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Diurnal Activity Patterns of Jeju Ponies (*Equus caballus*)

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We investigated seasonal variation of diurnal activity patterns in Jeju ponies (*Equus caballus*). The data were collected from a semi-natural herd during daylight hours from March to September 1998. Over all months, the mean proportion of time spent grazing was 83.7% (±29.7 S.D.); that resting was 15.7±17%, grooming 0.7±1.2%, and moving 0.56±5.4%. Activity patterns varied with the seasons. The mean proportion of grazing mares peaked during late winter and early spring (March), when there was not enough food, and declined during other seasons (between May and September), when food was abundant. The mean proportion of mares that were resting and mutual grooming peaked in spring (April and May), at which time the weather was warm and food became abundant. During other seasons when grasses started to grow and the weather was mildly cool, these activities were less common. The mean proportion of mares that were moving peaked in June, although it was a small proportion of the total activity. For those mares without foals, resting periods were longer in older mares than in younger mares, but for the mares with foals this pattern was not evident. From these data, we hypothesize that the dominance hierarchy of the mares effects the diurnal activity pattern.

Patterns of diurnal activity have been reported in many organisms, from insects to humans (Benedix, 1994; Haigen and Fengxiang, 1995; Kadri et al., 1997; Fleury et al., 2000; Jean-Louis et al., 2000a, b). Circadian activities are often driven by exogenous factors. Generally, patterns of diurnal activity of a species determine the range of abiotic environmental factors (temperature, light, photoperiod, etc.) to which they will be exposed, as well as the biotic milieu (prey, predators, competitors, etc) in which they are living. The activity pattern is, therefore, an integral part of the biology of a species and may provide insight into the factors that exert selection pressures on its behavior.

In horses, for example, horse flies (tabanids) are ectoparasites that might influence the social organization of horses. Ponies did not reduce the distances between one another when flies were scarce. However, ponies reduced the distances between individuals in environmental conditions that caused high fly abundance (Rutberg, 1987).

Studies of the time budgets and activity patterns of horses or zebra have been conducted by Houpt et al. (1986), Boyd et al. (1988), Beekman and Prins (1989), Hunter and Houpt (1989), Duncan (1992), van Dierendonck et al. (1996), Boyd (1998), and Berger et al. (1999). The study by Houpt et al. (1986) was of pregnant and lactating pony mares. Boyd et al. (1988) study was only conducted from early June to early August, but they collected data during both day and night times. Beekman and Prins (1989) presented the daytime grazing pattern of zebras (*Equus burchelli* Gray), and the study was conducted over nearly a two-year-period. Hunter and Houpt (1989) described the individual night time activity patterns of ponies who were kept in a stall. Boyd et al. (1988) observed the 24-h time budget of Tahki harem stallion over a 2-week period. Van Dierendonck et al. (1996) described time budgets after the reintroduction of Takhi and Przewalski horses in Mongolia. Berger et al. (1999) investigated diurnal and ultradian rhythms in mares of Przewalski horses over a period of one year by the storage-telemetry system and presented seasonal variation of activity and feeding patterns.

There are few reports on Asian native ponies (Boyd et al., 1988; Boyd, 1998). The Jeju pony (*Equus caballus*) is an endangered species in Korea. Very few studies have focused on the development of foals (Kang, 1996; Jang et al., 1996). There has been no study on the ecology and social behavior of Jeju ponies. It is very important to know activity patterns to care for Jeju ponies, and provide good condition of the pasture to improve their welfare. The present study describes their daylight activity patterns from early spring to late fall.

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Methods

Study subjects and site

The study was conducted on a farm (33° 25′ 50″ N, 126° 36′ E) established in 1986 on Jeju Island, Korea. The herd had been maintained by Jeju Province Institute for Livestock Promotion, kept in a pasture of 233 ha composed of shrubs and semi-natural grass and bounded by fences.

Since establishment, the herd size was usually maintained at 45-73 mares and 1 stallion. Stallions in the herd were exchanged with another stallion to avoid inbreeding every year. In 1998, the herd consisted of 73 mares, their 53 foals and 1 stallion. The mares consisted of 5 2-year olds (y.o.), 14 3-y.o., 1 4-y.o., 12 5-y.o., 2 6-y.o., 7 7-y.o., 2 8-y.o., 4 9-y.o., 3 10-y.o., and 6 11-y.o. Mares between 12 and 16 years of age were not present. The herd also consisted of 15 older mares, including 3 17-y.o., 1 18-y.o., 5 19-y.o., 2 20-y.o., 1 21-y.o., 2 23-y.o. and 1 24-y.o. The age of the stallion was 12 years.

During 1998, the herd fed on pasture grass from March to October as of 1998. It always had available water at an artificial drinking station. During winter, the herd was transferred onto pasture behind a barn. During winter, the horse managers sometimes supplemented the pasture with hay and processed meal. There were some shrubs and trees in the pasture which the horses occasionally used for shade to rest. Trees were also used to take shelter against heavy rain, wind, and midday sun. At those times, some members of the herd rested in a tight group or stood in small groups of one or two pairs under a tree.

Climate data were recorded once every hour by an automatic weather station located near the farm. Average monthly wind speeds during May to October 1998 ranged from 1.8 to 2.6 m/s. The average monthly rainfall for the same period was 86 mm in May, 1,110 mm in June, 434 mm in July, 320 mm in August, 466 mm in September, and 208 mm in October. We recorded air temperature at the pasture in the morning (between 0800 and 0830 h) and at midday (between 1250 and 1320 h). Fig. 1 shows the average temperature in the morning and at midday on the farm.

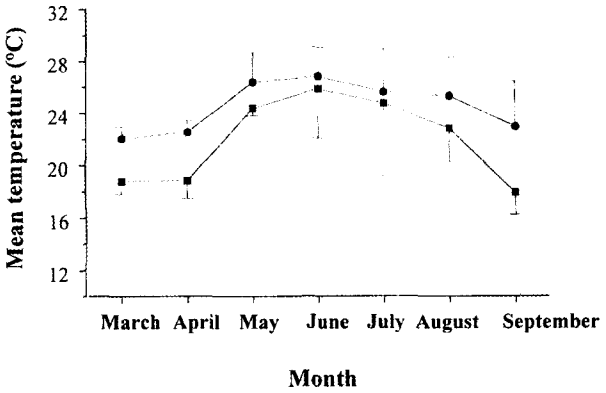

Fig. 1. Mean air temperature in the morning (■, 07:00~07:30) and at midday (●, 12:50~13:20) from March to September 1998.

Data collection

Data on diurnal activity patterns for all of the Jeju pony adult mares were collected from March to September 1998. In total, over 305.5 h of observations were recorded. We scan sampled the herd following the methodology of Altmann (1974). We classified activities according to the ethogram for horses presented by Boyd et al. (1988). We recorded time feeding, resting, moving, grooming, and combined other activities such as playing, nursing, and drinking. To provide detailed activity patterns of resting, we recorded resting as standing, lateral recumbency, or sternal recumbency. Grooming was also divided into mutual grooming, rubbing, and rolling. At 20-min intervals, the herd was scanned and an instantaneous activity of its mares recorded as grazing, resting, grooming or moving mares. The observations were discontinued for the time that the herd was disturbed by the horse manager.

Scan samples were made for two or three hours once every two or three days. All data were collected between 0800 and 1900 h. Daylight was subsequently divided into four periods: 0800-1000 h, 1000-1300 h, 1300-1600 h, and 1600-1900 h. To sample equally across the four daylight periods over the months of the study, observations were made in different time periods on different days. We sampled on foot with either the naked eye or a 10x38 pair of binoculars. Jeju ponies can be watched from distances of as little as 7-20 m without disturbance. The observations were interrupted when some of the herd was out of sight.

Additionally, to provide a detailed analysis of resting and grooming, we recorded the length of resting and grooming periods using the focal animal continuous sampling method (Altmann 1974). The data on the length of resting periods were recorded from mares without foals (n=27) and mares that were separated by the age of their foal. We tried to conduct observations of the same mare as its foal aged. However, in some instances, we substituted another mare and her foal of identical age, because rain or fog prevented observation of the focal mare. Because mares with foals were sampled repeatedly but not consistently, sample sizes varied depending on the foals' ages. Sample sizes consisted of 18 mares with foals aged 4 days old (d.o.), 31 with 7 d.o. foals, 35 with 14 d.o. foals, 49 with 30 d.o. foals, 36 with 60 d.o. foals, and 33 with 90 d.o. foals, and 31 mares with 120 d.o. foals. Data were collected over a total of 896 hours on pasture from April to September 1997 and from March to October 1998.

Analysis of activity

We analyzed 918 scan-samples, including 96 from

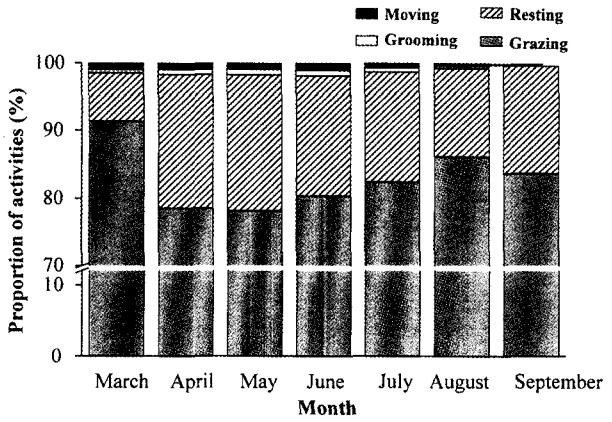

Fig. 2. Proportions of various activities from March to September 1998. All data are the mean values of 73 mares and 1 stallion.

March, 96 from April, 86 from May, 151 from June, 152 from July, 189 from August, and 148 from September 1998. We calculated the percentage of mares engaged in each activity per 2-3 h observation. We summarized the monthly activity by dividing by the number of scan-sampling days. In order to compare months, generalized linear model statistics (GLM, Statistical Analysis Software) were applied to the percentages of mares in each activity. In order to compare activities in the four daylight periods, we also applied a GLM to the mean proportion of mares engaged in each activity. We also applied a GLM to compare resting activity across the four daylight periods for mares without foals and mares with foals at each specific age. We used Pearson's correlation to associate the duration of rest with mare age for both foal-less mares and mares with foals, separately.

Results

Grazing

We accumulated 305.5 h of observation in 1998 on the 73 mares and 1 stallion. Typically, Jeju ponies spend most of their time grazing in the pasture. There was a significant difference in the mean proportion of grazing mares between months (GLM, $F = 8.71$, $df = 6, 130$, $P < 0.001$), suggesting that the season is a good indicator of grazing activity (Fig. 2). The proportion of grazing showed itself to be higher in March (91.4±9.14%, n = 96) than in May (78.1±20.1%, n = 86).

Fig. 3 illustrates the mean proportion of grazing mares in daylight for each month from March to September 1998. There was a significant difference in the mean proportion of grazing mares between months and daily observational periods (GLM, $F = 2.16$, $df = 6, 3$, $P < 0.001$). In May when food quality was sufficient and the weather was warm, the mean proportion of grazing mares fluctuated near midday (1100-1400 h). Grazing frequency did not fluctuate much in any other month.

The mean proportion of grazing mares increased over the course of the day (GLM, $F = 67.9$, $P < 0.001$). It was 74.7% (±18.1, n = 176) between 0800-1000 h, 77.4% (±18.6, n = 287) between 1001-1300 h, 88.1% (±11.2, n = 254) between 1301-1600 h, and 94.2% (±

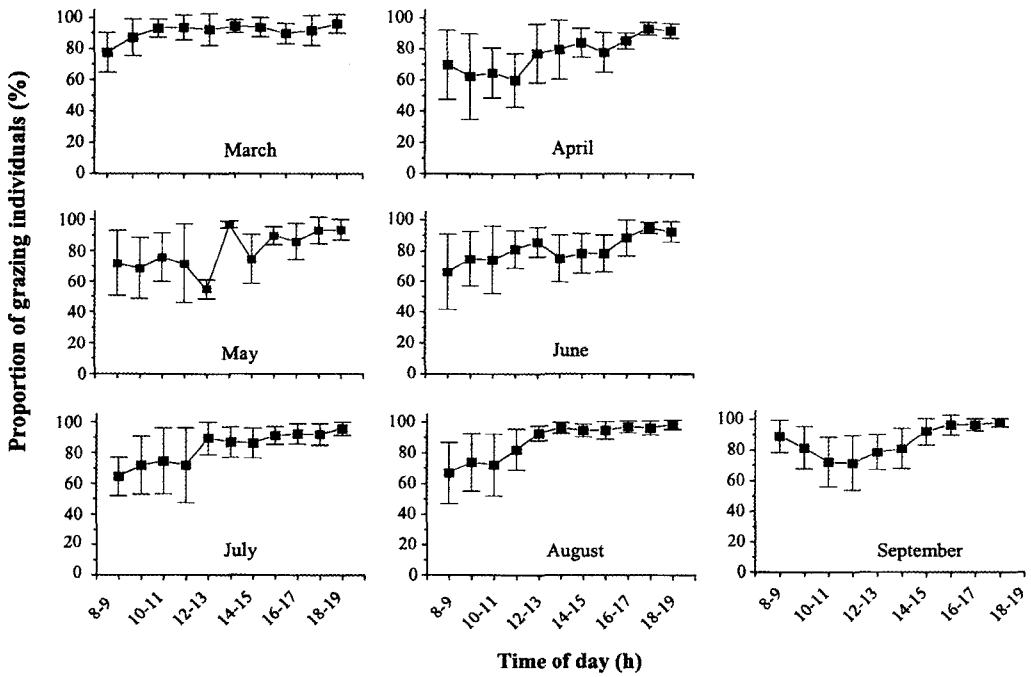

Fig. 3. The mean proportion of grazing mares at daylight (from 8 to 19 hours) from March to September 1998 in Jeju ponies.

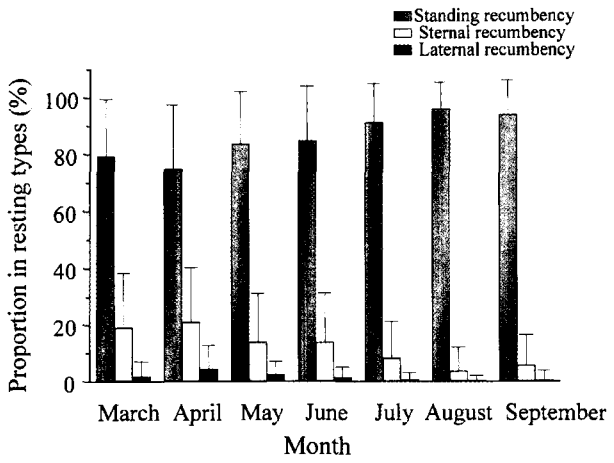

Fig. 4. The mean proportion of standing, sternal and lateral recumbency in daylight from March to September 1998.

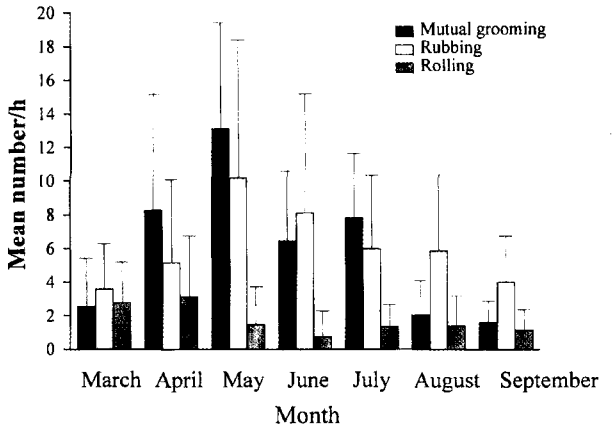

Fig. 5. The mean number of mutual grooming, rubbing, and rolling per hour from March to September 1998.

9.2, n = 201) between 1601-1900 h.

Resting

A total of 10,445 rests were recorded for the 73 mares and 1 stallion over a period of 305.5 h. The distribution of resting types was significantly different across months (GLM, F = 2984.1, *df* = 2, 917, *P* < 0.001). The most common type of rest was in the standing recumbency (85.2%, n = 8,894), followed by sternal recumbency (12.8%, n = 1,341), while only some mares engaged in a lateral recumbency (2.01%, n = 210).

There was a significant difference in the mean proportion of resting between months (GLM, F = 14.6, *df* = 6, 917, *P* < 0.001, Fig. 2). The mean proportion of resting was high between April (19.7±17.3%, n = 96) and May (20.1±20.2%, n = 86), in which it was warm and food quality was sufficient; but was relatively low in March (7.22±9.18%, n = 96), in which the weather was cool and the food quality insufficient.

Fig. 4 illustrates the proportion of resting types in daylight from March to September 1998. The mean proportion of standing recumbency decreased in April and then started to increase by August, whereas the mean proportion of lateral and sternal recumbency increased in April and then started to decrease by September.

The proportion of mares resting decreased over the course of the day (GLM, F = 1.93, *df* = 6, 3, *P* < 0.001). The mean proportion of mares that were resting was 24.4% (±18.8, n = 176) between 0800-1000 h, 21.5% (±18.8, n = 287) between 1001-1300 h, 10.6% (±10.9, n = 254) between 1301-1600 h, and 5.9% (±7.4, n = 201) between 1601-1900 h.

Data on the period of resting were recorded using the focal animal continuous sampling method in mares with foals (n = 233) and without foals (n = 27) from April to September 1997 and March to September 1998. The resting period did not differ from 1997 to 1999 (GLM, F = 1.56, *df* = 1, 258, *P* = 0.21). The mean resting period of the mares with foals (32.2±18 min, n = 233) was shorter than mares without foals (46.6±32.1 min, n = 27) (GLM, F = 7.38, *df* = 1, 246, *P* < 0.01), suggesting that presence of foals reduces the resting period because of the mare's need to guard its foal.

The mean resting period of the mares without foals was longer in older mares than in younger mares (Pearson's *r* = 0.66, SD = 25.18, *P* < 0.01), but there was no age effect in mares with foals (Pearson's *r* = 0.06, SD = 18.27, NS). The mean resting period of mothers increased slightly as their foals aged, but the relationship was not significant (GLM, F = 0.3, *df* = 6, 232, NS). The mean resting period for the mares with foals that were 4 d.o. was 24.4 min (±12.2, n = 18), 7 d.o. was 28.2 min (±16.6, n = 31), 14 d.o. was 30.3 min (±16, n = 36), 30 d.o. was 33.8 min (±22.1, n = 48), 60 d.o. was 33.5 min (±18.6, n = 36), 90 d.o. was 34 min (±18.4, n = 33) and 120 d.o. was 36.7 min (±17.9, n = 31).

Grooming (mutual grooming and self grooming)

A total of 4,088-groomings were recorded for 305.5 h from the 73 mares and 1 stallion. The most common grooming was mutual grooming (48.7%, n = 1,989), closely followed by rubbing (37%, n = 1,513) and tumbling (14.3%, n = 586). There was a significant difference in the mean proportion of grooming among months (GLM, F = 21.3, *df* = 6, 917, *P* < 0.001, Fig. 2), suggesting that weather is a very good indicator of the frequency of mutual grooming. Mutual grooming peaked in May (12.5±6.6%, n = 29), which is warm, and declined in March (1.4±1.5%, n = 10) and September (1.6±1.3%, n = 24), which is mildly cool.

Fig. 5 illustrates the mean number of mutual grooming, rubbing and tumbling per daylight hour from March to September 1998. There was a significant difference in the mean number of mutual grooming per

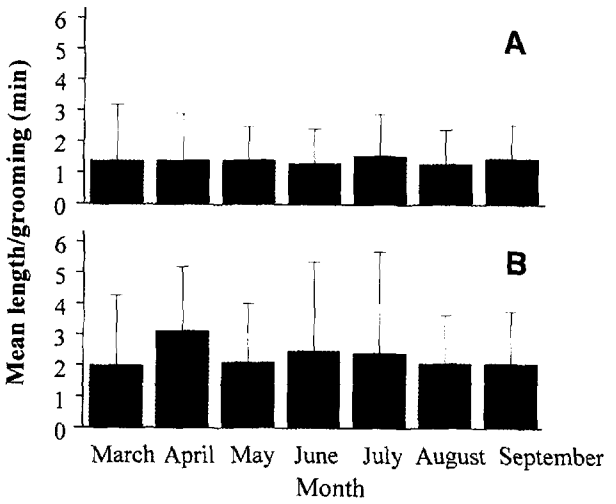

Fig. 6. The mean duration of mutual grooming and rubbing against objects per observation from March to September 1998. (A: Mutual grooming and B: Rubbing).

hour among months (GLM, F = 19.76, df = 6, 917, P < 0.001). The mean number of mutual grooming showed a relatively high peak in spring (13.3±6.3, May). The mean number of mutual grooming and rubbing per hour increased steadily from March, peaked in May and dropped relatively until September. There was not a significant difference in the mean length of mutual grooming period among months (GLM, F = 1.23, df = 6, 1971, P = NS, Fig. 6-A). The mean period of grooming ranged from 1.56 (±1.35 min., n = 373, July) to 1.3 (± 1.1 min., n = 107, August).

The proportion of mares that were grooming declined over the course of the day (GLM, F = 1.93, P < 0.001). The mean proportion of grooming mares was 24.3% (±18.8, n = 176) between 0800-1000 h, 21.5% (±18.8, n = 287) between 1001-1300, 10.6% (±10.9, n = 254) between 1301-1600, and 5.9% (±7.4, n = 201) between 1601-1900).

There was a significant difference in the mean number of rubbing per hour among months (GLM, F = 4.67, df = 6, 917, P < 0.001, Fig. 5). The mean number of rubbing per hour ranged from 3.6±2.7 (n = 10, March) to 10.2±8.2 (n = 28, May). There was also a significant difference in the mean length of rubbing periods among months (GLM, F = 4.67, df = 6, 1511, P < 0.001), suggesting that weather is a good indicator of frequency of rubbing (Fig. 6-B). The mean length of rubbing periods is long in spring season (3.1±2.1 min., n = 134, April), whereas, the mean length of rubbing is similar in mildly cool and rainy and post-rainy seasons (between 2±2.2 and 2.5±3 min, March, May, June, July, August, and September (GLM, df = 5, 1377, F = 1.85, P = 0.1). There was no significant difference in the mean length of rubbing periods between ages of mares (Pearson's, r = -0.03, SD = 142.1, NS).

There was a significant difference in the mean number of rolling per hour among months (GLM, F = 3.65, df = 6, 917, P < 0.01), suggesting that season is a good indicator of frequency of rolling. The mean number of rubbing per hour peaked in late winter and early spring season (2.8±2.4, n = 10, March; 3.2±3.6, n = 29, April) and dropped relatively until late fall season (1.1±1.2, n = 24, September).

The mean number of rolling per observation as well as its frequency peaked in spring (GLM, F = 7.18, df = 6, 590, P < 0.001). Rolling was relatively frequently observed during the late winter and spring seasons (March: 3.7±1.5, n = 111; April: 4±1.9, n = 181), whereas it was observed less often from May (3.1±1.8, n = 60) to September (3.6±1.7, n = 72). There was no significant difference between mares of different ages and the mean number of rolling per observation (Pearson correlation coefficient, r = 0.017, ±1.7, NS).

Moving

We observed that members of the herd sometimes moved from one grazing site to another area or to an artificial water tank. Watchfulness with little locomotion occurred if a stimulus such as an alarm or other acoustical stimulus occurred. There was a significant difference in the mean proportion of moving among months (GLM, F = 9.6, df = 6, 917 P < 0.001, Fig. 2). The mean proportion of moving was 0.69 (±1.2%, n = 918). The mean proportion of moving mares peaked in June (1±1.4%, n = 151), although it was always infrequent relative to other activities.

Discussion

Horses use hindgut fermentation for digestion, and they may devote 70-85% of the time to grazing (Sweeting et al., 1984; Houpt et al., 1986; Beekman and Prins, 1989). Cattle devote 50-60% of the time to grazing (Beekman and Prins, 1989), and they too must allocate time for rumination, resulting in a total grazing time of 70-80%. The grazing patterns of Jeju ponies were generally similar to those of other horses. They budgeted most of their daylight hours to grazing, although the proportion varied from one month to the next.

Previous studies on horses have presented monthly variation of daily total grazing (Waring, 1983; Berger, 1986; Boyd et al., 1988; Beekman and Prins, 1989; van Dierendonck et al., 1996; Berger et al., 1999). The proportion of grazing mares may decrease grazing time when they are able to harvest fresh green matter, which is of very high nutritional value in spring (Duncan, 1992). The Manyara zebra appear to fit this scheme very well, as they increase their grazing time to compensate for reduced food quality in the dry season (Beekman and Prins, 1989). Apparently, Jeju ponies also seem to fit this activity scheme. Jeju ponies decreased their grazing time in spring (April

and May), when there was always high-quality food available, but they increased their feeding time at the beginning of spring (March). Similarly, ponies in the New Forest in England spend much more time grazing in winter than in summer (van Dierendonck et al., 1996).

The diurnal activity patterns of horses tends to show the greatest grazing activity at dusk and dawn (Rubenstein, 1981; Boyd et al., 1988; Berger et al., 1999). Grazing activity declined to a low in the hottest hours of the day and around midday (Boyd et al., 1988; Boyd, 1998). For this study, we did not collect data on grazing activity at sunrise which is the cooler time period. However, Jeju ponies tended to graze the most during late afternoon when air temperatures were cooler. We sometimes observed that temporary groups of ponies rested during the hottest periods of the day or midday. This diurnal activity pattern suggests that Jeju ponies may conserve energy during the hottest periods of a day by resting until it becomes cool enough for them to resume activity and graze without incurring thermal stress.

Most horses spend a small amount of time resting, although there are some differences in frequency of resting between months and time periods (Houpt et al., 1986; Boyd et al., 1988; Hunter and Houpt, 1989; Boyd, 1998). The differences may be affected by abiotic environmental factors and biotic milieu such as temperature, time period, quality of food, and potential predators. In previous studies, the length of resting periods apparently increased as much as that of grazing periods decreased. Jeju ponies also spent a small amount of time resting. The resting length of mares with foals was shorter than mares without foals and shorter in younger mares than in older mares with foals. Additionally, the mares with foals gradually increased their resting period as their foals aged. Young mares with foals may reduce the grazing activity or increase vigilance to guard their foals from nearby mares. Our results suggest that the reproductive costs for young mares were higher than those for old mares.

Grooming is among the most commonly performed behavioral activity engaged in by a wide range of mammals and birds. The idea that ectoparasite removal is an important function of grooming is well established, and, where examined, grooming has been proven effective in removing ectoparasites (Mooring, 1995; Mooring and Samuel, 1998). The production of parasitic ova is affected by a variety of ecological factors. One of the ecological factors is time of year. Total egg production was significantly higher in the summer than in the autumn (Rubenstein and Hohmann, 1989). Some adult ticks peaked during the warm/wet season and other adult ticks peaked during the hot/dry season (Mooring, 1995; Borges et al., 2000). Such higher egg production may incur higher frequency of grooming to remove ectoparasites or their eggs. In our study, the mutual grooming peaked during May, when the weather was warmer or even hot, and declined during March, June, July and September, when the weather was mildly cool, rainy and part of the post-rainy season. Our results suggest that the function of mutual grooming may be to remove ectoparasites or eggs. However, we did not exclude the possibility that mutual grooming may also function as a subtle greeting or social contact to reduce social tension although it is not clear since the herd were in close formation almost constantly in Jeju ponies.

Self-grooming is a commonly performed behaviour among rodents, felids, ruminants and primates and is highly effective in removing ectoparasites. In horses, self-grooming frequency was significantly higher in the summer than in the autumn, and it correlated with the total egg production of parasites (Rubenstein and Hohmann, 1989). In Jeju ponies, the proportion of rubbing peaked during warmer weather rather than in mildly cool weather or the rainy season. We suggest that Jeju ponies may rub to remove ectoparasites against trees or stone.

Feist and McCullough (1976) and Waring (1983) described a general observation of rolling by horses, but the functions of rolling were not reported. In Jeju ponies, the frequency of rolling peaked during late winter and early spring (March and April) and then maintained a nearly constant frequency. We usually observed some fur on the sites after rolling in the early spring, but not in the other seasons. The results appeared to correspond with a season of shedding of winter coats although exact measurement of shedding period was not made. We suggest that rolling is related to the shedding of winter coats, although Crowell-Davis et al. (1986) described the shedding of foals' coats in association with mutual grooming.

Horses do not move frequently during daylight (Sweeting et al., 1984; Houpt et al., 1986; Boyd et al., 1988; Hunter and Houpt, 1989), and they move even less at night (Boyd et al., 1988). In Jeju ponies, patterns of movement during daylight were similar with those reported for horses. The ponies shifted their necks from side to side as they grazed slowly forward, stepping to make additional plants accessible. In addition, they moved toward the artificial water tank with other mares to drink. Sometimes, a mare that was separated from her group moved quickly to rejoin her group.

Although we have not investigated selection pressures on activity patterns in detail, we suggest that the diurnal activity pattern of the Jeju pony is environmentally modulated by temperature, food availability, and the activities of ectoparasites. Our study showed that the mares with foals rested for longer periods when the mare was older. Because older mares are dominant over younger ones (Rho, 2002), we hypothesize that the diurnal activity pattern is influenced by each mare's dominance rank. We also suggest that dominant mares have a greater benefit than subor-

dinate ones in that they are able to reduce the time spent vigilant and guarding their foals. Our understanding of the Jeju ponies activity patterns is helpful for breeding and improving the welfare of Jeju ponies living in pasture.

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