Friedman test) for effect of condition (baseline and foodball) on time spent in behaviour states and event behaviours per hour. *<.05, **<.01*

Evening	Baseline			Foodball			
	Med	Q1	Q3	**Med**	Q1	Q3	Friedman test *P*-value
Behaviour *(% of time)*							
Grazing	**72.1**	54	92.1	**72.8**	64	85.6	.32
Concentrates	**7.3**	0	22	**11.8**	6.8	34.1	.045*
Standing/resting	**11.1**	2.2	22.2	**3.5**	0.4	14.4	1
Locomotion	**3.8**	2.4	5.4	**2.5**	1.3	6.7	1
Grooming	**0**	0	0.4	**0**	0	0	.32
Behaviour *(per hour)*							
Brief groom	**10.4**	2.4	14.4	**1.2**	0	1.2	.045*
Head tossing	**3.7**	1.2	6.1	**0**	0	15	.56
Eliminates	**1.2**	0	1.2	**0.6**	0	1.2	.08
Drinks	**0**	0	2.1	**0**	0	4	.32
Agonistic	**0**	0	1.2	**0.6**	0	2.1	.16
Paws	**0**	0	2.4	**0**	0	13.8	.32
Vocalisations	**0**	0	1.2	**0**	0	3.7	.16
Yawns	**0**	0	0	**0**	0	0	1
Transitions†	**33.1**	22.7	40.4	**31.2**	22.7	56	.32

†median transitions between behaviour states per hour

6. Discussion

This study sought first to characterise the behavioural time budget of non-commercial horses housed individually in small paddocks in New Zealand, and second to evaluate the effects of providing a slow feeding device on the horses' behaviour. Before the intervention, the horses in this study spent three quarters of the time observed grazing. This falls on the upper end of the range commonly reported in previous studies of horse time budgets. Consequently, the proportion of time performing other behaviours such as standing and walking was quite low. Providing concentrates in a slow-feeding device served to slow down the time taken to consume the concentrates significantly, but did not alter the overall time budget. However, these findings are based on one day of post-intervention data collection using only four horses, and should be viewed as preliminary. The implications of these initial findings will be discussed.

6.1 Baseline time budget

6.1.1 Horses spent most of their time grazing

Although the proportion of time the horses in this study were observed to spend grazing falls in the range of what has been observed in other horses, it is higher than expected based on previous studies with similar management characteristics. All four horses in this study spent most of their time grazing, with approximately three-quarters of the time spent in this behaviour. When compared to the time budgets reported for feral, paddocked, yarded, and stabled horses, this result was most similar to those reported for feral horses. Feral horses and ponies living in bands of 3 to 14 and ranging over areas of 70ha to 44,440ha were generally reported to spend 60-75% of their time grazing (Duncan, 1980; Kaseda, 1983; Ransom et al, 2010; Rifa, 1985; Salter & Hudson, 1979). I had expected my study to show that these horses' grazing behaviour would be similar to that of other paddocked horses, if not lower, as generally reflected in the literature on stabled and yarded horses. The only other time budget study of horses managed individually in small paddocks found horses fitted with accelerometers to spend approximately 61% of their time grazing during the day, in paddocks of 0.24ha (Maisonpierre et al, 2019). The paddocks in the present study were much smaller at 0.01ha. The high proportion of grazing observed may be partly attributed to the sampling regime, access to grass, and amount of concentrated feed provided. These will be discussed.

6.1.2 Sampling regime

The high proportion of grazing observed may be partly attributed to the timing of behaviour recording during the day. Previous studies have shown that time of day influences behavioural patterns in both feral and domestic horses. Grazing tends to peak after dawn and before dusk (Arnold, 1984; Keiper & Keenan, 1980; Mayes & Duncan, 1986) whereas standing and resting tends to peak during the midday period (Mayes & Duncan, 1986). The aforementioned study of horses kept individually in 0.24ha paddocks, found horses to graze for a median 60.8% of the day and 46.8% of the night (Maisonpierre et al, 2019). The sampling regime of this study consisted of recording behaviour over four, one-hour periods of the day in the early morning (7-8AM, sunrise 7:12AM), midday (11AM-12PM), over the time when three of the four horses received access to new grass (4-5PM), and during the early evening (5-6PM, sunset 7:40PM). As the morning and early evening periods coincided with after dawn and before dusk, and most horses received new grass during the 4-5PM period, the timing of the sampling periods has likely overrepresented the time these horses spend grazing each day.

6.1.3 Access to grass

The large proportion of the time budget horses were observed to spend grazing is likely partly attributed to the ability of the pasture to support this behaviour, and supplementary hay feeding. Though this study took no measure of actual grass availability, the paddocks were managed so that the horses would always have access to grass. Two of the horses had their electric fence extended twice a day, one was extended once a day, and one had the entire paddock shifted to a fresh plot of grass once a week. Although the tape was moved regularly, the paddocks stayed at 132m^2. Horses consume large quantities of forage each day, an estimated 2% of their body-weight, and perhaps the supplementary hay feeding and dense autumn growth at the time of the study made it possible for the horses to be sustained for at least a whole day on such a small paddock (Pearson et al, 2006).

6.1.4 Amount of concentrated feed provided

The low quantity of concentrates received may have also influenced the proportion of time horses in this study were observed to spend grazing. There is a relationship between the quality of food the horse receives and the time spent grazing (Pearson et al, 2006). As concentrated feed delivers the horse an energy dense feed, the more concentrates the horse receives the less time it needs to spend grazing to meet its individual energy needs (Ellis, 2010). The horses in this study received different quantities of feed, and were in different levels of work. Two of the horses in this study were retired, one was in light work (1 to 3 hours/week of mostly walking and trotting), and the other in moderate work (3 to 5 hours/week of mostly trotting with some walking, some cantering and possibly some jumping or other type of more difficult activity). The horses received between 0.6-2.3kg of hard feed each day, with the horses in heavier work receiving more feed. For context, New Zealand racehorses, who are in much heavier training, receive approximately 5.5kg concentrates per day (Williamson et al, 2007). As all horses spent such a large proportion of the time observed grazing, it could be inferred that each of the horses did not receive a large enough quantity of concentrates to considerably reduce their grazing need.

6.1.5 Event behaviours

The most common event behaviours observed were brief grooms, head tosses, and eliminations. The only event behaviours that exhibited any temporal patterns were head tossing, which peaked between 1600 - 1700, prior to the arrival of their evening feed, and drinking, which peaked between 1100 – 1200 and coincided with the hottest observed part of the day (max 24°C). All other event behaviours rarely occurred.

No stereotypical behaviours identified

The horses in this study were not observed to perform any repetitive, functionless behaviour throughout the day. Increased visual contact with other horses has been found to be a factor in lowering the risk of stereotypy (McGreevy et al, 1995), and all horses in this study had visual contact with at least one other horse, while two shared a fence with another horse. The horses that did share a fence would occasionally stand close to one another when resting, though there was no contact involved. No allogrooming was observed during the study and almost all social interaction involved threats, such as lunging at the other horse.

Though the horses in this study were confined to a small paddock, they were able to spend most of their time grazing. Although confinement and reduced forage are implicated as common causes of the development of stereotypical behaviour (Cooper & McGreevy, 2007), my results suggest that sufficient grazing opportunity had greater influence on the behaviour of these horses than confinement.

6.2 Slow-feeding device

6.2.1 Foodball use

All horses engaged with the foodball until it was empty, though they prioritised eating the bucket feed. The horses always began with the bucket feed first and would then switch between eating the bucket feed, using the foodball, and grazing. It is unsurprising that the bucket feed was consistently finished first as it was of higher nutritional value than grass, a rarer occurrence, and was easier to access than the contents of the foodball. The horses were also competing with a population of ducks and pukekos that would flock to the paddock when the feed arrived, and would jump in the bucket if the horse was not eating. An unexpected benefit of the foodball was that the birds could not access the contents.

The foodball significantly increased the time horses spent eating their concentrates, and significantly lengthened the period over which they consumed all their concentrates. During the baseline condition, horses took several minutes to an hour to finish their feed, while with the foodball horses took one or two hours to finish. From a digestive health perspective this is a good thing. However, whether using the foodball eventually became tiresome, or whether grazing fresh grass was equally rewarding is unknown. Although the foodball offers a food reward, perhaps because using the ball required more effort than grazing, they become less motivated to pursue the activity. In this study horses were observed to push the ball sometimes 10-15 times before each reward would fall out. Perhaps the unpredictability of the reward would be tiresome or frustrating after a while and the horse would move on to grazing. Horses are strongly motivated to graze (Jørgensen et al, 2011), and there are likely to be positive biological feedbacks associated with having their head down and steadily selecting and chewing forage. As this was the first study to use a foodball on grass, it was useful to find that the horses were still motivated to use the device until it was empty, even in the presence of fresh grass.

6.2.2 Effect on time budget

While the foodball was found to slow down the rate of concentrate consumption, it did not have any effect on the horses' evening time budget. Even though the time spent eating concentrates significantly increased during the foodball condition, it still comprised a relatively small fraction of the overall evening time budget. Therefore, the proportion of time spent performing grazing, standing, locomoting and grooming behaviours remained similar between the conditions. A previous study that offered feeding enrichment to horses in yards, also found that the intervention had no effect on the overall time budget when horses had even a limited ability to graze (Jørgensen et al, 2011). In my study, grazing similarly occupied the majority of the horses' time, even when the foodball was available. In contrast, Winskill et al, (1996) found that foodball use did alter the time budgets of five stabled horses. In their study, horses were monitored for a 24-hour period for three days of baseline condition, four days of foodball condition, and three days of post-enrichment. These horses spent significantly less time standing during the foodball condition (mean 28.6%) compared to the baseline condition (mean 38.8%), and less time eating their bucket feed during the foodball condition (mean 2.4%) compared to the post-enrichment period (mean 4%) even though their diet remained the same. The study also found horses to move significantly less during the foodball condition (mean 2.1%) compared to both baseline (mean 3.6%) and post-enrichment (mean 2.7%). However, this value did not include the time horses spent manoeuvring the foodball (mean 2.2%). A key difference between the Winskill et al, (1996) study and the present one was that their horses had only hay as ad lib forage, and received 8kg of concentrates in the foodball per day whereas the horses in this study only received 120g of concentrates in the foodball.

It is probable that the horses in this study would have spent more time eating concentrates had all the concentrates been provided in the foodball instead of the feed bucket. This was not attempted in this study as a previous study found the horses to express frustration when the bucket feed they were conditioned to expect never arrived (Henderson & Waran, 2001).

As this study and other feed-related intervention studies found these devices to be effective at slowing the rate of concentrate consumption (Jørgensen et al, 2011; Winskill et al, 1996), this could be considered good for the digestive health of the horse (Andrews et al, 2005). The practical usefulness of a foodball for the individually paddocked horse would depend on whether the horse receives a lot of concentrates and could benefit from spreading the meal out over a longer time. Alternatively, the owner could adopt the commonly recommended practice of feeding the horse at multiple times of the day instead. A foodball would be of value to owners who cannot tend to their horses more than once a day, who want to promote different foraging behaviours such as pawing as nosing, or are excited by the novelty of the device and want the mental stimulation for their horse of learning to operate it. In this study, there was no real need for the intervention.

6.3 Limitations and recommendations

Though this study was successful at characterising the daily time budget of four non-commercial horses managed alone in a small paddock, and evaluating the effects of providing a slow feeding device on the horses' behavioural time budget, there are some important limitations to the findings. The data collection period of this study was unfortunately cut short due to the COVID-19 pandemic. This reduced the number of horses that could be observed in the available time period. As a result, the small sample size cannot be considered a representative sample of the intended population. More horses would be recommended for future studies.

The sampling regime of this study is unlikely to accurately reflect the time budget of these horses or the effect of the foodball condition. Although it is challenging to film outdoors under natural light and without power, filming at more times of the day would enhance the probability of reflecting an accurate daily time budget. Sampling over a 24-hour period would be recommended. As there was only one day of observations under the foodball condition, this produced too few data to draw robust comparisons between the conditions. Sampling over more days, and an equal number of days in each condition is recommended, and would be make for a design that better suits statistical tests.

The quantity of dry feed provided varied widely across the four horses (Table 5), and this presented several important limitations. During the foodball condition, 120g of concentrates were taken out of each feed and placed in the foodball. This was not proportional to the amount of feed received, and so the horses that were fed less displayed greatly increased feeding times during the foodball condition compared to the horses that were fed more. Also, the amount of concentrate feed available to each horse might influence the motivation of the horse to access the foodball and therefore, this would possibly confound the interactions of these horses with the foodball. In order to quantify the effects of the foodball on feeding time, a future study would benefit from sampling from a population of horses on the same diet.

Although my results indicated a high proportion of time was spent grazing, it is important to note that the relationship between time spent grazing and volume of forage consumed is unlikely to be linear. The horses were in very restricted paddocks, and it is likely that they ate most of the new grass on offer each day rather quickly, then intake rate slowed at the horses cropped the grass short. This study did not measure grass intake and therefore cannot identify how much grass was consumed. It would be interesting in a future study to examine grass intake with time from moving the break (extending the tape to give access to new grass) a practice common in horse and cattle management, to better understand the consistency of grass intake throughout the day.

This study focused only on how horses kept alone in small paddocks spend their time. It would be important for future studies to examine the other major feature of this situation, social isolation. For example, the effects of being paddocked separately on the formation of social bonds and behaviour towards other horses when outside of the paddock could be explored, and ultimately how this affects horse welfare. Previous work on stabled and paddocked horses have found horses to be more aggressive to each other and towards handlers when kept singly and in smaller enclosures compared to when managed in groups and in larger enclosures (Flauger & Krueger, 2013; Fureix et al, 2012; Yarnell et al, 2015). Building on from aggression, it would be interesting to examine other aspects of social behaviour such as separation anxiety (by evaluating behaviour, heart rate and cortisol level for example) with neighbouring horses or horses ridden together, when horses are paddocked in groups or alone. Mitigating distress is an important aspect of improving horse welfare, and mitigating herd-bound tendencies is often a reason for managing horses separately according to anecdotal information, even though it is against their nature. In the pursuit of improving the welfare of paddocked horses, it would be interesting to test this belief.

7. Conclusion

This characterised the behavioural time budget of non-commercial horses managed individually in small paddocks ($132m^2$) in New Zealand, and evaluated the effects of providing a slow feeding device on the horses' behavioural time budget. Despite the small paddock size, the horses spent most of the observed time grazing and consequently spent little time standing. The horses were not observed to perform any stereotypical behaviours, which is because of the significant time spent grazing and capacity for visual contact with other horses. Providing concentrates in a foodball slowed down feeding time significantly, which may be beneficial for digestive health. However, contrary to the findings of studies on foodball use in stabled horses, providing the foodball did not alter the overall time budget of the horses in this study. This was likely a function of the small quantity of concentrates received compared to studies of horses kept off grass.

On the basis of these preliminary findings, non-commercial horses kept in small paddocks were found to spend most of their time grazing, and although providing a foodball slowed down the consumption of concentrated feed it did not alter the overall time budget of these horses. Future work should examine the effect of a feeding intervention over multiple days, and investigate the impact of individual management on social behaviour in paddocked horses.

8. References

Andrews, F., Buchanan, B., Elliot, S., Clariday, N. & Edwards, L. (2005). Gastric ulcers in horses. *Journal of Animal Science, 83*(13), 18-21.

Argo, C. M., Curtis, G. C., Grove-White, D., Dugdale, A. H., Barfoot, C. F., & Harris, P. A. (2012). Weight loss resistance: A further consideration for the nutritional management of obese Equidae. *The Veterinary Journal, 194*(2), 179-188.

Arnold, G. W. (1984). Comparison of the time budgets and circadian patterns of maintenance activities in sheep, cattle and horses grouped together. *Applied Animal Behaviour Science, 13*(1-2), 19-30.

Belling, T. (1990). Sleep patterns in the horse. *Equine Practice, 12*(8), 22-26.

Benhajali, H., Richard-Yris, M. A., Ezzaouia, M., Charfi, F., & Hausberger, M. (2009). Foraging opportunity: a crucial criterion for horse welfare? *Animal, 3*(9), 1308-1312.

Berger, J. (1986). *Wild horses of the Great Basin: Social competition and population size*. Chicago, USA: University of Chicago Press.

Bloomsmith, M., Brent, L. & Schapiro, S. (1991). Guidelines for developing and managing an environmental enrichment program for nonhuman-primates. *Laboratory Animal Science, 41*, 372-377.

Bolwell, C., Rogers, C., Rosanowski, S., Weston, J., Gee, E. & Gordon, S. (2015). Cross-sectional survey of the management and training practices of endurance horses in New Zealand: a pilot study. *Journal of Equine Veterinary Science, 35*(10), 801-806. doi:10.1016/j.jevs.2015.07.019

Boy, V. Duncan, P. (1979). Time-budgets of Camargue horses I. Developmental changes in the time-budgets of foals. *Behaviour, 71*(3-4), 187-202.

Boyd, L., Carbonaro, D. & Houpt, K. (1988). The 24-hour time budget of Przewalski horses. *Applied Animal Behaviour Science, 21*(1-2), 5-17.

Boyd, L. E. (1988). Time budgets of adult Przewalski horses: effects of sex, reproductive status and enclosure. *Applied Animal Behaviour Science, 21*(1-2), 19-39.

Carson, K. Wood-Gush, D. (1983). Equine behaviour. II. A review of the literature on feeding, eliminative and resting behaviour. *Applied Animal Ethology, 10*, 179-190.

Committee, N. A. W. A. (2018). *Code of Welfare: Horses and Donkeys*. Retrieved from https://www.mpi.govt.nz/dmsdocument/11003/direct

Cooper, J. McGreevy, P. (2007). Stereotypic behaviour in the stabled horse: Causes, effects and prevention without compromising horse welfare. In N. Waran (Ed.), *The welfare of horses* (pp. 99-124): Springer.

Duncan, P. (1980). Time-budgets of Camargue horses: II. Time-budgets of adult horses and weaned sub-adults. *Behaviour, 72*(1/2), 26-49.

Duncan, P. (1985). Time-budgets of Camargue horses III. Environmental influences. *Behaviour, 92*(1-2), 188-208.

Ellis, A. D. (2010). Biological basis of behaviour in relation to nutrition and feed intake in horses. In A. D. Ellis, Longland, A.C., Coenen, M. & Miraglia, N. (Ed.), *The impact of nutrition on the health and welfare of horses*: Wageningen Academic Publishers.

Ellis, A. D., Redgate, S., Zinchenko, S., Owen, H., Barfoot, C. & Harris, P. (2015). The effect of presenting forage in multi-layered haynets and at multiple sites on night time budgets of stabled horses. *Applied Animal Behaviour Science, 171*, 108-116.

Fernandes, K., Bolwell, C., Gee, E., Rogers, C. & Thomas, D. (2014). *A cross-sectional survey of rider and horse demographics, and the feeding, health and management of Pony Club horses in New Zealand*. Paper presented at the Proceedings of the New Zealand Society of Animal Production, Napier, NZ.

Fernandes, K. A., Rogers, C. W., Gee, E. K., Bolwell, C. F., & Thomas, D. G. (2015). Body condition and morphometric measures of adiposity in a cohort of pony club horses and ponies in New Zealand. *Proceedings of the New Zealand Society of Animal Production, 75*, 195-199.

Flauger, B. Krueger, K. (2013). Aggression level and enclosure size in horses (Equus caballus). *Pferdeheilkunde – Equine Medicine, 29*(4), 495-504.

Fureix, C., Bourjade, M., Henry, S., Sankey, C. & Hausberger, M. (2012). Exploring aggression regulation in managed groups of horses. *Applied Animal Behaviour Science, 138*, 216-228.

Gaunitz, C., Fages, A., Hanghøj, K., Albrechtsen, A., Khan, N., Schubert, M., Seguin-Orlando, A., Owens, I., Felkel, S., Bignon-Lau, O., de Barros Damgaard, P., Mittnik, A., Mohaseb, A., Davoudi, H., Alquraishi, S., Alfarhan, A., Al-Rasheid, K., Crubézy, E., Benecke, N., Olsen, S., Brown, D., Anthony, D., Massey, K., Pitulko, V., Kasparov, A., Brem, G., Hofreiter, M., Mukhtarova, G., Baimukhanov, N., Löugas, L., Onar, V., Stockhammer, P., Krause, J., Boldgiv, B., Undrakhbold, S., Erdenebaatar, D., Leptez, S., Mashkour, M., Ludwig, A., Wallner, B., Merz, V., Merz, I., Zaibert, V., Willerslev, E., Librado, P., Outram, A. & Orlando, L. (2018). Ancient genomes revisit the ancestry of domestic and Przewalski's horses. *Science, 360*(6384), 111-114.

Geor, R. Harris, P. (2009). Dietary Management of Obesity and Insulin Resistance: Countering Risk for Laminitis. *Veterinary Clinics of North America: Equine Practice, 25*(1), 51-65.

Goodwin, D. (1999). The importance of ethology in understanding the behaviour of the horse. *Equine Veterinary Journal, 28*, 15-19.

Goodwin, D. (2002). Horse behaviour: evolution, domestication and feralisation. In N. Waran (Ed.), *The Welfare of Horses* (pp. 1-18). The Netherlands: Kluwer Academic Publishers.

Guinnefollau, L. (2019). *Effect of veterinary undergraduate practical teaching on herd dynamics at different time-points in a semester*. Massey University.

Hampson, B., de Laat, M., Mills, P. & Pollitt, C. (2010). Distances travelled by feral horses in 'outback' Australia. *Equine Veterinary Journal, 42*, 582-586. doi:10.1111/j.2042-3306.2010.00203.x

Hampson, B., de Laat, M., Mills, P. & Pollitt, C. (2013). The feral horse foot. Part A: observational study of the effect of environment on the morphometrics of the feet of 100 Australian feral horses. *Australian Veterinary Journal, 91*(1), 14-22.

Hampson, B., Morton, J., Mills, P., Trotter, M., Lamb, D. & Pollitt, C. (2010). Monitoring distances travelled by horses using GPS tracking collars. *Australian Veterinary Journal, 88*(5), 176-181.

Harris, P. (2006). Nutritional supplements in support of equine welfare. In A. Hemmings, Harris, P., Moore-Colyer, M., Tracey, S., Howells, K. & Northrop, A. (Ed.), *Applying* *equine science: Research into business* (pp. 95-101). Nottingham: Nottingham University Press.

Heitor, F., Vicente, L. (2010). Dominance relationships and patterns of aggression in a bachelor group of Sorraia horses (Equus caballus). *Journal of Ethology, 28*, 35-44.

Heleski, C. R., Shelle, A. C., Nielsen, B. D. & Zanella, A. J. (2002). Influence of housing on weanling horse behavior and subsequent welfare. *Applied Animal Behaviour Science, 78*(2-4), 291-302.

Hemsworth, L., Jongman, E. & Coleman, G. (2015). Recreational horse welfare: The relationships between recreational horse owner attributes and recreational horse welfare. *Applied Animal Behaviour Science, 165*, 1-16.

Henderson, J. V., & Waran, N. K. (2001). Reducing equine stereotypies using an EquiballTM. *Animal Welfare, 10*, 73-80.

Hoffmann, G., Rose-Meierhöfer, S., Berg, W., Bentke, A., Mazetti, P. & Hardarson, G. (2012). Influence of an active stable system on the behavior and body condition of Icelandic horses. *Animal, 6*(10), 1684-1693.

Hoskin, S. Gee, E. (2004). Feeding value of pastures for horses. *New Zealand Veterinary Journal, 52*(6), 332–341.

Jackson, J. (1997). *The natural horse*. Harrison, United States: Star Ridge Publishing.

Jørgensen, G., Liestøl, S. & Bøe, K. (2011). Effects of enrichment items on activity and social interactions in domestic horses *(Equus caballus)*. *Applied Animal Behaviour Science, 129*(2-4), 100-110.

Jørgensen, G. H. M. B., K.E. (2007). A note on the effect of daily exercise and paddock size on the behaviour of domestic horses (Equus caballus). *Applied Animal Behaviour Science, 107*, 166-173.

Kaseda, Y. (1983). Seasonal changes in time spent grazing and resting of Misaki horses. *Japanese Journal of Zootechnical Science, 54*(7), 464-469.

Keiper, R. & Keenan, M. A. (1980). Nocturnal activity patterns of feral ponies. *Journal of Mammalogy, 61*(1), 116-118.

Kiley-Worthington, M. (1987). *The behaviour of horses: In relation to management and training*. London: JA Allen.

Kiley-Worthington, M. (1990). The behaviour of horses in relation to management and training- Towards ethologically sound environments. *Equine Veterinary Science, 10*(1), 62-71.

Maisonpierre, I. N., Sutton, M. A., Harris, P., Menzies-Gow, N., Weller, R., & Pfau, T. (2019). Accelerometer activity tracking in horses and the effect of pasture management on time budget. *Equine Veterinary Journal, 51*, 840-845.

Mason, G. (1990). Stereotypies: A critical review. *Animal Behaviour, 41*, 1015-1037.

Mayes, E., & Duncan, P. (1986). Temporal patterns of feeding behaviour in free-ranging horses. *Behaviour, 96*(1-2), 105-129.

McGreevy, P. D., Cripps, P. J., French, N. P., Green, L. E., & Nicol, C. J. (1995). Management factors associated with stereotypic and redirected behaviour in the Thoroughbred horse. *Equine Veterinary Journal, 27*(2), 89-91.

Miller, R. (1983). Seasonal movements and home ranges of feral horse bands in Wyoming's Red Desert. *Journal of Range Management, 36*, 199-201.

Monk, A. (2006). Equine stereotypies and time budgets. In A. Hemmings, Harris, P., Moore-Colyer, M., Tracey, S., Howells, K. & Northrop, A. (Ed.), *Applying equine science: Reseach into business*. Nottingham: Nottingham University Press.

Nadeau, J., Andrews, F., Mathew, A., Argenzio, R., Blackford, J., Sohtell, M. & Saxton, A. (2000). Evaluation of diet as a cause of gastric ulcers in horses. *American Journal of Veterinary Research, 61*, 784-790.

Newberry, R. C. (1995). Environmental enrichment: increasing the biological relevance of captive environments. *Applied Animal Behaviour Science, 44*(2-4), 229-243.

Nover, M. (2013). *Horse husbandry in a region of Western Germany under aspects of animal welfare.* Freie Universität Berlin, Berlin.

Pearson, R. A., Archibald, R. F. & Muirhead, R. H. (2006). A comparison of the effect of forage type and level of feeding on the digestibility and gastrointestinal mean retention time of dry forages given to cattle, sheep, ponies and donkeys. *British Journal of Nutrition, 95*(1), 88-98.

Ransom, J., & Kaczensky, P. (2016). *Wild Equids : Ecology, Management, and Conservation*. Baltimore: Johns Hopkins University Press.

Ransom, J. I., Cade, B. S., & Hobbs, N. T. (2010). Influences of immunocontraception on time budgets, social behavior, and body condition in feral horses. *Applied Animal Behaviour Science, 124*(1-2), 51-60.

Rifa, H. (1985). *Activity patterns of feral Asturcon ponies during the breeding season.* Paper presented at the 19th International Ethological Conference, Toulouse, France.

Rifa, H. (1990). Social facilitation in the horse (Equus caballus). *Applied Animal Behaviour Science, 25*(1-2), 167-176.

Rivera, E., Benjamin, S., Nielsen, B., Shelle, J. & Zanella, A. (2002). Behavioral and physiological responses of horses to initial training: The comparison between pastured versus stalled horses. *Applied Animal Behaviour Science, 78*, 235-252.

Robin, C., Ireland, J., Wylie, C., Collins, S., Verheyen, K. & Newton, J. (2015). Prevalence of and risk factors for equine obesity in Great Britain based on owner-reported body condition scores. *Equine Veterinary Journal, 47*(2), 196-201.

Rochais, C., Henry, S. & Hausberger, M. (2018). “Hay bags” and “Slow feeders”: Testing their impact on horse behaviour and welfare. *Applied Animal Behaviour Science, 198*, 52-59.

Rogers, C., Bolwell, C., Tannera, J. & van Weerenb, R. (2012). Early exercise in the horse. *Journal of Veterinary Behaviour, 7*, 375-379.

Salter, R. E., & Hudson, R. J. (1979). Feeding ecology of feral horses in western Alberta. *Journal of Range Management, 32*(3), 221-225.

Sarrafchi, A. Blokhuis, H. (2013). Equine stereotypic behaviours: Causation, occurence, and prevention. *Journal of Veterinary Behaviour, 8*, 386-394.

Schuurman, S., Kersten, W. & Weijs, W. (2003). The equine hind limb is actively stabilized during standing. *Journal of Anatomy, 202*(4), 355-362.

Smith, D. (1999). *The impact of grazing time allowance on the dry matter intake and foraging behaviour of cattle and donkeys managed under traditional african grazing systems.* (PhD), University of Edinburgh.

Sneddon, J. Argenzio, R. (1998). Feeding strategy and water homeostasis in equids: The role of the hind gut. *Journal of Arid Envvironments, 38*(3), 493-509.

Sondergaard, E. (2003). *The effect of social environment and handling on the behavioural and physical development of young horses* (Vol. 122). Denmark: Royal Veterinary and Agricultural University.

Sweeting, M. P., Houpt, C. E., & Houpt, K. A. (1985). Social facilitation of feeding and time budgets in stabled ponies. *Journal of Animal Science, 60*(2), 369-374.

Thomason, J. (2007). The hoof as a smart structure. In A. M. Floyd, R (Ed.), *Equine podiatry* (pp. 46-53). St Louis: Elsevier.

Thompson, K., Clarkson, L., Riley, C. & van den Berg, M. (2017). Horse-keeping practices in Australia: findings from a national online survey of horse owners. *Australian Veterinary Journal, 95*, 437-443.

Thorne, J. B., Goodwin, D., Kennedy, M. J., Davidson, H. P. B., & Harris, P. (2005). Foraging enrichment for individually housed horses: practicality and effects on behaviour. *Applied Animal Behaviour Science, 94*(1-2), 149-164.

Van Soest, P. J. (1996). Allometry and ecology of feeding behavior and digestive capacity in herbivores: a review. *Zoo Biology, 15*(5), 455-479.

Veasey, J., Waran, N. & Young, R. (1996). On comparing the behaviour of zoo housed animals with wild conspecifics as a welfare indicator, using the giraffe (Glraffa camelopardalis) as a model. *Animal Welfare, 5*, 139-153.

Watts, K. (2010). Pasture management to minimize the risk of equine laminitis. *Veterinary Clinics of North America: Equine Practice, 26*(2), 361-369.

Werhahn, H., Hessel, E. F., Bachhausen, I., & Van den Weghe, H. F. (2010). Effects of different bedding materials on the behavior of horses housed in single stalls. *Journal of Equine Veterinary Science, 30*(8), 425-431.

Werhahn, H., Hessel, E., Schulze, H. & Van den Weghe, H. (2011). Temporary turnout for free exercise in groups: Effects on the behavior of competition horses housed in single stalls. *Journal of Equine Veterinary Science, 31*(7), 417-425.

Wheeler, E. Smith Zajaczkowski, J. (2016). Horse stable flooring materials and drainage. Retrieved from https://extension.psu.edu/horse-stable-flooring-materials-and-drainage

Whisher, L., Raum, M., Pina, L., Pérez, L., Erb, H., Houpt, C. & Houpt, K. (2011). Effects of environmental factors on cribbing activity by horses. *Applied Animal Behaviour Science, 135*(1-2), 63-69.

Williamson, A., Rogers, C. & Firth, E. (2007). A survey of feeding, management and faecal pH of Thoroughbred racehorses in the North Island of New Zealand. *New Zealand Veterinary Journal, 55*(6), 337-341.

Winskill, L., Waran, N. & Young, R. (1996). The effect of a foraging device (a modified 'Edinburgh Foodball') on the behaviour of the stabled horse. *Applied Animal Behaviour Science, 48*, 25-35.

Yarnell, K., Hall, C., Royle, C., & Walker, S. L. (2015). Domesticated horses differ in their behavioural and physiological responses to isolated and group housing. *Physiology & Behaviour, 143*(51-57).

Young, R. (2003). *Environmental enrichment for captive animals*: Blackwell Science Ltd.

Zeitler-Feicht, M. (2003). *Horse behaviour explained: Origins, treatment and prevention of problems*. Boca Raton: CRC Press.