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Patterns of dispersion, behaviour, and reproduction
in feral horses (*Equus caballus*), and plant growth in
Argo Valley, Waiouru.

a thesis presented in partial fulfilment of the requirements
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ABSTRACT.

Observations on feral horses (*Equus caballus*) in the Army Training Area at Waiouru from February 1993 to April 1994 showed that horses were not evenly distributed throughout their range and the highest density of horses was in the Argo ecological zone. After a muster in June 1993 which cleared horses out of the Argo Valley, horses returned to the valley suggesting that this area constituted preferred habitat for the horses. Home ranges of bands varied in size between 23.2 and 883.0 ha.

Horses associated in three types of social groupings. These included the single-male breeding group, the multi-male breeding group, and the bachelor band consisting entirely of males. Changes in membership occurred in bands. 95% of interactions between neighbouring bands were observed in summer. Band members groomed other members in 23% of observed interactions. 75% of interactions observed between mothers and their offspring were suckling bouts. 136 suckling bouts involved foals, and 8 involved yearlings. The average length of a bout was 49.0 seconds (sd=22.1). The average time elapsed between suckling bouts increased significantly as foals grew older ($F=28.64$, $P=0.000$). There was no significant difference between foals in the length of time any individual foal spent suckling. Mothers terminated 6.1% of observed suckling bouts. Scan sampling indicated a lull in grazing approximately 4 hours after sunrise. Grazing resumed at approximately 10 hours after sunrise.

Mating behaviour was observed in September and November. Post mortem data and blood oestrone level analysis for mustered mares indicated that between 72% and 81% of mares were pregnant. Foaling was observed between September and March. The foal-to-mare ratio was estimated to be 0.3 and 0.32 in two consecutive breeding seasons. Foal-to-mare ratios differed significantly between ecological zones. The yearling-to-mare ratio showed a 62% loss compared to the foal-to-mare ratio for the previous year.

59-60% of bands observed contained foals and no yearlings while 12-14% of bands contained yearlings and no foals, suggesting that not all mares are capable of producing a live foal every consecutive season. Some mares had both a foal and yearling present in their band suggesting an ability to breed successfully in consecutive seasons.

A search for dead horses revealed 63 skeletons. Of skeletons that could be aged using dental characteristics, most were aged between 2 and 9 years. More dead males were found than females. Using census figures from previous years, the death rate was calculated by dividing 63 known deaths by 11130 estimated horse-years, giving a death rate of 0.006.

Using exclosure cages, productivity in the Argo basin ranged between 2.98 and 1.54kgDM/ha/day in December 1993, February, April and July 1994. Introduced grasses dominated the sward. Using published biomass requirements for horses, I calculated the carrying capacity of the Argo valley. It ranged from 184 to 93 horses between October 1993 and July 1994. The number of horses observed in the Argo valley did not exceed these figures over this time interval.

Future management of the Kaimanawa feral horse population will trial immunocontraception on a reduced population. To arrest population growth, up to 80% of mares will be vaccinated with porcine zona pellucida (PZP) which prevents fertilization of the ovum.

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Chapter One. Introduction.

1.1. Ecology of feral horses.

1.1.1. Feral horse populations around the world.

Populations of feral horses (*Equus caballus*) occur in North America, Great Britain, Europe, Australia and New Zealand. Some populations are either unmanaged or randomly culled, while other populations are managed on a more intense basis through controlled breeding. For example, in North America and Australia, populations of feral horses have roamed without any form of management until the later years of this century, while herds such as the New Forest ponies in England and the Camargue horses in France have an established history of management.

In the United States, feral horses have posed management problems since they were protected by law 25 years ago. There are now an estimated minimum 45,000 horses in the western United States in 103 feral horse reserves (Garrott, Siniff and Eberhardt, 1991). At least 18 populations were distributed throughout Oregon, Idaho, Wyoming, Nevada, Utah, California and Colorado (Wolfe, 1980). These populations were mostly concentrated in the Great Basin, including Nevada, South-eastern Oregon, and the Red Desert of Wyoming. Well-studied populations include the Pryor Mountain herd in Wyoming (Feist and McCullough, 1975), the Pine Nut and Pah Rah herds in Nevada (Siniff, Tester and McMahon, 1986), Beatty's Butte and Jackie's Butte herds in Oregon (Eberhardt, Majorowicz and Wilcox, 1982), and the Red Desert herd in Wyoming (Miller, 1981). On the eastern seaboard of the United States, researchers have studied the Assateague ponies living on Assateague Island (Keiper, 1976, Kirkpatrick and Turner, 1991), the Shackleford Banks population (Rubenstein, 1981), and the Cumberland Island herd (Turner, 1988). There are also feral horses in Canada, particularly the Sundre population (Salter and Hudson, 1982), and the Sable Island herd (Lucas, Raeside and Betteridge, 1991).

Most free-roaming pony herds in Great Britain are managed by allowing only approved and registered animals to be released (Ponies are, by definition, small horses which measure 1.475m or below in height at the point of the spine above the shoulder (Cunha, 1991)). Such ponies are privately owned and their owners have the right to release the animals to graze on certain public tracts of land, such as in the New Forest. These include populations of Highland ponies, Exmoor and Welsh ponies. Researchers have investigated behaviour and home range in the New Forest ponies (Tyler, 1972), and the Exmoor ponies (Gates, 1979). The Highland ponies grazing on Rhum have also been studied (Clutton-Brock, Greenwood and Powell, 1976).

The Camargue horses live in southern France. They have been managed for many horse generations by provision of extra food during times of starvation, and by culling stallions to control the population growth rate. Duncan (1992) has conducted research into the nutritional requirements of these horses.

The Australian feral horses are found mainly in the Northern Territory, and there are populations in Queensland, Western Australia, South Australia, New South Wales and Victoria. Research has been conducted into control methods because the horses compete with livestock for grazing and water during times of drought, and cause environmental damage (Dobbie, Berman and Braysher, 1993). Researchers estimated that 300,000 horses roamed throughout these states.

1.1.2. Habitats colonised by feral horses.

Feral horses inhabit a variety of landscapes even within the countries in which they occur. However, they commonly occupy areas which are not required for grazing or cropping. Generally, horses use habitats with little or no forest, but two exceptions are the New Forest Ponies of Britain and the Sunde horses in western Canada. Both of these groups live in forest punctuated by open patches. Otherwise, many populations

live on plains or deserts, often at high altitude.

The Pryor Mountain group is a typical example. The vegetation there is semi-desert type, including grasses, shrubs and cacti at lower elevations with shrubs and scattered trees in sub-alpine higher elevations (Feist and McCullough, 1975). The Granite Range horses inhabit an area which is part of the Great Basin landform. The habitat is characterised by high altitude, resulting in short hot summers and long cold winters. The cover vegetation has been divided into seven types, including shrublands, grasslands, forests, rabbitbrush patches (*Chrysothamnus nauseosus*), riparian zone meadows and waste land (Berger, 1986). At least one of these vegetation categories is represented in the habitat of most feral horse herds. A very similar type of habitat is occupied by the Nevada herd studied by Wolfe (1986), where the horses live on subalpine shrubland.

Islands off the eastern coast of the United States present harsh conditions for horses. Storms often buffet these low-lying islands and the general lack of shelter results in a windswept and salt-laden environment. On Assateague Island, the habitat consists of mainly marsh and grassy dunes, with some forest patches also present (Rudman and Keiper, 1991). Shackleford Banks has a range of habitat types. These include sandy beaches, low dunes, salt-meadows containing grasses and sedges, salt marsh and maritime forest (Rubenstein, 1981). The habitat of Cumberland Island, off the coast of Georgia, includes salt marshes, dunes, interdune meadows and lawn areas (Turner, 1988). The horses on Sable Island off the coast of Nova Scotia also face rough conditions but there is some shelter against the prevailing winds available amongst the dunes. The horse diet consists of marram grass (*Ammophila breviligulata*), beach pea (*Lathyrus maritimus*) and sandwort (*Honckerya peploides*) (Lucas et al, 1991).

In Great Britain, there are some contrasts between the habitats of the Exmoor and New Forest pony herds. The Exmoor ponies studied by Gates (1979) inhabited an area of

heath moorland and rough land between 260 and 430m asl. In the New Forest, the habitat included a mixture of heathland, beech (*Fagus sylvatica*) and oak (*Quercus robur*) woodland and ponies also encountered bog vegetation (Tyler, 1972). In Canada the Sundre population in Alberta lived in habitat consisting of about 80% woodland (Salter and Hudson, 1982). In the Camargue, the land is extremely flat and the soil very salty. The horses experienced cool, wet winters and warm dry summers and marshes that flooded after heavy rain. The vegetation was constrained by both excessive water and high salinity (Duncan, 1992).

In Australia, horses mostly inhabit remote semi-arid rangelands. They also occur in tropical grasslands and swamps, temperate ranges, subalpine mountains and small offshore islands. The feral horse diet consisted largely of grasses, but also may include swamp vegetation, roots, bark, buds and fruit (Dobbie et al, 1993).

1.1.3. Home range sizes and population densities.

Feral horses range in social groups called bands that consist of family groups or temporary adult associations. Feral horses reach high densities, compared with other mammalian herbivores and their relatively small home ranges mean that horse bands may forage their environment intensively (Duncan, 1992). The home range sizes of horse bands in the Camargue ranged from 1000 to 5000ha (Duncan, 1992). Pryor Mountain held 225 horses on 3660ha with an estimated average range size of 1456ha per band (Feist and McCullough, 1975).

Table 1. Average feral horse densities measured as hectares of range per horse.

Herd(Reference)	Density(ha/horse)
Pryor Mountain Wild Horse Range (Feist and McCullough, 1975)	60.7
Pine Nut Mountain Range (Siniff et al, 1986)	93.0
Pah Rah Mustang Area (Siniff et al, 1986)	186.0
Beatty's Butte (Eberhardt et al, 1982)	422.0
Cumberland Island (Turner, 1988)	1.14
Sable Island (Lucas et al, 1991)	8.5
Australia (Dobbie et al, 1993)	100.0
New Forest (Tyler, 1972)	4.3
Exmoor (Gates, 1979)	25.0
Camargue (Duncan, 1992)	4.0

Variations in the population density of feral horses (Table 1) reflect both ecological variations between study areas and human intervention. For example, at Pryor Mountain some horses were excluded from the range by fencing during the study (Feist and McCullough, 1975). The Beatty's Butte area was fenced to prevent immigration or emigration of horses and over 700 horses were removed from the area during the time of the study (Eberhardt et al, 1982).

On islands, horse density is constrained by the finite amount of space for animals to roam. In Australia, the management of feral horses aimed to reduce density to 100ha/horse (Dobbie et al, 1993).

In Great Britain, the density of free-ranging pony herds also reflected management practices. A population of ponies living on Exmoor was managed by limiting the number of breeding stallions and removing some weak or ill animals (Gates, 1979). The New Forest ponies were also managed using breeding controls (Tyler, 1972). The

Camargue horses studied by Duncan (1992) lived in an enclosed area and reached a maximum density followed by population decline. To avoid any deaths due to starvation, managers removed the very thin individuals to more plentiful pasture. The density of horses in the area did not therefore represent the carrying capacity.

1.1.4. Reproduction and mortality in feral horse populations.

Many feral horse populations are characterised by high foaling rates and high survival of adult horses (Table 2).

Table 2. Foaling rates and survival in seven feral horse herds (* not reported).

Herd	Foaling rate(foals/mare/year)	Method for determining foaling rate	Survival of foals (%)	Survival of adults (%)
Wyoming, Nevada, Oregon (Garrott, 1991)	69.0%	Lactational status of mares	92.0-98.0	85.0
Oregon, Nevada, Utah, Wyoming, Colorado (Wolfe, 1986)	*	*	50.0-70.0	80.0
Nevada (Garrott et al, 1991, a)	25.6%	lactational status of mares	*	*
Pryor Mountain (Garrott and Taylor, 1990)	36.0-65.0%	Observation	*	93.0-98.0
Assateague (Keiper and Houpt, 1984)	57.1%	Observation	88.0	*
Assateague (Kirkpatrick and Turner, 1991)	32.5%	Observation	*	*
Sable Island (Lucas et al, 1991)	62.0%	Observation	*	*

The first reproduction (mating) in females commonly occurs at two years of age, and an increased proportion foal around 6 years of age. The highest measured foaling rates

in North American populations occurred between 6 and 15 years of age with a gradual decrease in productivity of females over 15 years (Garrott et al, 1991, a).

1.1.5. Strategies for control of population size.

Some herds have a long history of management, particularly those in Great Britain and France. Ponies have been grazed in the New Forest for hundreds of years. Owners of ponies who held grazing rights released their marked ponies into the forest, but most of the male foals were removed and sold each year during round-ups. Only approved stallions were permitted to roam the forest (Tyler, 1972). A similar situation existed for the Exmoor ponies studied by Gates (1979). These ponies did not receive any extra food or shelter during winter months, but only two mature stallions were present in this group. The Camargue horses of France were also managed by removing stallions that were thought to be "substandard" (Duncan, 1992) and some removals to supply riding horses also took place. During Duncan's study, only extremely thin individuals were removed, with no interference otherwise. As these horses belonged to controlled groups, no immigration or emigration outside the grazing area took place.

The oldest method of feral horse control is straightforward removal of horses from their range. In the United States, thousands of horses are removed every year under the jurisdiction of the Bureau of Land Management (Garrott et al, 1991, b). These horses are then placed in captivity, as it is prohibited to destroy them. One study estimated that over 100,000 horses were being maintained on feedlots (Boyles, 1986). The 'Adopt-a-horse' programme finds homes for some horses, but only a limited number can be placed. Horse herds living in the Western United States have been reduced in this way, including the Pryor Mountain herd (Garrott and Taylor, 1990), some Nevada herds (Garrott et al, 1991,a), and 18 feral horse populations in five states (Wolfe, 1980). In Australia, horses are commonly shot from helicopters, or rounded up

from the air and removed (Dobbie et al, 1993).

Periodic round-ups have occurred in the Pryor Mountain herd between 1970 and 1990 (Garrott and Taylor, 1990). The objective was to maintain 121 horses on 18900ha. During early roundups horses were immobilised then captured, but more recently managers have trapped horses by driving them into permanent corrals. Horses were removed from Nevada ranges using helicopters to muster them into corrals. Between 50 and 2221 horses were removed at a time. Australian methods for horse population reduction include trapping, mustering, exclusion by fencing and shooting, especially from the ground. The last is the most favoured method. Horses removed by other methods are generally slaughtered (Dobbie et al, 1993).

1.2. Feral horses in the Kaimanawa ranges.

Feral horses are found in the Army Training Area, east of Waiouru in the central North Island of New Zealand (Lat 39°S, Long 175°E). The landscape is generally steep and at high altitude, ranging between 700m and 1477m asl. The substrate is pumice soil. The horse range is bounded by the Rangitikei River in the east, farmland in the south, the Waipakihi Stream in the north, and State Highway 1 (the Desert Road) in the West. None of these barriers are impenetrable to horses, but horses are not protected in law if they migrate outside these limits and so they are either removed or herded back into the Training area when this happens. Many horses live in the Argo Valley in the southern part of the Training Area and this was therefore the most visited part of the range during my study. This area was previously farmed and has been heavily modified with introduced grasses.

The weather is cold and wet in winter and dry in summer. Annual rainfall is approximately 1780 mm (Aitken et al, 1979, unpub.). The wettest months are between March and June (autumn-early winter) and between September and November (spring).

The warmest months occur between December and February. Temperatures ranged from 26°C to -10°C between January 1993 and August 1994. The prevailing wind is from a westerly direction. Snowfalls are common throughout the winter months.

Due to the pumice makeup of the substrate, water runs away quickly meaning that there is only limited water available in the ground for vegetation growth. However, plenty of water is available for horses to drink at all times of the year. The vegetation consists of tussock grassland including both red tussock (*Chionochloa rubra*) and hard tussock (*Festuca novaezealandiae*). Extensive areas of introduced grassland including yorkshire fog (*Holcus lanatus*), sweet vernal (*Anthoxanthum odoratum*), and browntop (*Agrostis capillaris*) occur in the southern part of the region. Pockets of beech forest (*Nothofagus* sp.) occur particularly in the north and eastern parts of the range, and subalpine shrublands of monoao (*Dracophyllum subulatum*) are found at high altitude. Areas of manuka (*Leptospermum scoparium*) shrubland also occur scattered throughout the range.

1.2.1. History of the Kaimanawa population.

Feral horses were first seen in the Kaimanawa mountains in 1876 (R.A.L. Batley, pers com). The present group are thought to have origins in both the Exmoor and Welsh pony breeds, as well as thoroughbred, Arab and Clydesdale influences as the result of releases of horses onto the Kaingaroa Plains by Sir Donald McLean in 1877. Other liberations included military horses from Waiouru in 1941 during a strangles epidemic, and domestic horses over many years (Wright, 1989). Parts of the population, particularly in the south, are not isolated from the horses on privately owned farms that border the Army Training Area. Although thousands of horses are reported to have roamed the Central Plateau last century, numbers had dropped by the 1970's due to hunting of horses (Wright, 1989). The Kaimanawa Wild Horse Committee, comprising

Tony Batley and others, commissioned a report into the status of the population. It was estimated that 174 horses remained in 1979 (Aitken et al, unpub). After the horses were legally protected in 1981, the population began to increase. By 1990, an aerial census put the population at 1102 horses (Rogers, 1991). At this stage the horses were considered to have damaged the habitat of many native plants through grazing and trampling (Rogers, 1991). A draft management strategy for limiting horse damage to native plant communities was developed and circulated for public review by the Department of Conservation.

1.2.2. Legal status of the population.

The Kaimanawa wild horses are protected under a Special Order in Council enacted in 1981 under the provisions of the Wild Animal Control Act of 1953. Only those horses that live within the confines of the Army Training Area are protected and horses living in a wild state elsewhere in New Zealand are not protected.

1.2.3. Impacts of Kaimanawa horses on native plant communities.

Rogers (1991) studied the dispersion, density and recruitment of plants between 1982 and 1989. He also studied the dispersion and density of the horse population according to census records dating back to 1979. By measuring the growth of plants inside enclosure plots which excluded horses, he found that horse grazing reduced recruitment of young red tussock (*Chionochloa rubra*) into the community and that horses also grazed heavily on *Chionochloa pallens* in tussock grasslands (Rogers, 1991). More recruitment of hard tussock (*Festuca novaezealandiae*) occurred in the absence of horse grazing. Rogers predicted that *Hieracium pilosella* grasslands would develop under this extreme grazing pressure. He also predicted that it was unlikely that horses would inhibit the regeneration of beech forest. During the study, Rogers found that the habitats of 10

plant species found only within the wild horse range in the North Island suffered damage from grazing and trampling by horses. This damage particularly affected those plants inhabiting the margins of marshy areas. These include *Amphibromus fluitans*, *Carex berggrenii*, *Carex petrei*, *Carex unciifolia*, *Gnaphalium ensifer* and *Koelaria* sp. Rogers predicted that introduced plants such as heather (*Calluna vulgaris*) would also have an adverse effect on the habitat of special plants as horse grazing damage accelerates the spread of weeds.

1.3. Research Objectives.

The demography of the horse population, the site-attachment of herds and dispersion of horses on a daily and seasonal basis need to be measured in order to understand population growth patterns of the Kaimanawa wild horse population. As described above (1.2.3), horse grazing and trampling poses a threat to many native plants in the Army Training Area. Feral horse populations are capable of causing damage to the landscape as their numbers escalate. In Australia, control schemes have been implemented to protect the interests of domestic livestock owners (Dobbie et al, 1993). In the case of the Kaimanawa horses, the Department of Conservation proposed to manage horse numbers by first removing horses and then maintaining the remainder at a low level using immunocontraception.

To be effective, any management scheme must be based on information about the population itself. It would not be safe to extrapolate from studies overseas because environmental conditions differ elsewhere. By investigating the dispersion of horses, I determined the numbers of horses in different parts of the range, as discussed in Chapter 2. Horses which live in parts of the range containing sensitive habitat pose more of a risk than do those horses living in heavily modified parts of the range. However, if bands of horses are very mobile and readily move between areas of high

and low sensitivity, then sensitive habitat remains at risk even after horse removal. Research was necessary to determine whether the social behaviour of Kaimanawa horses differed markedly from that of other feral horse populations studied. The results of this are discussed in Chapter 3. To reduce horse numbers, there must be either increased mortality or decreased natality, since emigration and immigration are negligible. The draft management strategy included mustering horses and removing them from the range, which simulated increased mortality. By implementing an immunocontraception scheme, managers would also reduce fertility (the proposed immunocontraceptive vaccine interferes with fertilisation so that the mare does not become pregnant). It is necessary to determine what proportion of mares must be immunised to result in an effective decrease in population fertility. The structure of the population, including the age and sex ratio shows what portion of the population are potential targets, that is, mares of breeding age. By determining the number of births and deaths annually the dynamics of the population can be investigated. The foal-to-mare ratio shows how many foals are produced by each breeding-age mare in one season and this is discussed in Chapter 4. This is balanced by a mortality figure which removes horses from the population each year as described in Chapter 5. Finally, I conducted trials to determine what number of horses might be adequately maintained in heavily modified vegetation in part of the range. By measuring grass growth and nutritional content, I calculated the stocking rate for horses in the Argo basin and this is discussed in Chapter 6.

Chapter Two. Dispersion of feral horses in the Army Training Area before and after the June 1993 muster.

2.1. Introduction.

In an undisturbed situation, we would expect to find Kaimanawa horses distributed in patterns that depend on resources available in their environment. The mating system in horses is a polygynous one which may be shaped by the distribution of resources (Emlen and Oring, 1979). The ecological pressures that affect sociality in horses elsewhere include the need to avoid predators and the requirement for food and water. These affect males and females differently because of differing reproductive interests (Rubenstein, 1986). Females require sufficient access to food and water to maintain their condition and nurture healthy offspring. This enhances their lifetime reproductive success. Males need access to females in order to breed and produce the largest number of offspring that they can. In this chapter I present results that show feral horses occurred in higher numbers in certain parts of their range in the Army Training Area. It would seem that those areas represent pockets of resources important for horses.

After a muster in which a proportion of the population was removed from high density areas, the remaining horses were predicted to resettle the areas in the same densities as before. An observer would expect to find the same percentage of the population in the same areas as previously. However, if a large differential in resource availability had previously existed then horses may move into the newly cleared area in search of greener pastures, and resettle in much higher numbers than before. This would mean that horses must be prepared to leave one ecological zone and move into another. By measuring the difference in densities before and after the muster conducted for the Department of Conservation in June 1993, it was possible to determine changes

in the dispersion of Kaimanawa horses.

2.2. Methods.

Field trips were limited in duration by both weather conditions and Army access restrictions. However, 12 trips were made during 1993, and 8 trips were made during 1994. The Argo ecological zone was visited most often as it was easily accessible and provided excellent opportunities for horse observations (Table 3).

Table 3. Number of visits to each ecological zone.

Ecological Zone	Number of visits
Argo	12
Awapatu	3
Motumatai	2
Ngawakaakaue	6
Otokoro	4

On sighting a band, I recorded the number of horses in it, and if possible made notes and sketches to identify individuals. The sex of each horse was determined by observing secondary sexual characteristics. These were more easily discerned in mature animals than juveniles. In addition, certain behaviours such as the herding posture shown by stallions were only seen in one sex. Accurate physical description of individuals for future reference became difficult if the animals were too far away to see properly or if wet conditions caused the horses to be darkened in colour by having damp coats. Adults and juveniles were aged according to body size. Foals could be identified by their small size, short fluffy manes and tails, and often the close proximity to their mothers (Fig. 1). Yearlings also had a smaller body size than the adults, but were generally independent of their mothers.



Fig. 1. Mustered foals of approximately eight months of age showing characteristic short fluffy tails.

In order to follow the progress of bands over many months, it was necessary to identify individual horses and their bands. Individuals were recognised by hair colour, facial and leg markings, noticeable scars, and also geographic location of their band which did not vary for some horses. Without a system of marking horses, many could not be identified as they had no particular feature which could be easily recognised. However, if a band had one distinctive horse in it and the band membership had remained the same, then they were assumed to be the same horses present as in the previous sighting. Some bands had more than one horse which could be recognised, and information about all band members built up with increasing number of sightings. These groups were described as "familiar bands". Many horses with recognisable features were seen only once and could not be relocated during the remainder of the study.

2.2.1. Explanation of Roger's ecological zones.

Rogers (1991) divided the Army Training Area into six ecological zones based on vegetation, climate and geology. These zones varied in size, and I assumed that horses were able to move freely between them (Fig. 2).

The Argo zone is the largest by area, and contains the largest number of horses (Rogers, 1991). This zone is directly east of Waiouru and has been greatly modified by human intervention, having been grazed, fertilized and oversown at various times in the past. It also contains some of the lowest altitude habitat available to the horses in the Army Training Area. The Awapatu zone is north-east of the Argo zone and contains one of the areas set aside from vehicle use to protect the rare plants within it. The Awapatu zone also has high conservation values because of the extensive red tussock grassland there (Rogers, 1991). The Motumatai zone is on the eastern boundary of the Training Area, and also contains tussock grassland, but human activities have

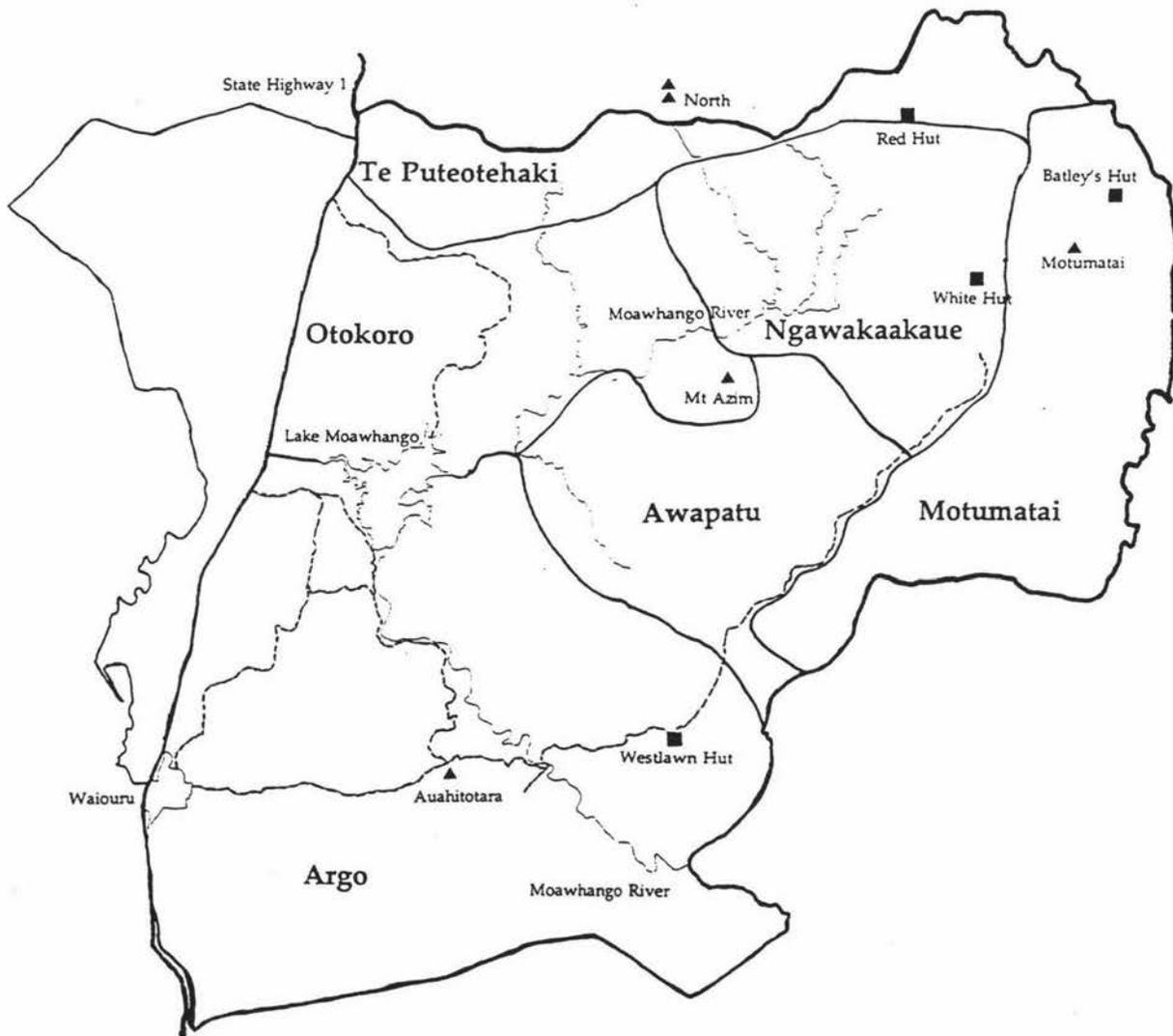


Fig. 2. Map showing Roger's ecological zones and landmarks.

modified it over many years. This zone includes part of the Kaimanawa Forest Park, and part of a reserve owned by the Batley family. Motumatai abuts onto the Ngawakaakaue zone which is characterised by extensive swamps and contains most of the biogeographically rare plants (Rogers, 1991). The Otokoro zone is north of Lake Moawhango and contains some forest cover. The northernmost zone is Te Puteotehaki, which contains high altitude habitat, and is characterised by rough terrain. Few horses were seen here during census flights or other searches (B. Fleury, personal communication).

2.2.2. Aerial census.

Aerial census data was collected during April 1994. A team of four people counted horses from the air. The census was flown using a Hughes 500 helicopter, and a satellite tracking system to record the location of horses as they were sighted. The Army Training Area was divided into areas based on geographical features and each of these areas was flown in transect lines. The entire area was covered in two days.

2.2.3. Removal of horses in June 1993 muster.

I searched the ecological zones (March and April 1993) before a muster took place in June 1993 to measure the horse presence in each area. The first muster of the wild horses instigated by the Department of Conservation took place in June 1993. Horses were mustered into yards located beside the Moawhango River, in a natural basin which ended in a steep-sided gorge with no exit. The muster gathered horses from the Argo and Awapatu zones (Fig. 3.). After the initial roundup, horses were driven alongside the river into the yards for drafting and sorting into groups.

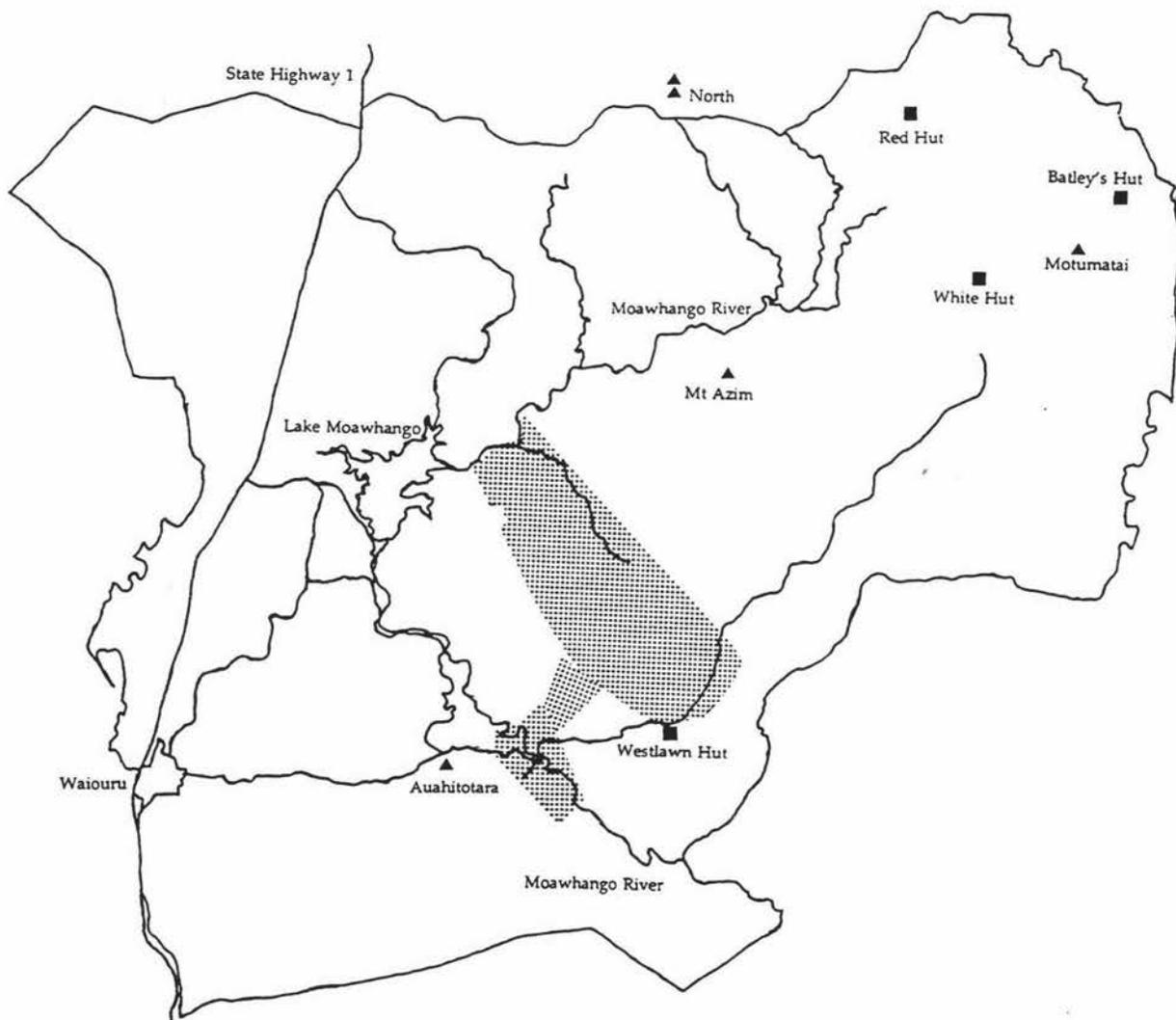


Fig. 3. Zones from which horses were mustered in June 1993.

2.2.4. Measurement of home range sizes.

Home range sizes for familiar bands were measured using the convex polygon method (Mohr, 1947). I plotted the locations at which each band was sighted on a map of the area. Having drawn a line around the outermost points of each home range, I cut out and weighed the pieces. The size of each range was calculated by dividing the weight of each piece of paper by the weight of the reference piece which was equivalent to 1km² by area.

2.3. Results.

2.3.1. Horse bands in each ecological zone before the muster.

I spent more field hours searching in some zones than others (Table 4.). Te Puteotehaki zone was not visited.

Table 4. Time spent by observer in each ecological zone.

Zone	Area(ha)	Field Days
Argo	18066	42
Awapatu	6815	3
Motumatai	13381	8
Otokoro	5713	4
Ngawakaakaue	8927	1
Te Puteotehaki	10673	0

The greatest number of bands was seen in the Argo, and the least in the Ngawakaakaue (Table 5). Some bands were sighted on more than one occasion. If this band contained a distinctive individual or was well-known because of continued resightings then it became a "familiar band". I commonly saw bands more than once during one trip to a particular zone, but did not see those bands again on returning to that zone. All of the familiar bands occurred in the Argo ecological zone, although I observed one band in the Awapatu zone on two occasions.

Table 5. Density of horses in each zone before muster in June 1993.

Zone	Density (ha/horse)
Argo	19
Awapatu	27.3
Motumatai	94.2
Otokoro	892.7
Ngawakaakaue	248.4

2.3.2. Horse bands in each ecological zone after the muster.

After the muster, I revisited the Argo and Motumatai zones. I visited the Argo zone from July to September. During October and December, horse densities rose compared with September. By late summer in 1994 (January-February), the density of horses had again decreased in the Argo zone (Fig. 4). However, the area available for each horse remained high in both the Motumatai and Otokoro ecological zones. During the April 1994 census, both the Argo and Awapatu zones had the highest density of horses, while Otokoro had the lowest density (Table 6).

Table 6. Observed density in each ecological zone using two methods during April 1994 (in ha/horse).

Zone	Ground observations	Aerial observations
Argo	19.3	22.11
Awapatu	82.1	22.57
Motumatai	172.0	51.27
Otokoro	357.1	90.17
Ngawakaakaue	51.0	64.92

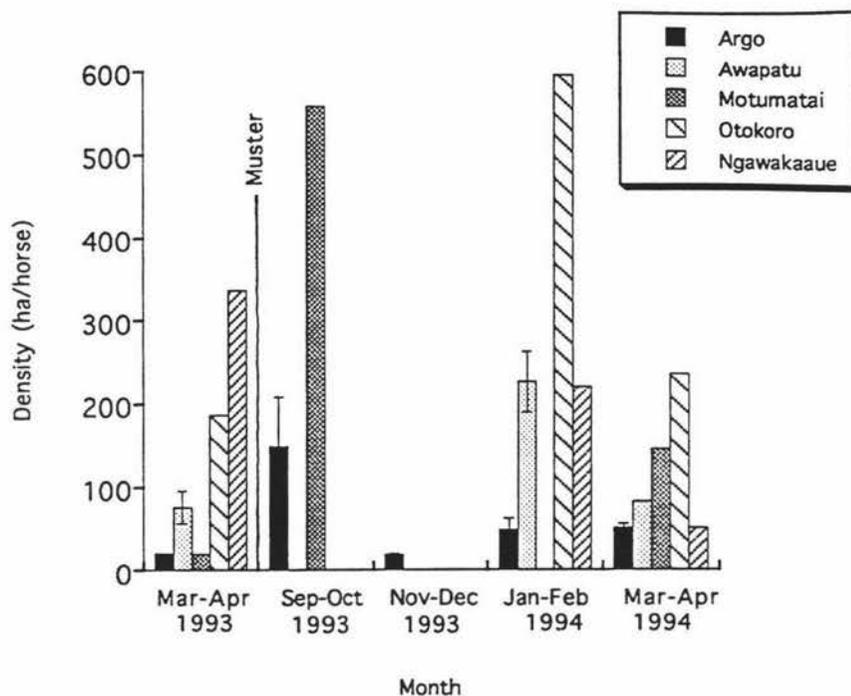


Fig. 4. Mean horse densities in each ecological zone before and after the muster in June 1993 (with standard error bars).

2.3.3. Average home range size of bands.

Home range data were collected from sightings of familiar bands. Six familiar bands occupied the Argo Valley before the muster in June 1993. One other band was first observed after the June muster. All of these bands were resighted in more than one season of observations (Table 7). The mean home range size was 251.6ha (sd = 287.4). Red Yellow band moved between the Argo and Awapatu ecological zones during the duration of the study and was the only band observed to do so. All other familiar bands remained within the Argo zone (Fig. 5). Blue band remained within a small sector of the Argo basin throughout the study.

Table 7. Average home range size of familiar bands.

Band	Size of Range(ha)	Sightings
Red	23.2	20
Green	240.0	32
Blue	98.0	21
Red Yellow	883.0	21
Yellow	208.0	24
Brown	140.0	16

2.4. Discussion.

Kaimanawa horses lived throughout the Army Training Area, but the greatest concentrations occurred in the Argo ecological zone. Some zones had a much lower observed density of horses than others, as illustrated by the difference between the Argo and Otokoro zones. One possibility is that history will explain this differential in horse dispersion. Horses were released from Waiouru during the Second World War (See Chapter One) and their descendants may simply have remained close to the original release point. However, there are two arguments against this. One is that horses have dispersed from the Motumatai area where a study was conducted in 1979 (Aitken et al, 1979, unpub), and at that time horses were not recorded in the Argo Valley. The second is that after horses were cleared from the Argo Valley in the muster in June 1993, horses soon returned to the valley and many horses were present during spring and summer. This suggests that resource availability may differ between zones. The Argo ecological zone contains large tracts of introduced grassland and parts of the zone are at the lowest altitude found in the Army Training Area. In comparison, the Otokoro zone contains red tussock grasslands and subalpine shrubland vegetation, and is bleak in winter due to high altitude. Therefore it may constitute less preferable habitat for horses.

Assuming that introduced grasses are preferred forage for horses (See Chapter Six),

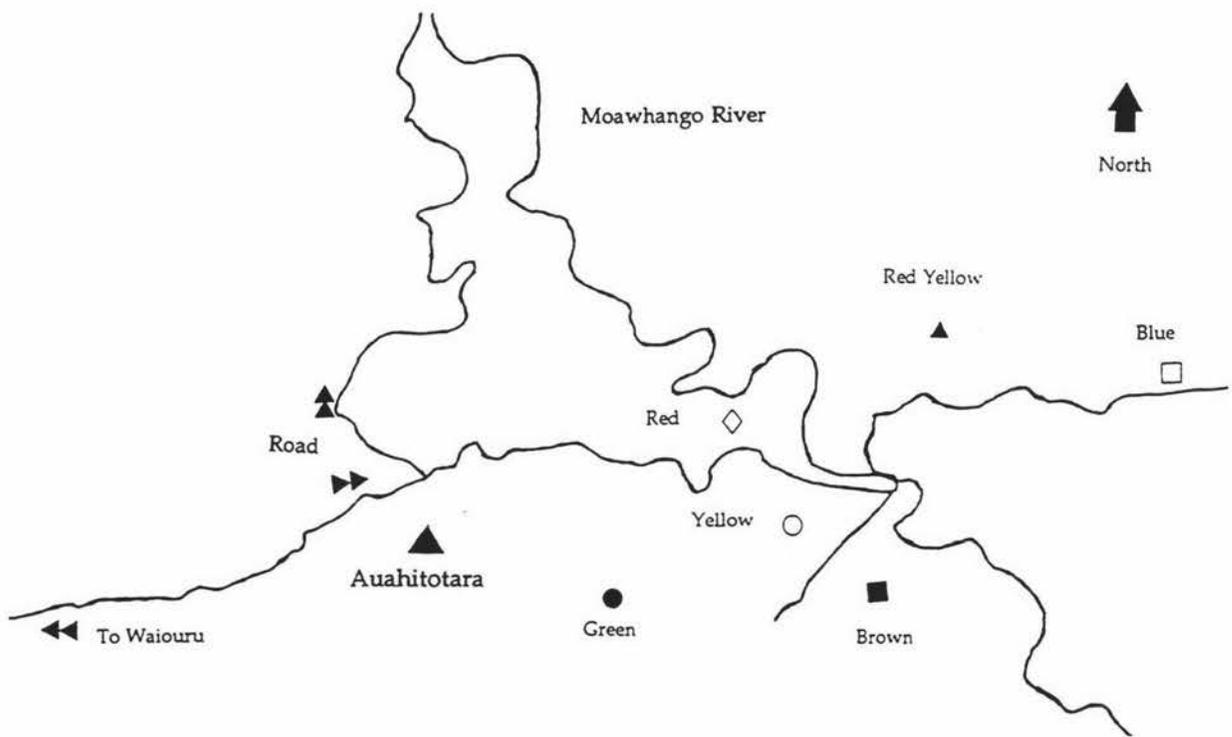


Fig. 5. The central point of each familiar band's observed home range.

the type of vegetation found in the Argo ecological zone would suggest plentiful resources. A rich patch would probably attract breeding mares and the stallions associating with them. Horse density results reflect this pattern, with the Argo zone containing high numbers of horses and the Otokoro and Ngawakaakaue zones containing far fewer horses.

Horse density has also changed within zones over time. This suggests that some bands, if not all, were prepared to move between zones. Of the familiar bands, only Red Yellow was observed to do so, but some bands were not sighted for a period and then reappeared, suggesting that they moved in and out of the Argo basin.

Horse density changed seasonally, with lower densities observed in the Argo basin during midwinter (June) and late summer (January and February). Although this decrease in one zone should be matched by a corresponding increase in density elsewhere, I did not observe this trend. However, detailed observation in other zones would be required to record any increase. The muster in June 1993 did not remove all horses from the Argo Valley, but it appeared to affect the density of horses in the Argo zone, causing it to drop by 75%. However, it is possible that this result was confounded by the change in season from winter to spring which also occurred during the same period. Despite this confounding variable, the results suggest Kaimanawa horses will move to refill an area which has been emptied by mustering. This is also common in Australia, where horses from a neighbouring population will move into newly cleared areas (Dobbie et al, 1993). This creates a potential problem for managers if Kaimanawa horses keep returning to areas which are sensitive to horse damage.

Chapter Three. Social and maternal behaviour and time-activity budgets of Kaimanawa horses.

3.1. Introduction.

In this chapter, I describe social bands of Kaimanawa horses in terms of size, membership, turnover of membership and social acts initiated and received by band members and neighbours. These data were collected because I wanted to discover if social patterns among Kaimanawa feral horses resembled those observed in American, French and English populations. Similar behaviour patterns would enable managers to develop an immunocontraception scheme for horses at Waiouru based on research done elsewhere. However, if Kaimanawa horses differed markedly in social behaviour patterns from other populations, then detailed investigation would be required as the basis of a management scheme. Although feral horses may be phenotypically similar different habitats may shape their social behaviour in different ways.

Preliminary observations established that Kaimanawa horses associated in bands as horses do in other feral populations (See Chapter 2). Although horses are commonly found in groups, the associations that they form are not necessarily permanent. Studies elsewhere show variation in band stability (Berger, 1986). The design of my field observations allowed me to determine the structure of Kaimanawa horse bands and to discern any possible differences in social structure from populations described elsewhere. I also investigated the ways in which horses behaved towards each other both within those social groups and when two or more bands converged. In the Red Desert, interactions between bands occurred during water shortages (Miller and Denniston, 1979). During spring a stallion would investigate the receptivity of mares in a band of breeding individuals and I predicted that this would increase the number of social interactions among the horses. Quantifying the number and type of

interactions within and between bands reflected the different seasonal concerns of horses.

Field observations also allowed me to quantify interactions between mothers and their offspring. Knowing that mothers provide nutritional assistance to their foals for some time after birth, I speculated that there must be some point at which mares stopped providing this assistance. Conflict is common between parents and offspring at this point (Clutton-Brock and Godfray, 1991). However, the foal is likely to try to continue receiving care for as long as possible and my results indicate evidence of this conflict. Having observed that bands differed in size and structure, it seemed likely that the amount of care given by mothers to foals might vary in different bands. This assumption was based on the evidence that some bands occupied much larger home ranges than others, suggesting that they might have access to poorer resources than others. According to optimality theory, these bands may need to travel further between patches to maximise their energy intake (Krebs and Kacelnik, 1991). If horses occupying a richer patch did not need to travel very far to fulfil their nutritional requirements then they may be able to invest more in their offspring. Studies in other populations have shown that investment levels in foals by mares can depend on the quality of resources to which they have access (Rutberg, 1990). I measured suckling bout lengths to investigate this prediction. Determining if some bands have access to better resources than others may indicate which bands are more successful than others at raising offspring and are therefore effective targets for immunocontraception

During field observations, I recorded the numbers of horses grazing at intervals throughout each day. As hindgut fermenters, horses are constrained by digestion time in a different way to ruminants. They have higher intake rates of forage but are less efficient at digesting nutrients and spend more time grazing (Duncan, 1992). By recording the daily grazing pattern of Kaimanawa horses, I was able to compare the

results with grazing patterns of horses found elsewhere.

3.2. Methods.

Data about band composition was collected by observing horses whenever they were encountered. The ages and sexes of horses were recorded if possible and distinguishing features of individuals noted (See Chapter 2). If the band had been sighted on a previous occasion then this was also noted, and bands which were resighted on many occasions became "familiar" bands. The ecological zone in which the sighting occurred was also recorded.

A scan sampling regime on three bands from September 1993 until April 1994 provided information about the amount of time horses spent in daily activities. The three bands were selected because they always remained in the same general area in the Argo basin, making them easy to locate for the commencement of scan sampling times. After collection of data in spring 1993, one band left the area and sampling continued with two of the three original bands. In order to quantify horse activities throughout daylight hours, I visited each group at different times on consecutive days with each two hour block of observations following on from the time at which the previous day's block had finished. Each band was observed for two hours at a time, with all members of the band being scanned and their behaviour recorded every five minutes. Scan sampling was only done during daylight hours. All-occurrence sampling was used to record interactions between band members during the sample period. I observed horses while hidden from their view to avoid interfering with behaviour patterns. As foals were already present in bands at the commencement of sampling, it was not possible to identify any age differences between them and so data were blocked together for analysis. Maternity was determined when suckling from a mare was recorded. Mares did not allow suckling access to more than one foal or yearling concurrently.

3.3. Results.

3.3.1. Band composition.

Information about band composition was collected in 494.5 hours of observation between March 1993 and May 1994. The most common format of those bands in which 75% or more of the members could be sexed and aged was the single-male breeding band, containing a single mature stallion and one or more mares. Some stallions lived in all-male bands (Table 8). Singleton horses were observed, but I have not included them here. I discerned different bands by identifying individuals using distinguishing features.

Table 8. Structure of 229 wild horse social groups seen between March 1993 and May 1994.

Type of band	Number of bands (%)	Mean band size
Single male breeding band	149(65.0)	6
Multi-male breeding band	49(21.3)	4
Bachelor band	31(13.5)	3

3.3.2. Changes in band membership.

The composition of eight familiar bands remained very stable over throughout the study. These groups had a core of members, including at least a stallion and mare, while some other members changed bands and often were not observed again. In Red band, for example, one mare left and one foal was born to another mare. The changes in other bands usually consisted of mares and their foals leaving or entering the group. A mare left Yellow band with her foal but eventually returned without her foal. A stallion left Blue band and a young mare joined the group. One mare left Green band

soon after foaling. Both Green and Red bands contained young horses over twelve months of age but none left the natal group during the study. In all cases, at least two horses remained stable in the group throughout the changes. Red Green band was not sighted for twelve months from Autumn 1993 but was seen often during Autumn 1994 (Table 9).

Table 9. Changes in band membership in familiar bands (* was not sighted).

Band	Autumn 1993	Spring 1993	Early Summer 1993	Late Summer 1994	Autumn 1994
Red	5	4	4	5	5
Green	*	10	10	11	8
Blue	*	4	4	4	4
Brown	7	6	7	6	9
Yellow	5	7	9	8	7
Red-Yellow	12	8	12	11	10
Green-Yellow	*	6	7	9	7
Red-Green	21	*	*	*	22

3.3.3. Interactions between neighbouring bands.

I recorded 43 interactions between neighbouring bands during periods of all occurrences sampling of social behaviour in bands. I observed 41 of these interactions between neighbouring bands during the early summer (Fig. 6). Bands were apart from each other even when grazing in the densely populated Argo basin or approaching favoured drinking sites. Whenever they came into closer proximity during grazing, stallions from the respective groups sniffed and squealed (See 3.6.0. below) towards each other and then separated. The groups would then move away without intermingling. The stallion of one band might chase away another stallion if it approached too closely. On one occasion a foal became disoriented as to where its dam

was and joined the wrong band. The mother then called to the foal and the stallion herded it back to its natal group.

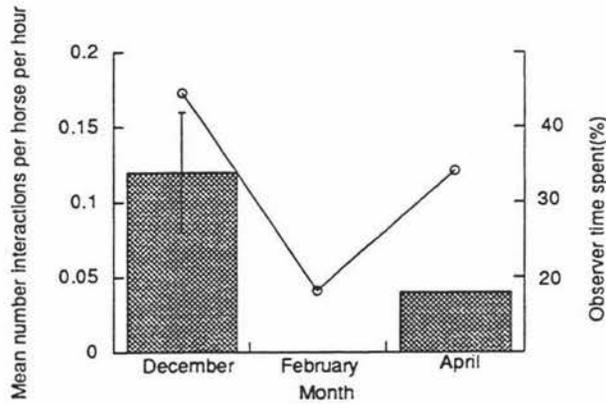


Fig. 6. Frequency of interactions between neighbouring bands in each season in relation to observer time as a percentage of the total hours spent (line indicates observer time spent).

3.4. Interactions between band members.

77.0 hours of observation were completed. Social interactions between band members consisted of sequences of stereotyped acts, which were divided into nine categories based on previous descriptions in the literature (Feist and McCullough, 1975). Young individuals, including foals and yearlings, "teeth-clapped" by drawing back the lips and gnashing the teeth together when a larger individual approached or passed by. This occurred particularly when a foal passed by a stallion. A "sniff" occurred between two horses, most often between foals of the same band. One animal would extend its muzzle towards the other, most often contacting the nasal, neck, or flank region of the other's body. A "threat" consisted of flattened ears, swishing tail, and sometimes a raised hoof, but no physical contact resulted. A horse would "chase" another horse which did not belong to its band and the stallion usually chased away non-members.

Two individuals would "mutually groom" by gently biting at the each other's withers. When two stallions met, they would "sniff and squeal", first sniffing at each others faces and then throwing up their heads and squealing. Stallions would "herd" a straggler back into the group or move the group away from some perceived risk. The stallion herding posture consisted of a flattened elongated neck with head close to the ground and ears back. Males "courted" females by sniffing at their faces and necks and brushing against their flanks. The greatest number of interactions between band members occurred amongst mothers and their offspring. The most frequent interaction apart from mare-foal interactions occurred when a horse approached another and initiated a mutual grooming bout (Table 10). If rejected, it would either search for another partner or resume grazing. I observed 64 mutual grooming bouts. The most common grooming partners were adult mares. They took part in 75% of all grooming bouts observed but not necessarily with other adult mares. Adult mares groomed with their offspring, other youngsters, or a stallion more often than with another mare in the same band.

Table 10. Breakdown of interactions between band members (not including parent-offspring interactions) as percentage of total observed.

Groom	Sniff	Threat	Chase non-member	Herd	Sniff and squeal	Teeth clap	Whinny	Court
23.0	18.0	17.0	13.0	13.0	5.0	6.0	2.3	1.4

The number of observed social interactions between band members increased during the summer months and also declined during autumn, as had the number of interactions between neighbouring bands (Fig. 7).

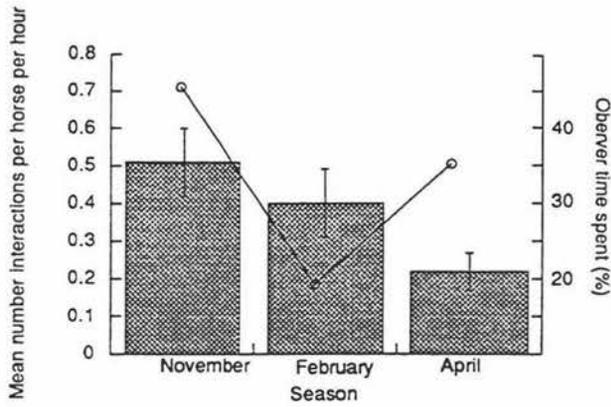


Fig. 7. Number of interactions between band members in each season (line indicates observer time recorded as a percentage of the total hours spent).

3.4. Parent-offspring interactions within bands.

I observed 192 interactions between mares and offspring throughout the duration of sampling. In all, I observed 144 suckling bouts. Of these, 136 involved foals and 8 involved yearlings. Suckling bouts were often preceded by the foal sniffing at its dam. Several yearlings suckled from their mothers, including one individual in Green band and male yearlings in both Blue-Green and Green-Yellow bands. Mares were observed to resist suckling by yearlings on three occasions, by walking forward as the yearling attempted to begin suckling, and by threatening to bite or kick. This behaviour deterred a yearling from suckling only once. Occasionally mares would also resist suckling by foals in the same manner, but the foal would persist and eventually succeed. The average time between suckling bouts significantly increased as autumn approached and the foals grew older ($F=28.64$, $df=68$, $P=0.000$)(Fig. 8). There was no significant difference between the foals in three separate bands in the length of time from one suckling bout to the next (Kruskal-Wallis, $H=0.08$, $p=0.77$). The average suckling bout was 49.0 seconds ($sd = 22.1$) in duration. I found no significant difference in the length of time spent suckling by different individual foals observed. Only 6.1% of observed suckling events were terminated by the dam. Of these, two thirds were rebuffs by the mare of suckling attempts, and the other third were suckling bouts which

were terminated by the mare walking forward before the foal detached its muzzle from the udder.

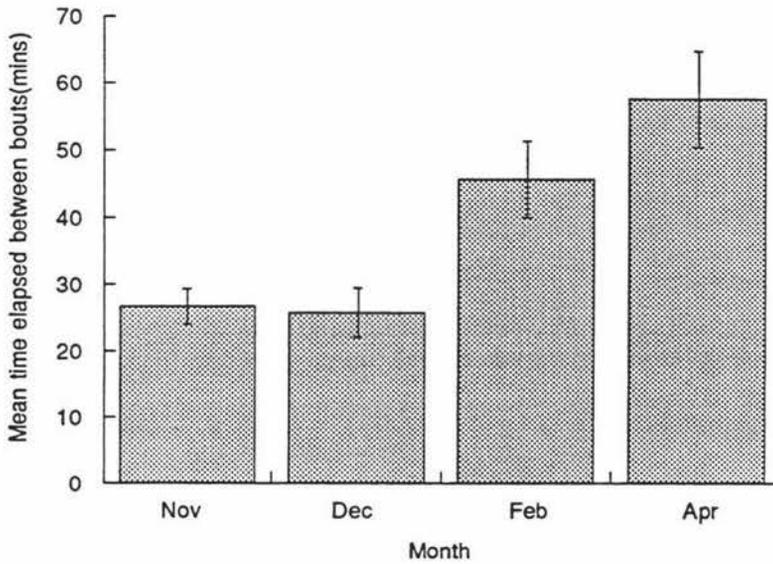


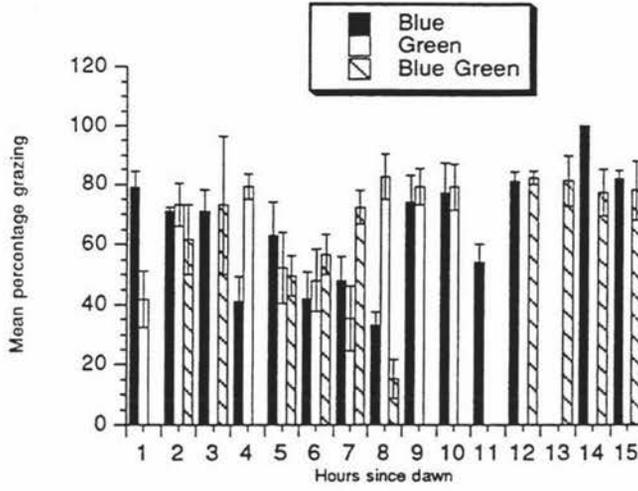
Fig. 8. Average time elapsed between each suckling bout (with standard error bars). I observed 30 interactions between foals and band members other than their dams.

Of these interactions, 37.0% consisted of a "sniff" between the two animals. During sampling times, 63.0% of observed interactions took place between foals and adults.

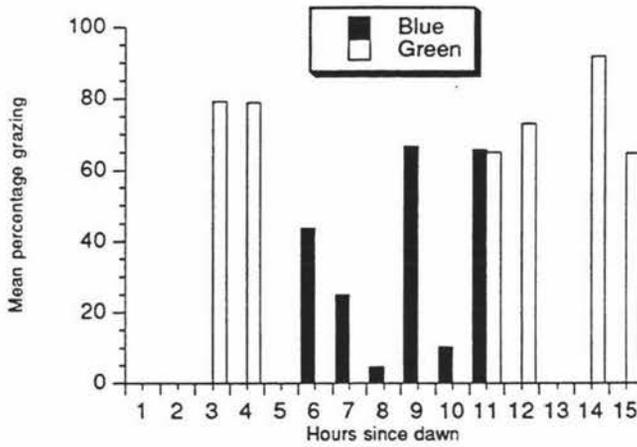
3.5. Time-activity budgets.

Kaimanawa horses grazed throughout daylight hours with a detectable lull during the middle of the day. During spring, summer and autumn, bands of horses grazed until about 4 hours after dawn. Grazing resumed about 10 hours after dawn and the afternoon-evening peak continued at least until I ceased observations at sunset (Fig. 9). Some horses continued grazing during the midday lull. But there was a significant difference between the number of horses observed grazing and the number of horses resting at midday. I observed more horses resting at midday during spring (Kruskal-Wallis, $H=47.81$, $p=0.000$), summer ($H=9.48$, $p=0.024$), and autumn ($H=29.60$, $p=0.000$).

a)



b)



c)

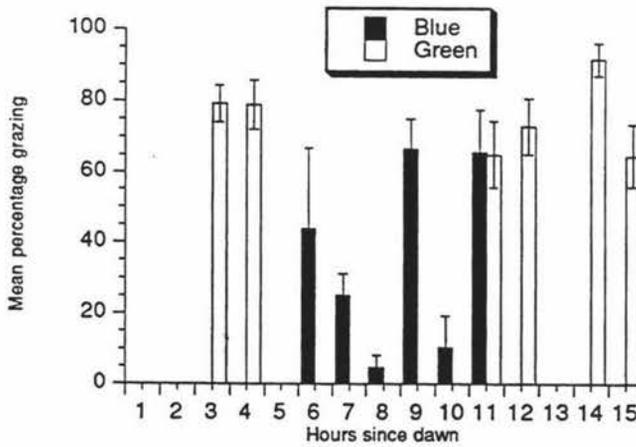


Fig. 9. Mean percentages of band members observed grazing during daylight hours in (a) spring, (b) summer, (c) autumn (bars represent standard error).

Foals had already commenced grazing when my observations began in 1993. The time between each suckling bout increased, and the number of grazing observations during scan samples also increased (Table 11). I assumed that all foals were the same age and pooled foal-observations together for analysis. There was a significant difference between months in the proportion of scans in which foals were grazing (Kruskal-Wallis, $H=13.84$, $df=3$, $p=0.000$).

Table 11. Grazing observations as percentage of total between November 1993 and March 1994.

Month	Grazing observations (%)
November	33.0
December	37.0
February	35.1
March	50.0

When horses were not grazing, their behaviours were recorded in seven categories based on observations in previous studies (Feist and McCullough, 1976). These included "sitting" and "lying down" where the animal showed signs of resting with slack ears and drooping eyelids and occasional snoring sounds. When "sitting", a horse rested on its chest and abdomen with its legs folded beneath it and its head upright, whereas while "lying down" it lay on its side with legs extended and head and neck on the ground. When "standing", horses stood upright, and occasionally rested a hind leg while bearing weight on the other. Horses moved quietly while "walking". Horses would "groom" other members of the same band (See 3.3.). Other self-grooming behaviours included "rolling" where an animal rolled its body from side to side while lying on its back, and "scratching" where an individual either reached around to its flank with its mouth, or lifted a hind leg to scratch around its head. I observed 1802

instances of horses involved in non-grazing behaviours. Of these, standing was the most common (Table 12).

Table 12. Number of non-grazing behaviours observed among band members during scan sampling periods.

	Standing	Sitting	Walking	Lying	Grooming	Rolling	Scratching
Adults	573	45	135	2	20	1	2
Yearlings	151	91	28	19	9	1	0
Foals	355	189	106	108	7	0	5

3.6. Discussion.

The social behaviour of Kaimanawa horses had much in common with that of other feral horse populations around the world. As found elsewhere, the most common social unit is one harem (Klingel, 1982) and bands of unmated males also occur.

Feral horses commonly change the group that they associate with. Young horses disperse from their natal band and adults may also move between groups. In Red Desert horses, multi-male bands were more stable in their membership than single male bands because mares were less likely to leave (Miller, 1981). Stevens (1990) also found that more mares left single-male bands. On Assateague, most young males and females left the natal group at or just before two years of age (Rutberg and Keiper, 1993). Many more males than females dispersed despite the fact that mares that did not disperse had diminished fecundity and produced fewer foals in successive seasons (Rutberg and Keiper, 1993). Most Kaimanawa horses which dispersed from their groups were not seen again and no youngsters were observed to disperse from Blue band, Red band or Green band. In Kaimanawa horses membership changes occurred in all bands observed during the study.

The number of interactions between Kaimanawa bands decreased as winter

approached. The number of horses observed in the Argo valley dropped during late summer (See Chapter 6) and so bands were less likely to be in close proximity. Numbers of social interactions within groups of Kaimanawa horses also declined with the onset of autumn. Stevens (1990) observed this pattern in horses living on the Rachel Carson Estuarine Sanctuary off the coast of North Carolina. Both Feist and McCullough (1976) and Salter and Hudson (1982) found that interband interactions mainly took place between stallions, and this pattern was evident in Kaimanawa horses.

Mutual grooming was common among horses on Pryor Mountain (Feist and McCullough, 1976). As well as the visible benefits of loose hair and skin removal, being groomed about the withers has a calming effect on the horse causing its heart rate to drop (Feh and De Mazieres, 1993).

The average length of a suckling bout was shorter in Kaimanawa foals than in foals on Pryor Mountain which spent about 1.5 minutes suckling each time (Feist and McCullough, 1976). The New Forest foals suckled for over 1 minute during each bout in the first week of life. There was no significant difference between suckling bout length among individual Kaimanawa foals. Measuring bout length did not give an indication of which mares were able to invest more resources in their foals.

The length of time elapsing between each bout increased as New Forest foals grew older. Foals suckled four times an hour on average during the first week but the frequency declined to about once per hour in the fifth month (Tyler, 1972). In Camargue foals, the proportion of their time budget spent suckling decreased rapidly (Boy and Duncan, 1979, Duncan et al, 1984). The frequency of suckling in Kaimanawa foals also declined significantly with increasing age. Camargue mares terminated about half of all suckling bouts in early lactation and during weaning (Duncan et al, 1984). During the central portion of lactation, foals terminated most of the bouts. In Kaimanawa horses, most foals terminated suckling bouts themselves, with the

terminations of bouts by the dam occurring more in some bands than others. New Forest mares did not tolerate suckling by any strange foals and generally chased them away. Mares that did tolerate the presence of strange foals usually ignored them (Tyler, 1972). Kaimanawa mares would sniff at strange foals and then ignored them after the initial contact. However, one young mare in Blue band did initiate mutual grooming bouts with the foal in her band which was not her offspring.

Among Camargue horses, standing was the most common non-grazing activity, with yearlings spending more time lying flat than adult horses, and adult horses spent between 50% and 63% of their time foraging (Duncan, 1980). Tyler (1972) described the New Forest ponies as "spending less time grazing during the day as the resting time increased" during summer months. The New Forest ponies also showed a midday lull in grazing as did the Kaimanawa horses, but in the New Forest this became less pronounced during winter months. White rhinos (*Ceratotherium simum*) are also active mainly in the early morning and late afternoon, with the length of the inactive period becoming shorter in the cooler months (Owen-Smith, 1988). Research done elsewhere suggests that horses are constrained in the length of their foraging periods by time that must be spent digesting and assimilating nutrients (Duncan, 1980). However, horses are less constrained than other herbivores, such as white rhino, by these digestive passage rates (Owen-Smith, 1988).

Chapter Four. Reproduction.

4.1. Introduction.

The breeding system of feral horses results in the distribution of males being dependent on that of females (Rubenstein, 1986). Male and female Kaimanawa horses, as expected, are found living in the same areas, and often living in the same social groups (See Chapters 2 and 3). As the success of a male horse depends on his fertilising as many females as possible, I would predict that conflict between Kaimanawa stallions would be observed during the time of the year when mares are regularly coming into oestrus. From observations of domestic mares and feral mares elsewhere, Kaimanawa mares are most likely to solicit matings from males during the spring and summer months.

Feral horses have the ability to colonise rapidly under suitable habitat conditions (Garrott and Taylor, 1990). This ability to colonise is characterised in part by high foaling rates. The Kaimanawa herd has expanded rapidly in recent years and this population growth could be attributed to successful breeding (Rogers, 1991). If successful breeding results in a population increase of Kaimanawa horses then a high pregnancy rate would be expected. The most accurate prediction of the pregnancy rate amongst mares would be provided by mares which were collected during a muster. If 52% of adults are mares, as indicated by the sex ratio in the May 1994 muster, then there would be about 681 mares in the population of 1311 adults counted in the April 1994 census. I would expect at least 252 (37%) of these to be pregnant if the population is growing at a rate of 16% per annum as calculated by Rogers (1991).

Recently researchers have determined pregnancy rates of mares using non-invasive methods. These have shown some differences between pregnancy rates and eventual foaling rates suggesting that many mares may lose foals even before birth (Kirkpatrick

and Turner, 1991, Lucas et al, 1991). After comparing pregnancy rates with foals observed, I would expect the results to show that loss of pregnancy in Kaimanawa mares was low, due to the apparent population growth.

Feral mares elsewhere will only suckle one offspring at a time and will not support both a yearling and a foal, although the yearling may remain in the same social group (Rutberg, 1990). I would expect Kaimanawa mares to attempt to wean their foals as soon as possible. This will allow them to invest in the next pregnancy. If however survival of foals is very low in particular circumstances, then a mare may invest in her yearling instead and only produce foals which have a good chance of survival in every second year. Some Kaimanawa mares may well follow this strategy, while others are able to produce a foal each year.

Managers planning to reduce the growth rate of the Kaimanawa horse population would probably be unable to target all mares in the herd. Therefore it would be most effective to select those mares which are most likely to be pregnant and those which are most likely to be able to raise a foal in each consecutive year.

4.2. Methods.

Observations of courtship of mares by stallions and mating attempts defined the breeding season. I observed these behaviours while investigating horse presence in the Argo ecological zone. Pregnancy rate estimates were collected from mares collected in the June 1993 and May 1994 musters. Some mares were diagnosed pregnant and their lactational status assessed during post mortem examination at the Taumarunui slaughter plant. Blood samples were collected from mares not sent to slaughter for pregnancy diagnosis. These were analysed by the Animal and Veterinary Sciences Group at Lincoln University using oestrone bioassay techniques for pregnancy diagnosis. I used the presence of young foals, as indicated by body size, to determine

the limits of the foaling season. No new foals were seen during late March so it was considered the end of the breeding season. During March 1993 and March 1994 reproductive success was measured by recording the foal-to-mare ratio of bands observed. The yearling-to mare ratio was also recorded. These ratios were calculated by dividing the number of foals or yearlings present in a band by the number of mares present.

4.3. Results.

4.3.1. Mating Behaviour.

Courtship and 'checking' behaviour was observed from September until December. The stallion involved would 'check' a mare's readiness to mate by sniffing at her perineum or attempting to mount. No systematic sampling was done to record mating behaviour, but horses in 6 bands were observed to attempt mating between September and November 1993 (Fig. 10). During this period, observations were made of horses in one multi-male band. On one occasion, a group of three satellite stallions in close proximity to a band herded around a female (who had a young foal at foot) which was in oestrus and these males were joined by the lead stallion who attempted to mate the mare. The male was forced to withdraw after intromission but before ejaculation as the mare stepped forward. Following this attempt, one satellite male also attempted to mate. In both cases, the attempts were frustrated by forward movement of the mare. The presence of the satellite stallions was accepted by the lead stallion, and he showed no defence behaviour such as chasing or fighting.

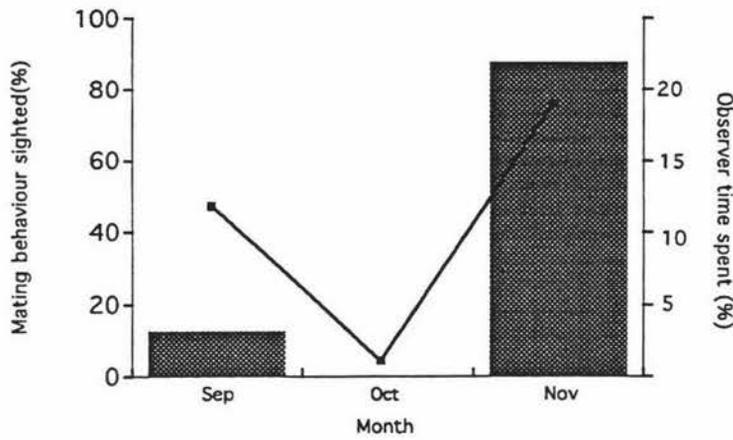


Fig. 10. Mating behaviour sighted between September and November 1993 (line indicates observer time spent as percentage of the breeding season total).

4.3.2. Pregnancy.

Only mares captured during the musters were tested for pregnancy. Both methods of pregnancy diagnosis estimated the proportion of pregnancies at about 80% (Table 11). Of the mares slaughtered after the muster in June 1993, 12 (46%) were lactating, and 19 (37%) mares slaughtered in May 1994 were still lactating (Table 13).

Table 13. Number of pregnancies diagnosed amongst captured mares from two musters, using oestrone level analysis and post mortem examination.

Sample	Post mortem			Oestrone analysis		
	n	Number pregnant	%	n	Number pregnant	%
June 1993 muster	26	20	77.0	41	33	80.0
May 1994 muster	52	42	81.0	-	-	-
June 1994 muster	37	27	72.0	-	-	-

Of non-breeding mares in the 1993 muster, half were under 3 years old and half were over 14 years old. The only non-breeding mare (not pregnant or lactating) slaughtered in June 1994 was 3 years of age. Just over half of the pregnant mares in each sample were aged between 7 and 9 years (55% and 52% in June 1993 and 1994

respectively)(Table 14 and Table 15).

Table 14. Reproductive status of mares mustered in June 1993 in relation to age.

Age(years)	Pregnant and lactating	Pregnant only	Lactating only	Not pregnant or lactating
3-5	0	4	0	2
6-9	7	3	0	0
10+	5	0	2	3

Table 15. Reproductive status of mares mustered in June 1994 in relation to age.

Age(years)	Pregnant and lactating	Pregnant only	Lactating only	Not pregnant or lactating
3-5	1	5	1	1
6-9	10	4	0	0
10+	1	3	0	0

4.3.4. Timing of foaling.

Foaling was observed during seven months in the 1993-94 breeding season. A new foal was defined as one which was judged by physical appearance and size to be less than a week old or had appeared as a new entrant in a recognised group since the group was last sighted. The first new foal since the previous winter was observed in September 1993, and the last new foal observed before the following winter was in March 1994 (Fig. 11).

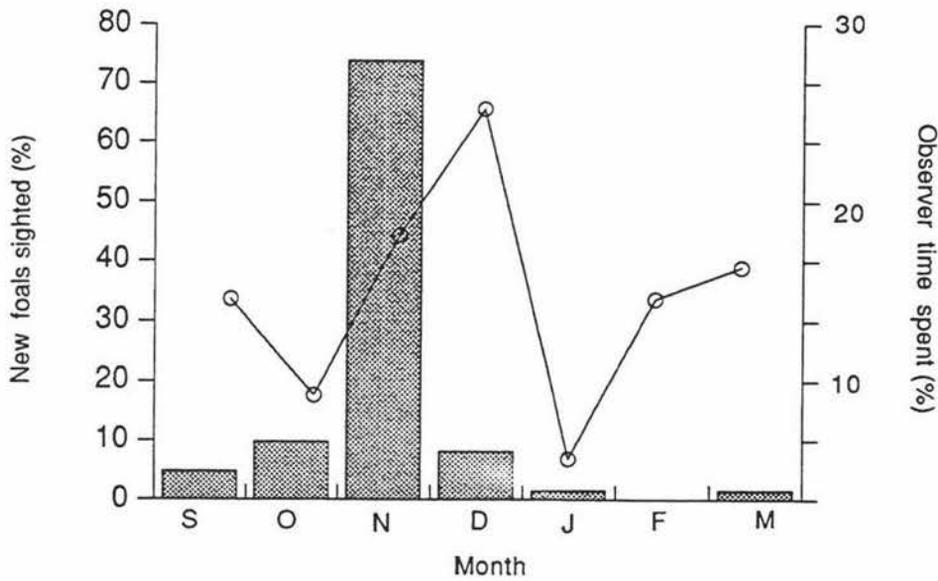


Fig. 11. New foals sighted between September 1993 and March 1994 (line indicates observer time spent as percentage of breeding season total).

4.3.5. Annual Reproductive Success.

Many horses could not be aged or sexed during observations in the field. The ratio of mares to stallions captured during the muster in June 1993 was 0.62 and in May 1994 was 0.52. Multiplying the unidentified horse class by 0.62 provided an estimate of mare numbers that was then used to calculate the foal-to-mare ratio. Using this sex ratio, the foal-to-mare ratio for the 1992-1993 breeding season was 0.3. Using the same procedure, the foal-to-mare ratio for the 1993-1994 season was also 0.3 (Table 16).

As different parts of the horse range varied in climate and vegetation, the foal-to-mare ratios for each ecological area were calculated in order to detect any effects of habitat on breeding success. A significant difference was observed between the foal-to-mare ratios in each ecological zone (Kruskal-Wallis, $H=19.81$, $p=0.001$). When data for all areas were pooled, the difference between foaling rates over the two seasons was not significant (Kruskal-Wallis, $H=0.76$, $p=0.385$).

There was no relationship between the breeding success of mares (measured as the foal-to-mare ratio) and horse density ($R_s=-0.422$, $P>0.05$). However, in 1994 mares in

areas of high horse density such as the Argo ecological zone exhibited significantly higher reproductive success ($R_s=0.8$, $P<0.05$).

Table 16. Foal-to-mare ratios in each ecological zone during the 1993 and 1994 breeding seasons.

Zone	March 1993			March 1994		
	n	\bar{x}	sd	n	\bar{x}	sd
Argo	103	0.34	0.35	112	0.37	0.35
Awapatu	36	0.21	0.36	11	0.24	0.25
Motumatai	29	0.40	0.41	18	0.29	0.46
Ngawakaakaue	5	0.26	0.37	25	0.16	0.31
Otokoro	9	0.49	0.45	5	0.54	0.45
Mean		0.34	0.39		0.32	0.37

4.3.6. Yearling Survival.

The observed number of yearlings was lower than that of foals at the end of both the 1993 and 1994 breeding seasons (Table 17). This decrease suggested that mortality had occurred during the first year of life. When the yearling-to-mare ratio for 1994 is compared to the foal-to-mare ratio in 1993, it implies a 62% loss. There was a significant difference between yearling-to-mare ratios in different zones (Kruskal-Wallis, $H=10.77$, $p=0.030$). There was no significant difference between the two seasons (Kruskal-Wallis, $H=0.072$, $p=0.397$) (Table 17).

Table 17. Observed yearling-to-mare ratios over two breeding seasons.

Areas	March 1993			March 1994		
	n	\bar{x}	sd	n	\bar{x}	sd
Argo	103	0.08	0.20	112	0.11	0.24
Awapatu	36	0.22	0.39	11	0.25	0.33
Motumatai	29	0.38	0.48	18	0.17	0.38
Ngawakaakaue	5	0	0	25	0.12	0.31
Otokoro	9	0.12	0.25	5	0	0
Mean		0.16	0.26		0.13	0.25

During February and March 1993, I observed 115 different bands that contained either foals or yearlings or both. To test the hypothesis that investment in foals was costly to mares and resulted in the loss of a foetus or newborn foal when mothers were already supporting a yearling, I tabulated the numbers of bands containing foals but no yearlings, yearlings but no foals, and both foals and yearlings (Table 18). Data collected from 106 bands observed in February and March 1994 were tabulated in the same way (Table 19).

Table 18. Bands sighted containing either yearlings or foals or both during February and March 1993 (* is excluded from analysis).

Foals	Yearlings		
		0	1-9
0	*	16	
1-8	69	30	

Table 19. Bands sighted during February and March 1994 containing either foals or yearlings or both (* is excluded from analysis).

Foals	Yearlings		
		0	1-3
0	*	13	
1-5	65	28	

In both years, the majority (59% and 60% respectively) of bands containing foals did not have yearlings. In 1993, 14.0% of bands with yearlings had no foals, and in 1994, 12.0% of bands with yearlings had no foals. These data are consistent with the hypothesis that mares cannot invest successfully in offspring in consecutive years, even though 80% of them were pregnant. However, in each year some mares did rear a foal while supporting a yearling. In Red band, one mare foaled in January 1994 while still accompanied by the previous year's foal. In Green band, three yearlings remained with the band between September 1993 and March 1994, although two of three mares had produced foals during this time.

The ratio of foals to adults in 1993 was positively associated with the ratio of yearlings to adults for the 30 bands which contained both foals and yearlings ($F_{1,8}=6.36$, $P<0.036$). A similar correlation was found for the 28 bands containing foals and yearlings in 1994 ($F_{1,8}=59.09$, $P<0.001$).

In both 1993 and 1994, the Argo was the area with the largest number of "good" bands (Fig. 12). Bands which contained both foals and yearlings were described as "good", meaning simply that they had high reproductive success in that breeding season.

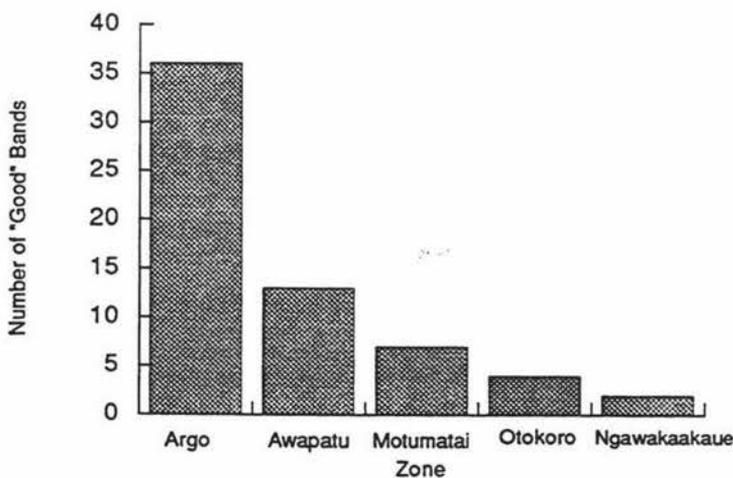


Fig. 12. Bands sighted containing foals and yearlings in each ecological zone.

4.4. Discussion.

The multi male mating episode shows that it is possible for the mating behaviour of feral horses to be very fluid, and that not all stallions will aggressively defend access to breeding females. This behaviour is not uncommon among equids and asses have a more varied social structure than horses with unstable bands and a loosely structured system based on territoriality in desert regions (Woodward, 1979). In Red Desert horses, researchers observed a large proportion of multi-male bands. Dominant stallions were responsible for 49% of mating encounters, while subordinate stallions and stallions from other bands were responsible for 42% and 9% respectively of mating (Miller, 1981). This behaviour apparently caused no serious fighting between males. Miller (1981) found that breeding systems varied among different bands and also within a band through time. Multiple-male mating episodes also occurred in much the same way as that seen in Kaimanawa horses.

The data show that despite the high pregnancy rate, the number of foals observed at foot was low. Among other populations, this loss has also been observed though not to such a great extent. In the Assateague horses, the pregnancy rate was diagnosed by analysing urine samples for creatinine and oestrone levels and researchers found that 7.1% of pregnancies were lost (Kirkpatrick and Turner, 1991). On Sable Island the pregnancy rate was measured by assessing faecal samples for levels of oestrone and 25.4% of pregnancies were lost (Lucas et al, 1991).

The pregnancy rate among Kaimanawa mares was well in excess of the 37% required to sustain the population growth rate of 16%. If all of the pregnant mares produced a surviving foal, the annual growth rate would exceed that measured in previous years. However, the data collected during the 1993 and 1994 breeding seasons suggest that Kaimanawa mares cannot sustain the cost of gestation and lactation in consecutive years. This has important implications for immunocontraception. If the reproductive

success of a mare is already depressed during every second year, then there may not be a need to vaccinate her against becoming pregnant. The mares which do need vaccination are those "super-mares" capable of annually producing a foal capable to survive beyond its first year. In horses on Pryor Mountain, the reproductive history of a mare from the previous year did not affect the probability of foaling, unless the mare was primiparous in the previous year and therefore was less likely to produce a foal (Garrott and Taylor, 1990). Assateague mares showed a pattern of foaling in alternate years (Keiper and Houpt, 1984). Sable Island mares did not foal every consecutive year, despite their high conception rate (Lucas et al, 1991). However, Garrott et al (1991, b) assigned a foal each year to breeding-age mares in their feral horse population simulations so that simulated population growth would match that observed in aerial census data. Seal and Plotka (1983) found that mares of breeding age tended to have foals in every breeding season. Determining which females can produce foals in every season will indicate target mares for immunocontraception. Data from mustered Kaimanawa horses showed that the largest proportion of pregnant and lactating mares was between the ages of 5 and 9. Mares within this age group have the highest likelihood of being "supermares" and therefore the most effective targets.

Chapter Five. Mortality.

5.1. Introduction.

Rogers (1991) reported that the Kaimanawa horse population was growing at a rate of 16% per annum ($r=0.167$). Up to 251 horses would be required to enter the population during 1994 to fulfil a 16% predicted growth rate from the 1569 horses counted during a census in April 1994. Assuming there is no immigration or emigration, then this increase would need to be the result of foal births. A proposed immunocontraception scheme would depress this birth rate, but some horses die each year and the overall growth rate is also affected by death rate. To implement a successful control scheme, information about the death rate of Kaimanawa horses is required. Depressing the birth rate too far would prevent replacement of dead individuals and the population would begin to decline.

In other populations of feral horses, the mortality of horses is generally low once horses have reached adulthood (See Chapter 1). Feral horses studied elsewhere were most likely to die during the first two years of life (Garrott and Taylor, 1990, Wolfe, 1980). A common problem in feral horse population studies is the difficulty of knowing whether horses have disappeared because of emigration from the study area, or because of death. Generally this problem is solved by radio tracking of individuals (Siniff, Tester and McMahon, 1986). In the case of Kaimanawa horses, skeletons which are discovered provide the only mortality estimate possible at this time. This type of mortality estimate was used in the red deer (*Cervus elaphus*) population on Rhum, where searches are conducted on an annual basis (Clutton-Brock, 1982).

5.2. Methods.

I found some skeletons while searching for live horses (Chapter 2). In addition,

during February 1994, teams of searchers looked for skeletons in areas not intensively covered while observing horses. Awapatu, Argo, Ngawakaakaue, Otokoro and Motumatai zones were searched. A team of 17 searchers took part, moving in teams of three. Each group of searchers was assigned a section of the ecological zone being searched on a particular day. This avoided wasted effort caused by repeated searches of the same area. In all, 37.5 people days were expended. The valleys in which horses had been observed on previous occasions were searched, as it was assumed that habitat preferred by horses during life would yield the most skeletons. Searchers filled in questionnaire sheets about the site in which a skeleton was found and its state of decomposition. The latter provided some information about the calendar year in which the horse had died as a recently dead horse was indicated by the presence of skin, hair, and muscle tissue. Portions of the lower jaw containing the incisors were collected if this was still intact to age and also sex the horse at the time of death.

5.3. Results.

5.3.1. Causes of death.

Most of the 63 dead horses found on the range during the study had died of unknown causes. Six adult horses had clearly been shot. One foal was found still wrapped in its placental membranes with deformed hips and had never stood up. One dead stallion found during December 1993 appeared to have stumbled and flipped over while descending a steep slope as the animal was lying on its back with a broken neck. The most common causes of death in Kaimanawa horses were probably accidents or illness.

5.3.2. Locations of skeletons.

During the skeleton hunt in February 1994, searchers answered questions about the location of each skeleton discovered. I also found skeletons while observing live horses

and included these in the summary. The largest number of skeletons was found in the Argo zone (Table 20).

Table 20. Percentage of skeletons found in each ecological zone.

Zone	Skeletons found(%)
Argo	39.7
Awapatu	19.0
Motumatai	14.3
Otokoro	17.5
Ngawakaakaue	9.5

5.3.3. Descriptions of skeleton discovery sites.

Commonly, dead horses were found near water in open grassland. None were found in manuka patches where horses took shelter during the worst weather but 52% of the skeletons were located in a position described as sheltered by searchers, such as in the lee of a gully or under a bank. 59% of skeletons were found near water. 94% of skeletons were found in grassland.

5.3.4. Sex and age at death from skeletal remains.

The sex and age of the dead horse was determined using the lower jaw, if enough remained intact. Skeletons provided 54 lower jaw sections for sexing and aging. Age was determined by patterns of tooth eruption and wear. Results suggested that horses are most likely to die between the ages of 2 and 9 years (Fig. 13).

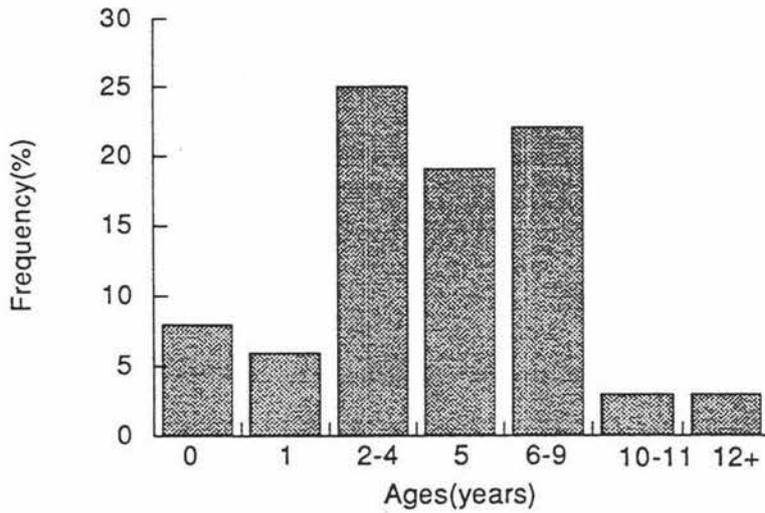


Fig. 13. Ages of horses at time of death.

Sex was also determined by eruption of teeth. The presence of fully erupted tushes (teeth equivalent to canines) on the upper and lower jaw indicated an adult male horse. Half of the jaw sections did not indicate sex, either because they were not intact or they appeared to be from an immature horse. However, significantly more male skeletons were identified than female ($\chi^2=2.14$, $df=1$, $P=3.84$). There was no significant difference between the estimated age at death of male and female horses ($H=2.82$, $P=0.093$). However, those skeletons which had complete lower jaw sections, and yet could not be sexed, had a significantly lower mean age ($H=14.77$, $P=0.001$) (Fig. 14). Of those skeletons which could be aged, 25 were estimated to be between 4 and 6 years of age at the time of death.

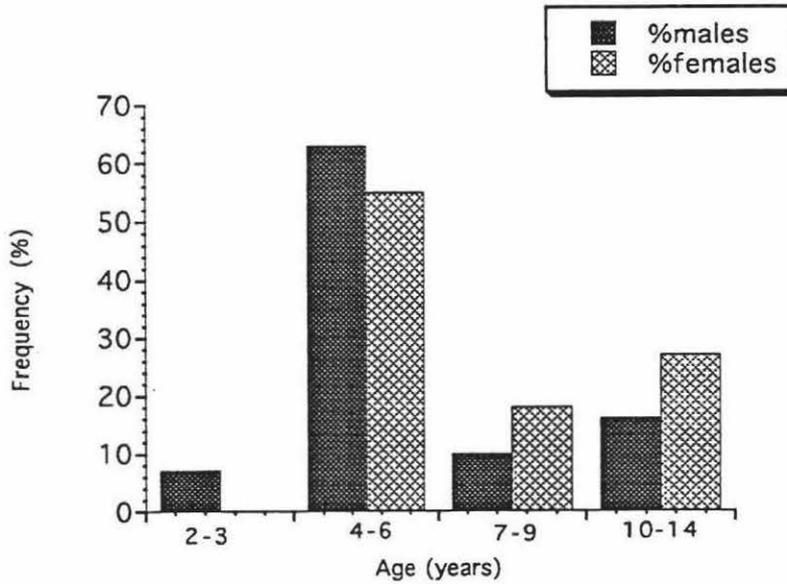


Fig. 14. Sexes and ages of horses at time of death.

5.3.5. Annual mortality.

I estimated the annual mortality rate among Kaimanawa horses with the total number of skeletons found. Using census figures and population size estimates from Rogers (1991), I calculated the total number of horse-years attributable to the population. The 63 skeletons found divided by 11130 horse-years gave an estimate of 0.006 annual mortality in Kaimanawa horses.

5.4. Discussion.

The causes of death in feral horse populations elsewhere include accident and illness. Injuries from fighting killed stallions in the Granite Range herd. Foals died when they became bogged, and starvation killed many animals in their second year after they had lost maternal assistance with nourishment (Berger, 1986). In the Camargue, stallions occasionally killed foals that they had not sired after herd owners moved males around amongst different bands of horses (Duncan, 1992). In Australia, horses died during drought seasons. Researchers estimated that 20% of the population died annually.

Many Australian feral horses were also killed as a result of control measures (Dobbie et al, 1993). Illness or starvation amongst Kaimanawa horses could not be diagnosed after death unless the horse had died in the previous day or so, but are very common in other feral horse populations.

Foal survival in the Granite Range population was affected by drought, particularly through a reduction in the maternal milk supply and increased risks of becoming mired at waterholes. However, once the foals became yearlings, their survival rose to 100% (Berger, 1986). In the Pine Nut and Pah Rah population the proportion of foals in the population decreased markedly during the first year of life (Siniff, Tester and McMahon, 1986). In Australian feral horses, mortality was thought to be mostly juvenile or subadult (Dobbie et al, 1993). Of foals born in the Camargue, 10-20% either died or were removed after losing too much condition. But amongst surviving foals, there was no further mortality until weaning (Duncan, 1992). From the skeletons located it appeared that Kaimanawa horses were at highest risk of mortality during the middle years, between the ages of 2 and 9 years. These are the years in which feral horses in other populations disperse from their natal bands, and also the age at which Kaimanawa horses commence breeding, suggesting that these are risk-filled activities.

During the study of Granite range horses, Berger (1986) found 42 horse skulls. There was no significant difference between the number of males and females. During population modelling of North American feral horses, researchers noted that sex ratios of young horses below five years of age were commonly skewed towards females, but in the older age classes males outnumbered females. This was attributed to differences in the energetic costs of reproduction and disparity in their reproductive life spans, with females suffering stress during pregnancy and lactation but having a longer breeding life than males (Garrott, 1991). Significantly more male Kaimanawa horses were found dead than female horses. It seems likely that the segment of the horse population most

likely to suffer mortality is that of males aged between 4 and 6 years.

Kaimanawa horses appear to have a high annual survival rate. This is a feature of feral horse populations elsewhere, including the Pryor Mountain Wild Horse Range, where the survival rate was estimated at 0.97 (Garrott and Taylor, 1990). Another population in Nevada had a annual survival rate of 0.96-0.98 (Siniff et al, 1986). However, the survival estimate for Kaimanawa horses could be affected by three factors. The method of ground searching was dependent on the ability of searchers to locate skeletons in the rough terrain. Not all parts of the range could be searched as Army regulations prevented access to some target areas. This meant that probably many skeletons were not found. The accuracy of the estimate also depends on the accuracy of the population information presented elsewhere which gives the original census figure of 174 and a population rate of increase of 16.7%.

Chapter Six. Carrying capacity of the Argo valley.

6.1. Introduction.

In studying the Camargue horses, researchers found that horses chose some areas to graze in more often than others and these selected areas provided quality food (Duncan, 1992). In Canada, feral horses utilised a variety of habitats based mostly on food supply with some consideration for shelter, particularly during winter (Salter and Hudson, 1978). Among Kaimanawa horses, high observed horse numbers and the greatest encounter rate of observers with horses in comparison with other parts of the range suggest that many horses are choosing to graze in the Argo basin. Originally, feral horses were only counted in the Motumatai zone (Aitken et al, 1979, unpub.). Research before and after the muster in June 1993 suggests that bands will move into the Argo basin after horses are removed (See Chapter 2). As the floor of the basin is at 700m asl compared with over 1000m asl in other parts of the range, it may also fulfil a shelter requirement for some horses. Consequently it may constitute a rich patch for foraging horses.

Managers of wild horses commonly use carrying capacity or stocking rate as an indicator of the level at which horse numbers must be maintained (See Chapter 1). On Cumberland Island, horses were grazing on saltmarsh vegetation and causing damage (Turner, 1988). Research based on grazing simulations showed irreversible damage to the vegetation, and recommended that the number of horses be reduced to minimise this damage. Managers of the Kaimanawa horses propose to maintain a herd of horses in the Argo ecological zone, and preliminary work showed that horses inhabited the Argo basin in high numbers. With an estimate of the carrying capacity, managers could ascertain a herd size of horses which could be maintained in healthy condition without being forced to migrate in search of better forage.

Managers of agricultural pasture commonly estimate stocking rate by eye. By inspecting body condition of stock and height and appearance of the sward, they adjust the numbers of stock grazing paddocks to suit the conditions (J. Millner, pers. com.). If feral horses are able to roam freely and to choose which patch they will graze, I predict that the number of horses observed in the Argo basin will not exceed any carrying capacity calculated from enclosure trials.

6.2. Methods.

A vegetation map of the Argo Valley was drawn from an aerial photograph to identify those parts of the valley which were covered in introduced grasses, native bush or other vegetation. Four vegetation associations were inspected for evidence of horse grazing, and these included associations between native tussocks (*Chionochloa rubra* and *Festuca novaezealandiae*) and introduced grasses (particularly *Holcus lanatus*, *Anthoxanthum odoratum* and *Agrostis capillaris*), and introduced grasses and manuka (*Leptospermum scoparium*). Cages were eventually placed in three vegetation associations which showed signs of horse grazing.

The first, located on the southeastern slopes of the valley, consisted of red tussock (*Chionochloa rubra*) and introduced grasses. The red tussock did not show signs of horse grazing so was excluded from the trial. The second, located on valley slopes on the western side of the Argo Valley, was defined as hard tussock/introduced grassland, composed of patches of hard tussock (*Festuca novaezealandiae*) growing in a predominantly yorkshire fog (*Holcus lanatus*), sweet vernal (*Anthoxanthum odoratum*) and browntop (*Agrostis capillaris*) sward. The second, also located on the western side of the Argo Valley, consisted of manuka patches interspersed with introduced grass patches, which included yorkshire fog, sweet vernal, and browntop. The third area was also located in the western side of the Argo valley on the basin floor, and was composed

almost entirely of introduced grasses.

Exclosure cages were installed in the Argo basin to measure productivity. The 18 cages measured 0.50 × 0.50m in size, and 0.30m in height, and each was constructed of steel rods covered with wire netting (Fig. 15). The cages were driven into the ground, and the wire edges secured to the ground by wire pins to prevent grazing by hares (*Lepus europaeus*) present in the valley. A 0.10m margin was allowed inside the cage to avoid edge effects caused by wire interfering with light availability or nibbling by excluded animals.

The cages were installed in October 1993. Six cages were randomly placed within each of the three areas which had been chosen for the representativeness of vegetation within the Argo Valley. I placed cages on flat areas not easily accessible to vehicles to avoid interference. Control plots measuring 0.50x0.50m which were not enclosed, allowing grazing by any herbivore, were also set out at this time. The species content of the sward was quantified by estimating percentage cover at this time and the grass clipped to determine the initial standing crop. The species composition of the sward was determined by estimating by eye the percentage cover of each species within each quadrat using a grid with 0.05m squares to assist with estimation.

The contents of the cages were harvested every two months. At harvest time, the cages were removed, the species content of the sward recorded, and the grasses clipped down to a height of 0.01m. The cages were then moved to a new position and the species composition of the sward recorded anew. The clipped grass at the new location provided the standing crop. The clipped grasses were dried at 98°C for three days, and then weighed. The dry weights were multiplied to give the amount of grass as g/m². This was equivalent to grass weight as kgDM/ha which was the standing crop. This amount of grass growth was divided by the number of days since the previous harvest to give kgDM/ha/day of productivity in that plot. Multiplying this figure by the gross



Fig. 15. Exclosure cage used to measure standing crop and productivity.

energy measurement gave the total amount of energy available to grazers. Horses can obtain 37.5% of this energy for their metabolic requirements (Frape, 1986). I used an aerial photo to determine the area of introduced grassland in the Argo basin. Areas of introduced grassland were traced onto pieces of paper which were put through a leaf area meter to determine their total size. This total was then converted to hectares for the final measure. I estimated the carrying capacity of the Argo basin by dividing the daily total metabolic support figure by the average daily megajoule requirement of an theoretical average Kaimanawa feral horse.

6.3. Results.

6.3.1. Species composition of sward.

Vegetation in Argo basin consisted of a mosaic of different plant communities. *Hieracium pilosella* occurred in extensive patches throughout the area, especially where military activities or horse hooves had damaged the sward. Hard tussock (*Festuca novazealandiae*) occurred in patches on the sides of the basin, particularly in the upper reaches, but not on the valley floor. Ground cover species included sweet vernal (*Anthoxanthum odoratum*) and browntop (*Agrostis capillaris*) which were common in spring and summer, while Yorkshire fog (*Holcus lanatus*) provided the greatest cover in winter. Ryegrass (*Lolium perenne*) was found but only rarely, while clover species occurred (*Trifolium repens*, *T. dubium*) in very small amounts throughout almost all plots. Flatweeds (*Taraxacum officinale* and *Hypochaeris radicata* in particular) also occurred in profusion, particularly in plots where the height of the sward was low. Data from each cage at each trial site was used to determine the mean percentage cover of each species when sampling took place (Table 21).

Table 21. Mean percentage cover of identified species at each sampling time (* indicates no data).

Species list	Oct 1993	Dec 1993	Feb 1994	Apr 1994	Jul 1994
<i>Holcus lanatus</i>	39.12	10.47	18.25	20.31	25.08
<i>Anthoxanthum odoratum</i>	0	11.86	7.33	5.72	0.81
<i>Hieracium pilosella</i>	19.03	11.58	6.86	6.83	2.44
<i>Agrostis capillaris</i>	6.46	2.57	4.72	7.28	11.72
<i>Linum catharticum</i>	0	0.83	3.89	0.53	0.25
<i>Trifolium repens</i>	2.11	1.63	1.94	0.89	0.75
<i>Leucopogon fraseri</i>	2.68	0.61	0.89	1.14	1.14
<i>Hydrocotyle sp.</i>	0	0.38	0.33	0.61	0.56
<i>Taraxacum officinale</i>	2.14	4.28	3.89	3.72	2.28
<i>Hypochaeris radicata</i>	0	1.03	0.69	1.06	0.25
<i>Rytidosperma sp.</i>	0	5.25	3.17	3.44	0.47
<i>Festuca novaezealandiae</i>	0	1.22	0.50	0.19	0.56
<i>Prasophyllum sp.</i>	0	0.11	0.08	0	0.14
<i>Acaena ovina</i>	0	0.03	0.39	1.67	0.44
<i>Acaena sp.</i>	0	0.17	0.17	0.08	0.11
<i>Trifolium dubium</i>	0	0.44	0.28	0.44	0.56
<i>Uncinia rubra</i>	0	0.06	0.03	0.33	0.06
<i>Gnaphalium albomarginata</i>	0	0.11	0.11	0.11	0.14
<i>Leptospermum scoparium</i>	0	0.194	0.64	0.64	0.28
<i>Lolium perenne</i>	5.44	0	0.03	0.03	0
<i>Cirsium vulgare</i>	0	0.22	0.06	0.19	0
<i>Cerastium sp.</i>	0	0.17	0.06	0.06	0.14
<i>Senecio jacobea</i>	0	0.0833	0	0	0
<i>Prunella vulgaris</i>	0	0	0.08	0.03	0.14
Litter	*	32.83	32.64	35.56	38.78
Bare ground	10.62	10.56	7.36	1.56	1.56

6.3.2. Standing crop and productivity estimates.

I collected five grass samples in total and these consisted of the combined harvest for each sampling time in each vegetation association. The dry weights of these were used as an indicator of vegetation standing crop present in the plot at the time of clipping (Table 22).

Table 22. Standing crop estimates over nine months in kgdm/ha.

Month	Tussock	Manuka	Introduced Grasses
October	69.9	200.2	106.8
December	142.9	167.4	145.2
February	221.7	191.1	403.4
April	147.2	190.0	271.1
July	497.8	529.9	551.2

Daily productivity estimates were obtained from four out of five samples by measuring the amount of growth of vegetation in kg/ha within the enclosure cages and dividing this by the number of days since the previous sample was collected. The greatest growth of vegetation occurred in the spring months between October and December 1993, while the least growth occurred in the Autumn months between February and April 1994 (Table 23).

Table 23. Productivity estimates over nine months in kgDM/ha/day.

Month	Productivity
December	2.98
February	2.68
April	1.54
July	2.46

Results were analysed by analysis of variance using a general linear models procedure. Both standing crop and productivity results for each cage and control site for each

replicate were entered as kg/ha into the analysis. Although enclosure cages at 3 sites had different vegetation associations, no significant difference was found in standing crop (ANOVA, $F=0.90$, $df=2$, $P>0.4093$). There was however a significant difference in the productivity measured at three different sites, with highest productivity in the introduced vegetation association (ANOVA, $F=3.51$, $df=2$, $P>0.0331$). There was also a significant difference in both standing crop and productivity over time (standing crop, $F=8.82$, $df=2$, $P>0.0001$, productivity, $F=6.94$, $df=3$, $P>0.0002$). There was also a significant difference in productivity between enclosure cages and control plots (ANOVA, $F=5.80$, $df=1$, $P>0.0176$). The overall mean production in cages was 22.8 kgDM/ha, while the overall mean production in uncovered plots was 13.7 kgDM/ha. Grazed plots had approximately half their production removed, presumably by herbivores including hares and horses.

6.3.3. Horse metabolic rates and daily biomass requirements.

From estimates by eye done by Mr. C. Tickle during the June 1993 muster, and using body condition scoring methods (Carroll and Huntington, 1988), it was assumed that the average weight of a mature horse was 300kg. Based on this figure, each horse requires 60.29 MJ per day to survive if it is doing light exercise including movement in search of forage and has no other demands on it (Frape, 1986). The analysis was simplified by using this average figure. These daily energy requirements vary if weather conditions become colder, and under the pressure of lactation or growth.

6.3.4. Total metabolic support available in Argo valley.

Three standing crop samples were analysed for gross energy content using bomb calorimetry by the Massey University Animal Nutrition Laboratory (Table 24).

Table 24. Gross energy available to grazers in three bulked samples in kJ/g.

Month	Gross Energy
December 1993	17.869
April 1994	17.509
July 1994	16.993

Horses can obtain 37.5% of gross energy available for their metabolic requirements (Frape, 1986). I calculated that approximately 616 ha of grassland were available for horses to forage on in the Argo basin. The largest number of horses that could be supported was calculated for October to December 1993. The lowest number of horses was calculated for the February to April interval (Table 25).

Table 25. Plant productivity and estimated horse carrying capacity in the Argo Basin between October 1993 and July 1994 (* indicates no estimate was possible).

Time interval	Daily productivity	Carrying capacity
October-December	2.98 kg/ha/day	184 horses
December-February	2.68 kg/ha/day	*
February-April	1.54 kg/ha/day	93 horses
April-July	2.46 kg/ha/day	160 horses

6.3.5. Changes in horse numbers in the Argo valley.

Horse numbers fluctuated in the Argo zone over the course of 12 months with the highest numbers being present during early summer (Fig. 16). The number of horses observed dropped as winter approached during 1994. This rise and fall in numbers coincided with the increase and decline in the amount of dry matter harvested from enclosure cages.

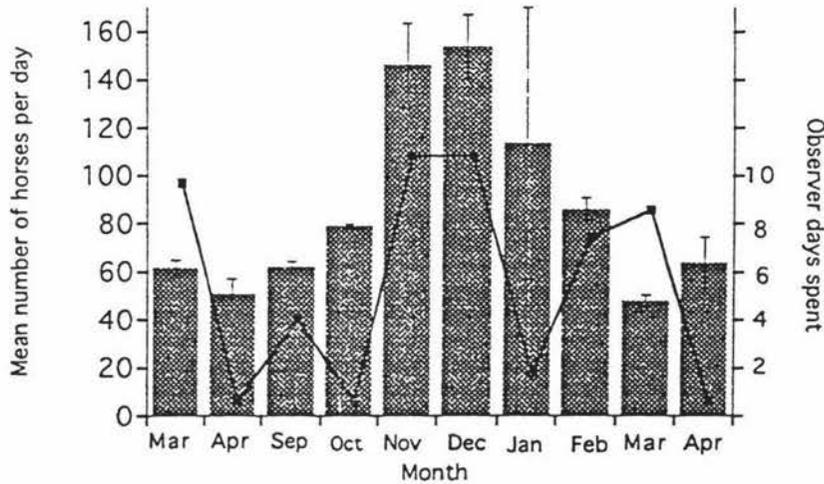


Fig. 16. Average number of horses sighted per day in the Argo valley over 12 months (line indicates observer time spent in days).

6.4. Discussion.

Productivity on Lower North Island farmland during June 1994 was between 5 and 36kgDM/ha/day and a Hawkes Bay dry pasture was expected to produce 8kgDM/ha/day (Tui Milk Consulting Officer Service, 1994). The productivity in the Argo basin falls well below this figure. There was great variability in the standing crop of different vegetation associations in the study, and the patchiness of the sward meant that some areas provided richer forage than others. The daily number of horses present in the valley has indicated that horses are not exceeding the stocking rate calculated during the study.

The results indicate a number of horses which might adequately survive in the valley, but does not measure the true environmental carrying capacity which is measured when horses and the plants are at equilibrium. Results from aerial census figures over several years indicate that the horse population is growing and so an equilibrium has not yet been reached. The calculated figure is based on the assumption that all production will be consumed by horses, while the effects of other herbivores have been ignored in order

to simplify the analysis. The number of horses suggested by the analysis is based on an average horse which is an adult male weighing 300kg, doing light work, in moderate environmental conditions. During winter extremes of temperature, horses may require a much greater energy input to maintain their internal temperature. A proportion of the population will consist of mares which are pregnant or lactating or both. The demands of supporting offspring greatly increases the daily requirements of such mares. Young animals which are still growing also have a greater energy requirement than adults. All these factors are likely to decrease the calculated carrying capacity.

Although there is evidence to show that some bands tend to have a small home range which does not extend outside the Argo valley, other bands appear to be willing to migrate in and out of the valley (See Chapter 2). This suggests managers may face the problem of keeping horses within the confines of the valley. With fencing ruled out by the Army, one solution might be to make the valley extremely attractive to horses by increasing the food supply. This could discourage horses from migrating in search of a better food supply. An increased food supply could be achieved in two ways. Managers could spread fertiliser, thereby increasing productivity of the grassland, or introduce supplementary feeding. The second option would undoubtedly increase the horses attraction to the valley, but both options would be expensive in time and labour. Managers would also have to consider the possibility of horse numbers increasing once more as population growth was fuelled by the improved foraging conditions for the horses. I would predict that horses would migrate in that situation. Although the current management strategy suggests that horses will remain in the Argo zone, some of the tussock grassland perceived to be most at risk occurs in the Awapatu zone (B. Fleury, pers com). Horses migrating into the Awapatu zone could pose an ongoing management problem.

Chapter Seven. Discussion.

The impetus for the implementation of a control scheme for Kaimanawa horses came during the late 1980's as the population size increased from the 174 horses originally counted during a study in 1979 (Wright, 1989). Research showed that horses were trampling the habitats of rare native plants endemic to the region, and that horses grazed on areas of hard tussock causing severe damage (Rogers, 1991). The horses were protected by law and there was public support for the retention of a horse herd (Wright, 1989). The Department of Conservation developed a draft management strategy based on Rogers' research and this was released for public comment in 1992. Submissions received by the Department numbered 174, with 73 supporting some form of management and 39 advocating total removal as reported in the submissions summary (1992). The Department of Conservation, after consultation with many parties such as the Kaimanawa Wild Horse Committee and the Army Training Group, implemented a programme of control which initially reduced horse numbers by muster and then aimed to maintain a steady herd size using remotely delivered immunocontraception. These musters took place in June 1993, and in May and June 1994. Horses were mustered using helicopters and those horses deemed impossible to sell because of age or poor health were removed for slaughter, while the rest were removed to be sold at a later date. Horses left on the range included 139 which had been branded and re-released during the June 1994 muster. These horses will be the subjects of immunocontraception trials. However, information about the population parameters was required on which to base the management scheme.

My research centred on questions relating to five areas of interest. The first regarded horse use of the range, particularly where horses were concentrated and how much they moved about. Horses were concentrated at highest density in the Argo ecological zone

which contained large tracts of modified grassland. Horses moved back into the Argo basin, which formed part of this zone, after a muster in June 1993. This seemed to indicate that the basin contained preferred habitat. The second area of research interest regarded social behaviour. If the horses' social behaviour was markedly different from feral horse behaviour elsewhere, then detailed information would be required for any management scheme. My results showed that bands were variable in both size and structure, with multi-male bands being common. Work elsewhere suggests that horses only associate in harem groups or bachelor groups (Klingel, 1982). However, multi-male bands were recorded in the Red Desert (Miller, 1981), and also in Western Canada (Salter and Hudson, 1982). Some authors suggest mares are constrained by the costs of lactation and can only raise a foal in alternate years (Tyler, 1972). Others suggest foaling occurs in consecutive years (Seal and Plotka, 1983, Garrott and Taylor, 1990). I observed suckling by yearlings, suggesting that mares sometimes invested in yearlings rather than producing a foal each year. A grazing lull was observed amongst horses during the middle of the day. Other work suggests horses are constrained in foraging time by the need to spend time resting (Duncan, 1980). Thirdly, I investigated reproduction which was an important part of planning for the immunocontraception scheme. Results gathered during one muster in 1993 and two in 1994 showed that 70-80% of mares were pregnant. During observations on foot, I found that 30% of mares had foals with them and 13-16% of mares had a yearling in their band. Some breeding bands contained either foals or yearlings, while some bands contained both. Of bands containing foals, 69% had no yearlings, while between 12-14% of bands contained yearlings and no foals. This is consistent with the hypothesis that females cannot invest in foals in consecutive years (Tyler, 1972), despite the 80% pregnancy rate. However, some mares were capable of raising a foal and a yearling. Fourthly, to answer questions about mortality in the population, I located 63 skeletons. Most horses had

apparently died from natural causes, and the greatest number were found in the Argo ecological zone. I aged and sexed the skeletons using dentition. These data suggested that horses between the ages of 2 and 9 years were most likely to die. More male skeletons were found than female. I estimated mortality by dividing 63 known deaths by 11130 horse-years which I assumed had elapsed since 1979. This gave a mortality rate of 0.006. Finally, to answer questions about carrying capacity in the Argo Valley, I measured productivity. Productivity ranged between 1.54 and 2.98 kgDM.ha.day⁻¹. Using a vegetation map, I calculated that the area available for horses to graze in the Argo valley was 616 hectares in size. Bulked samples from three separate harvests were analysed using bomb calorimetry for gross energy content. The December 1993 sample contained 17.87kJ.g⁻¹, the April 1994 sample contained 17.509kJ.g⁻¹, and the July 1994 sample contained 16.993 kJ.g⁻¹. Using these data, the carrying capacity of the Argo basin was calculated as being 184 horses in December 1993, 93 horses in April 1994, and 160 horses in July 1994. The number of horses actually observed in the Argo basin did not exceed these figures during any of these months.

Research in the United States in recent years has centred on using porcine zona pellucida (PZP) vaccine for suppressing fertility in feral horses (Kirkpatrick et al, 1990). It prevents fertilisation of the ovum because it consists of several glycoproteins, one of which is the receptor molecule for sperm surface molecules. Equine antibodies which are raised against PZP after vaccination probably then block sperm receptor sites on the ovum which prevents fertilisation (Kirkpatrick et al, 1990). In research on Assateague ponies, no mares had foals after being treated with three inoculations of PZP, while 12% of mares had foals after two inoculations of PZP, 50% of control mares had foals, and 45% of untreated mares had foals (Kirkpatrick et al,1990). Control mares had received injections of the same adjuvant that the test mares had received, but it did not contain PZP. Some Assateague pony mares became extremely wary after one vaccination and

had to be dropped from the study (Kirkpatrick et al, 1990). It was also necessary to maintain antibody levels in the mares. Kirkpatrick et al (1992) found that a single annual booster shot helped to extend infertility, but this also extended the cost of management. Recent research by Kirkpatrick et al (1992) showed that there was some alteration in ovulatory cycles of treated mares in the long term. After three years of treatment, some mares showed no sign of ovulating, and vaccination appeared to have interfered with the secretion of oestrogen. These results suggested that long-term treatment of mares may result in them becoming completely infertile.

Due to excessive costs in both time and money, managers of Kaimanawa horses predict that they will not be able to vaccinate all mares. Consequently, only a proportion of them can be targeted. Using population information provided in Chapters Four and Five, I calculated this proportion. Having observed a very low mortality rate, I assumed that the survival rate of adults was 95%. Previous work on the population estimates the population is growing at rate of 16% (Rogers, 1991). Based on the April 1994 census figure of 1576, the predicted increase in size would be 252 horses. Of the horses seen in the same census, 1311 were adults. From the May 1994 muster, I predict the sex ratio would be 0.52. This would mean that there were 681 mares, and 37% of them must foal to fulfil the predicted rate of increase of 252 foals recruited into the population. However even if 80% of mares are pregnant, observations suggest only about 30% of them have a surviving foal. Therefore, selecting the mares to target for the most efficient result becomes important. To target 80% of mares for vaccination would probably result in much wasted effort.

Despite the legal protection of the horses on their range (See Chapter 1), evidence from Rogers (1991) suggested that this introduced species was damaging its habitat. Organisations supporting the preservation of as much native flora as possible voiced their support for the complete removal of feral horses (Smith, 1991). There are other

introduced species in New Zealand which are protected by law and these include several game bird species, such as grey teal (*Anas gibberifrons*) which have a limited hunting season in parts of the country. Other cases similar to that of the horses include the Enderby Island cattle and Arapawa island goats which were also feral populations descended from domestic stock. They were originally introduced to their respective islands by European settlers. All of the Enderby Island cattle were shot apart from two females. Semen was collected from males and then frozen in order to preserve the genetic pool as requested by the Rare Breeds Society (H. Blair, pers com). A remnant of the Arapawa goat population was also preserved. Even though there are some precedents for this kind of policy situation, the legal situation remains unresolved. With no set procedure for the situation where an introduced species requires population control, problems arise if people wish to maintain a gene pool for possible future use.

In recent years the Department of Conservation has determined priorities in its approach to conserving species in order to define where the most help is required. Using the ranking system of Molloy and Davis (1992), I scored Kaimanawa horses at 25. This means that they do not constitute a threatened species (Molloy and Davis, 1992). In most of the criteria, the horses did not rank highly. That is, they were not taxonomically distinct from other species in New Zealand or elsewhere. However, they did score highly in the area of public perception. Although not taxonomically distinct by the standards of many of New Zealand's threatened species or sub-species, basic genetic variability measures for Kaimanawa horses do suggest some differences from common breeds. Preliminary testing showed that Kaimanawa horses had a genetic similarity coefficient of 0.829 with Thoroughbreds and Welsh pony breeds, and 0.812 with Arab breeds (I. Anderson, pers com). This puts them well within the range of genetic similarity covered by other known feral horse groups, such as the Pryor Mountain herd which has a genetic similarity coefficient of 0.792 with Thoroughbreds

(I. Anderson, pers com). Consequently, it seems that the main issue in protection of the horses still centres around the perception of horses by the public.

In an article published in the New Zealand Geographic, the writer posed several questions about management of Kaimanawa horses. These questions were as follows (Wright, 1989):

- i. How many horses can the Moawhango River headwaters support without unacceptable environmental damage?
- ii. What is the effect of horse grazing and hoof damage on indigenous plants, some of which are extremely rare?
- iii. If the horses extend their grazing territory because of their increased numbers, where will they increase to?
- iv. Who is legally responsible for the horses?
- v. If they have to be culled, what is the best means of doing this?
- vi. Are the horses worth saving?

Five years later we can answer most of the questions. In reply to the first and second, evidence presented by Rogers (1991) suggested that horses caused damage to indigenous plant and this damage was deemed to be at an unacceptable level. After the presentation of this evidence, a strategy was developed to manage horse numbers. To answer the third question about the expansion of the feral horse range, many sightings of horses near State Highway 1 resulted in a muster being undertaken to remove horses from that area. This suggests that horses were expanding their range to the land across the highway. To reply to the fourth question regarding responsibility, the Department of Conservation has held itself responsible for managing horse numbers since 1991 when a draft management strategy was released to gauge public reaction. Despite the reactions of interest groups, the Department initiated the management process. To answer the fifth question regarding the horse culling method,

this process involved three musters in 1993 and 1994. Following the removal, some horses were sold at auction while others were sent for slaughter. The Department proposed to control the numbers of horses left behind after the removals using immunocontraception. As for the last question, the decision about the worth of preserving feral horses probably depends on the New Zealand public.

References.

- Aitken, V., Kroef, P., Pearson, A., and Ricketts, W. 1979 unpublished. *Report on observations of feral horses in the southern Kaimanawas (February 1979)*. Report to the Kaimanawa Wild Horse Committee, Massey University, Palmerston North, New Zealand.
- Berger, J. 1986. *Wild horses of the Great Basin*. University of Chicago Press, Chicago.
- Boy, V., Duncan, P. 1979. Time Budgets of Camargue horses I: Developmental changes in the budgets of foals. *Behaviour*, 71,187-202.
- Boyles, J.S. 1986. Managing America's wild horses and burros. *Journal of Equine Veterinary Science*, 6,261-265.
- Carroll, C.L. and Huntington, P.J. 1988. Body condition scoring and weight estimation of horses. *Equine Veterinary Journal*, 20,41-45.
- Clutton-Brock, T.H., and Albon, S.D. 1982. Winter mortality in red deer. *Journal of Zoology*, 198,515-519.
- , and Godfray, C. 1991. Parental investment. In: *Behavioural Ecology: an evolutionary approach*. (Edited by J.R. Krebs and N.B. Davies). Blackwell Scientific Publications, Oxford, pp 234-262.
- , Greenwood, P.J. and Powell, R.P. 1976. Ranks and relationships in Highland ponies and Highland cows. *Zeitschrift fur Tierpsychologie*, 41,202-216.

- Connell, Wagner Rankine and Hill Ltd. 1992. *Kaimanawa wild horse herd draft management strategy executive summary*. unpub.
- Cunha, T.J. 1991. *Horse feeding and nutrition*. 2nd edn. Academic Press, San Diego.
- Dobbie, W.R., Berman, D.M., and Braysher, M.L. 1993. *Managing vertebrate pests: Feral horses*. Australian Government Publishing Service, Canberra.
- Duncan, P. 1980. Time budgets of Camargue horses II. Time budgets of adult horses and weaned sub-adults. *Behaviour*, 72,26-49.
- , Harvey, P.H. and Wells, S.M. 1984. On lactation and associated behaviour in a natural herd of horses. *Animal Behaviour*, 32,255-263.
- . 1992. *Horses and grasses*. Springer-Verlag, New York.
- Eberhardt, L.L., A.K. Majorowicz, and Wilcox, J.A. 1982. Apparent rates of increase for two feral horse herds. *Journal of Wildlife Management*, 46,367-374.
- Emlen, S.T. and Oring, L.W. 1977. Ecology, sexual selection and the evolution of mating systems. *Science*, 197,215-223.
- Feh, C. and De Mazieres, J. 1993. Grooming at a preferred site reduces heart rate in horses. *Animal Behaviour*, 46,1191-1194.
- Feist, J.D. and McCullough, D.R. 1975. Reproduction in feral horses. *Journal of Reproduction and Fertility Supplement*, 23,13-18.
- . 1976. Behaviour patterns and communications in feral horses. *Zeitschrift fur Tierpsychologie*, 41,337-371.
- Frape, D. 1986. *Equine nutrition and feeding*. Longman Group, London.
- Garrott, R.A. 1991. Sex ratios and differential survival of feral horses. *Journal of Animal*

Ecology, 60,929-937.

-----, Eagle, T.C., and Plotka, E.D. 1991 (a). Age-specific reproduction in feral horses. *Canadian Journal of Zoology*, 69,738-743.

-----, Siniff, D.B. and Eberhardt, L.L. 1991 (b). Growth rates of feral horse populations. *Journal of Wildlife Management*, 55,641-648.

----- and Taylor, L. 1990. Dynamics of a feral horse population in Montana. *Journal of Wildlife Management*, 54,603-612.

Gates, S. 1979. A study of the home ranges of free-ranging Exmoor ponies. *Mammalian Review*. 9,3-18.

Keiper, R.R. 1976. Social organization of feral ponies. *Proceedings of the Pennsylvania Academy of Science*, 50,69-70.

----- and Houpt, K. 1984. Reproduction in feral horses:an eight year study. *American Journal of Veterinary Research*, 45,991-995.

Kirkpatrick, J.F., Liu, I.K.M., and Turner, J.W.Jr. 1990. Remotely-delivered immunocontraception in feral horses. *Wildlife Society Bulletin*, 18,326-330.

-----, -----, -----, Naugle, R., and Keiper, R. 1992. Long-term effects of porcine zonae pellucidae immunocontraception on ovarian function in feral horses. *Journal of Reproduction and Fertility*, 94,437-444.

-----, and Turner, J.W. Jr. 1991. Compensatory reproduction in feral horses. *Journal of Wildlife Management*, 55,649-652.

Klingel, H. 1982. Social organisation of feral horses. *Journal of Reproduction and Fertility Supplement*, 32,89-95.

Krebs, J.R., and Kacelnik, A. 1991. Decision-making. In: *Behavioural Ecology: an*

- evolutionary approach*. (Ed by J.R. Krebs and N.B. Davies). Blackwell Scientific Press, Oxford. pp 105-136.
- Lucas, Z., Raeside, J.I., and Betteridge, K.I. 1991. Non-invasive assessment of the incidences of pregnancy and pregnancy loss in the feral horses of Sable Island. *Journal of Reproduction and Fertility Supplement*, 44,479-488.
- Miller, R. 1981. Male aggression, dominance and breeding behaviour in Red Desert feral horses. *Zeitschrift fur Tierpsychologie*, 57,340-351.
- , and Denniston, R.H. 1979. Interband dominance in feral horses. *Zeitschrift fur Tierpsychologie*, 51,41-47.
- Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. *American Midland Naturalist*, 37,223-249
- Molloy, J., and Davis, A. 1992. *Setting priorities for the conservation of New Zealand's threatened plants and animals*. Department of Conservation, Wellington, New Zealand.
- Owen-Smith, R.N. 1988. *Megaherbivores*. Cambridge University Press, Cambridge.
- Rogers, G.M. 1991. Kaimanawa feral horses and their environmental impacts. *New Zealand Journal of Ecology*, 15,49-64.
- Rubenstein, D.I. 1981. Behavioral ecology of island feral horses. *Equine Veterinary Journal*, 13,27-33.
- 1986. Ecology and sociality in horses and zebras. In: *Ecological Aspects of Social Evolution* (Ed by D.I. Rubenstein and R.D. Wrangham), pp 282-302
- Rudman, R. and Keiper, R.R. 1991. The body condition of feral ponies on Assateague Island. *Equine Veterinary Journal*, 23,453-456.
- Rutberg, A.T. 1990. Inter-group transfer in Assateague pony mares. *Animal Behaviour*,

40,945-952.

----- and Keiper, R.R. 1993. Proximate causes of natal dispersal in feral ponies: some sex differences. *Animal Behaviour*, 46,969-975.

Salter, R.E. and Hudson, R.J. 1978. Habitat utilisation by feral horses in Western Alberta. *Naturaliste Canadien*, 105,309-321.

----- . 1982. Social organisation of feral horse in Western Canada. *Applied Animal Ethology*, 8, 207-223.

Seal, U.S. and Plotka, E.D. 1983. Age-specific pregnancy rates in feral horses. *Journal of Wildlife Management*, 47,422-429.

Siniff, D.B., Tester, J.R. and McMahon, G.L. 1986. Foaling rate and survival of feral horses in Western Nevada. *Journal of Range Management*, 39,296-297.

Smith, K. 1991. Reining in the brumbies. *Forest and Bird*, 2237-40.

Stevens, E.F. 1990. Instability of harems of feral horses in relation to season and presence of subordinate stallions. *Behaviour*, 112,149-161.

Turner, M.G. 1988. Simulation and management implications of feral horse grazing on Cumberland Island, Georgia. *Journal of Range Management*, 41,441-447.

Tui Milk Consulting Officer Service. 1994. Pasture and profit. *Tui News*, July, 16-17.

Tyler, S. 1972. The behaviour and social organisation of the New Forest ponies. *Animal Behaviour Monographs*, 5,85-196.

Wolfe, M.L. 1980. Feral horse demography: a preliminary report. *Journal of Range Management*, 33,354-360.

----- 1986. Population dynamics of feral horses in Western North America. *Journal*

of *Equine Veterinary Science*, 6,231-235.

-----, Ellis, L.C., and MacMullen, R. 1989. Reproductive rates of feral horses and burros. *Journal of Wildlife Management*, 53,916-924.

Woodward, S.L. 1979. The social system of feral asses (*Equus asinus*). *Zeitschrift fur Tierpsychologie*, 49,304-316.

Wright, V. 1989. Wild horses. *New Zealand Geographic*, 1,52-67.