PRELIMINARY SURVEY OF PHYSICAL, GENETIC, PHYSIOLOGICAL AND BEHAVIORAL TRAITS OF FERAL HORSES (*EQUUS CABALLUS*) ON SANTA CRUZ ISLAND

Karen M. Blumenshine[1], Suzanne V. Benech[2], Ann T. Bowling[3], and Ned K. Waters[4]

[1]Santa Barbara Equine Practice, 15 St. Ann Drive, Santa Barbara, CA 93109
(805) 962-4414, FAX (805) 899-4160, E-Mail: kmblumenshine@vmth.ucdavis.edu
[2]Benech Biological, 487 Lincoln Drive, Ventura, CA 93001
(805) 643-2755, FAX (805) 643-1378, E-Mail: ajfield@msn.com
[3]Veterinary Genetics Lab, School of Veterinary Medicine, University California, Davis, CA 95616
(530) 752-2211, FAX (530) 752-3556, E-Mail: atbowling@ucdavis.edu
[4]Department of Radiology, School of Veterinary Medicine, Veterinary Medical Teaching Hospital, University of California, Davis, CA 95616
(530) 752-3753, FAX (530) 752-9815, E-Mail:nkwaters@ucdavis.edu

ABSTRACT

Horses were first introduced to Santa Cruz Island (SCI) in the 1830s. A feral horse population developed by 1984, after cessation of ranching operations. This wild population provided a unique opportunity to study island adaptations on traits in feral horses. Preliminary field observations of physiological and physical traits, social structure, and behavior were studied from 1995 to 1998. Forty-one survey days were completed during all seasons. Physical collections, written records, video, and photographic documentation were analyzed. Migratory habits were mapped. Polymerase Chain Reaction (PCR) amplification of DNA was conducted on hair follicle and blood samples to determine familial relationships, consort behavior, and genetic variation. Urine and manure samples were analyzed to determine reproductive and parasite status. Long-bone (metacarpal) measurements were compared to data from mainland horses. Results indicate the SCI feral horse population resembles other wild horse herds in 1) matriarchal social structure, 2) elimination-marking sequence, 3) consort behavior, and 4) hoof wear patterns. However, SCI wild horses were unique from other wild horse populations in 1) a shift in reproductive season, 2) closer familial relationships, 3) high foal survival rate, 4) decreased long-bone length, and 5) genetic character. These differences appear to be a result of environmental adaptation and genetic isolation.

Keywords: Feral, wild, horse, behavior, physiology, genetics, bones, Santa Cruz, island, California.

INTRODUCTION

Horses (*Equus caballus*) were first introduced to Santa Cruz Island, off the southern California coast, in approximately 1830 when convicts from Mexico were dispatched there to live (de la Guerra Ord 1856). The court petition by Andres Castillero to secure confirmation of his title to Santa Cruz Island confirms his transport of horses to the island along with cattle and sheep in 1851 (Case #176, 1852). Horses were used in the construction of roads and buildings, and remained an integral part of every agricultural operation on the island ever since (M. Daily, pers. comm., 1996). The feral horse herd studied was released into the wild when the last commercial sheep ranching operation was discontinued in the early 1980s (F. Gherini, pers. comm. 1997). It was determined by the ages of the current herd that all 16 members were born in a wild state. The natural range of the horses consisted of approximately 2,549 hectares of primarily grassy coastal plateau of both volcanic and sedimentary origin, gradually inclining to the east to steep basaltic hills. There is no historical evidence that the population was manipulated by man in any way before this study except 20 to 40 members (approximate, from historic accounts, J. Owens, pers. obs. 1997) were apparently culled during a severe drought lasting from 1986 through 1991. Although genetic studies of the Channel Island fox (Wayne 1995) provide a cogent example "that small populations can persist for long time periods, even in the near absence of genetic variability," a benchmark genetic reference point for the Santa Cruz horses will allow appropriate paradigms to be applied in population discussions. This feral horse herd presented a unique opportunity to study the effects of this island ecosystem on feral horse behavior and physiology, and the effects of isolation and culling on genetic makeup. In October 1998, all of the horses were removed from the island. Thus these preliminary results represent the only behavioral, physical, and physiological studies conducted on this wild horse herd while it was intact on Santa Cruz Island.

METHODS

The social behaviors, familial relationships, grazing habits, seasonal migratory habits, reproductive patterns, genetic character and variation, long bone dimensions and hoof wear patterns in the wild horse population on Santa Cruz Island were studied. In order to efficiently cover their 2,549-hectare range, scouting on foot began in an area where the animals were last seen or near common water holes. Observations of the herd were made over a three-year period (1995 to 1998), in both wet and dry seasons. Severe weather conditions prohibited island access during portions of some years. Some herd information was collected by interviewing visitors and park rangers to more precisely pinpoint dates of birth or death. The herd was generally observed at a distance of 6 to 30 m. Behaviors such as social interactions, grazing habits, and migratory patterns were recorded by the investigator and knowledgeable volunteers, using field notes, video, and photographic documentation. Over the period of the study, the herd grew from about 11 to 17 horses.

Biological material used for initial genetic analysis of the feral horses included hair follicle cells from mane or chin hairs, which were used for determination of microsatellite variation by DNA fragment length analysis. These samples were taken from individuals without restraint. Follicle samples were collected from mature stallions (Buck Bay and El Dorado), mares (Tinker, Inez, Albina, Blanca, and Freckles), and young stock (Delphine, Primo and Miguel). During the period of capture and relocation from the island, blood samples were taken from all members of the herd, including the mature mare Panocha and from the youngest foals, and were used for both analysis of blood typing and DNA markers. DNA testing was conducted using the Polymerase Chain Reaction (PCR) method and 15 loci of dinucleotide repeat microsatellites (11 loci discussed in Bowling [1997]) augmented with LEX3, LEX33, ASB2, and UCDEQ425). After PCR amplification, an Applied Biosystems 373 DNA Sequencer with 672 Genescan Analysis software was used to analyze the fluorescently-tagged fragments for length polymorphisms. Due to difficulty in collecting hairs in the field from Panocha, the #1 herd alpha mare, and the foals born from 1996 to 1998, genetic information was not available until after the blood samples were received at the time of capture and relocation efforts. In this manuscript we describe only the results of the DNA analysis. However, familial relationships were determined from analysis of genetic variation (at least 30 loci) detected by a combination of DNA and blood typing methods (Bowling and Clark 1985).

Physical condition was monitored in several ways. The skin and coat on all individuals of the herd were visually examined to determine external parasite status. Fecal samples from six out of the 11 individuals comprising the heard at the start of the study were collected from the ground and examined. Fecal parasite egg counts were performed by flotation method using sodium nitrate (sp. gr. 1.20) (Fecalsol - Evsco Reno, NV) to check for internal parasites. Hoof wear was observed and photographed during both wet and dry seasons. For comparison of cross sectional area of long bone to that of domestic horses, a specimen was taken from the carcass of a 12 year-old mare which had died of natural causes. The specimen was stripped with a NaOH solution and allowed to dry before sections. The midshaft of the cannon bone (metacarpal) was cut through and the cross-sectional area traced and measured by plani-meter. The cross-sectional area at the level of 50% of the distance from the proximal end of the metacarpal bone to the tip of the distal saggital ridge was measured so as to be comparable to existing data compiled from several breeds (Piotrowski et al. 1983). Further metacarpal measurements were acquired from Computerized Axial Tomography (CAT scan) images (General Electic 9800 Quick C.T. scanner). Eight third-metacarpal bones from domestic horses and one third-metacarpal bone from the SCI mare (Inez) were imaged and compared. The longitudinal (mid-saggital) measurement was made from the radiographic center of the carpo-metacarpal joint proximally to the radiographic center of the distal margin of the condyles of the third metacarpus. Cross-sectional areas from three transverse images were measured: midshaft (equidistant from either end of the longitudinal measurement), and 20 mm proximal and distal to midshaft. All cross-sectional measurements were acquired at 120 kvp and 100 ma. Measurements included cross-sectional area, shortest medulary diameter, longest dorsopalmar and mediolateral diameters, and thickest dorsal, medial, and lateral cortices.

Reproductive patterns were traced by collecting fresh urine and manure samples from mares to determine pregnancy status. These data were utilized in the pilot program for immunocontraception, developed to manage herd size. Immunocontraception was administered to one alpha mare for one season. Two doses of porcine zonae pellucidae vaccine were administered intramuscularly by a remote darting system, three weeks apart, during the last month before the time that foaling was predicted. This followed the protocol developed for the Assateague National Seashore feral horses. (Kirkpatrick et al.1992). Pregnancy status was evaluated by urinary oestrone level in EIA assay (Kirkpatrick et al. 1991). Urine samples were aspirated fresh from the ground by syringe. Foaling dates and survival rates were recorded (Tables 1 and 3).

RESULTS

Genetic Characteristics and Variation

For the 15 tested loci, the SCI feral horse population had two to four genetic variants (alleles), all previously identified in recognized domestic breeds. Nine loci had four variants, including an X-chromosome locus (LEX3). This observation suggested that at its smallest (genetic) size, regardless of the number of founder animals, the “bottleneck” population was at least three and likely four or more animals. The average number of variants per locus was 3.0.

Observed heterozygosity for the four adults El Dorado, Buck Bay, Tinker, and Inez ranged from 0.50 to 0.71 with an average of 0.61. The offspring sired by Buck Bay (Table 1) were genetically excluded to be sired by El Dorado, and could not be excluded to be sired by Buck Bay.

Social Organization

The general social unit of the feral horse herd consisted of a stallion, an alpha mare and her offspring, and other mares and their offspring. The stallions acted as sentinels guarding their harems, but did not take the lead in most herd decisions. Alpha mares tended to lead the herd to drink or to pastures. If a threat was perceived, the alpha mares lead the entire band away while a lead stallion was observed to stay behind to face and ward off danger. During the first two years of study, the alpha mares were the only mares producing foals (Table 1).

During most of the study (1995 to 1997) there were only two herds (Table 1). There was a predominance of females in each herd (Table 1). This may have been in part due to human intervention (culling) prior to the study. Neither stallion expended substantial energy in the defense of their mares from conspecific male attention. For instance, when one stallion was observed to be grazing closely to the mare from the other stallion's herd, the second stallion often responded by directing his path of grazing so as to position himself between the first stallion and the mares of the second stallion. This would often occur without any threat posturing. If the first stallion displayed increased interest and drew closer to a mare in the second herd, the second stallion would respond with threatening gestures such as ear pinning, vocalizations, and flexation of the muscles of the neck and chest. If the first stallion responded to these threatening gestures, the interaction tended to intensify with "striking" motions with the front limbs followed by rearing onto the hind limbs and "striking." These more energetic confrontations were observed primarily during spring months.

Harem Stability and Territoriality

Social organization of the SCI wild horses during the study consisted of two comparably stable harems, displaying harem changes of two mares, 6.2% instability (Table 2). The first to move was Albina. Albina was a subordinate mare, closely bonded to another subordinate mare (Blanca). Blanca delivered a healthy foal in January 1997 and was elevated in social status. She and her foal (Rubio) were fiercely defended from Albina by the harem #2 (H#2) stallion (Buck Bay). Evidence of aggression (hair loss from bites) was observed on Albina when she was ostracized from H#2. She was then observed nuzzling with H#1 stallion (El Dorado) and was subsequently accepted into his harem and bore his foal the subsequent year. The second move observed over three years was a filly from H#2 to a new harem (H#3) which was established in 1998 (Table 1). This harem consisted of two animals, a 1.5-year-old colt (Pedro) and 2.5-year-old filly (Vera), both previously from H#1. Prior to the formation of H#3, the H#1 stallion began showing interest (genital sniffing) in Vera. During the formation of H#3, there were no physical signs of nonspecific fighting such as hair loss over the rump and sides. Harem #3 moved into previously

Table 1. Santa Cruz Island wild horse population structure, 1994 to 1998.

Name	Sex/Social Position	Est. Age in 1998	Birth**	Sire	Dam	Herd	Consort
El Dorado	alpha male	14 years	unkn	unkn	unkn	#1	
Panocha	alpha mare	unkn	unkn	unkn	unkn	#1	Buck Bay
Delphine	mare	6-7 years	unkn	Buck Bay	Inez	#1	
Freckles	mare	6 years	unkn	Buck Bay	Panocha	#1	
Albina	mare	4.5 years	Early 94	Buck Bay	unkn	#1	
Miguel*	male	3.5 years	1/2/95	Buck Bay	Panocha	#1*	
Cricket	male	1 year	10/7/97	El Dorado	Panocha	#1	
El Nino	male	foal	2/19/98	El Dorado	Albina	#1	
Last stand on S.C.	filly	foal	9/9/98	El Dorado	Panocha	#1	
Buck Bay	alpha male	12 years	unkn	El Dorado	unkn	#2	
Inez-deceased 2/97	alpha mare	12 years	unkn	El Dorado	unkn	#2	
Tinker	mare	5.5 years	Early 93	El Dorado	unkn	#2	
Blanca	mare	4.5 years	Early 94	Buck Bay	Inez	#2	
Primo	male (gelded 6/96)	3 years	11/24/95	Buck Bay	Inez	#2	
Rubio	male	1.5 years	1/29/97	El Dorado	Blanca	#2	
Nickels	filly	foal	1/29/98	Buck Bay	Blanca	#2	
Vera	mare	3 years	12/2/95	El Dorado	Panocha	#3	
Pedro	male	2 years	10/25/96	El Dorado	Panocha	#3	

* Adopted out of the herd as a yearling.

** Dates prior to 1995 were determined from oral histories from caretakers.

Table 2. Harem instability for the Santa Cruz Island wild horses.

Year	#Changed Harems/Total # Mares	% Instability	% Stability
1994	0/7	0%	100%
1995	0/7	0%	100%
1996	0/7	0%	100%
1997	1/6	17%	83%
1998	1/7	14%	86%
Ave. 5yr	**2/34**	**6.20%**	**93.8%**

unoccupied territory known as "No Man's Land," a rocky basaltic ridge approximately 500 m high, that forms a natural barrier to the west. Manure and tracks were first seen on the crest of this range in April 1998. Seasonal water was plentiful there in the spring. In June, with diminished water sources in the highlands, H#3 was observed in a confrontation with H#1 and H#2 on the plain, and after July, frequented a region near a vernal pool on Cavern Point (Figure 1). During mid-summer 1998, H#1 and H#2 were also observed in the vicinity of the vernal pool water source at Cavern Point. Subsequent to these observations, both members of H#3 and the stallions and some mares of H#1 and H#2 displayed hair loss on their rumps and sides, indicating conspecific fighting and evidence of territorial behavior. Harem #1 and H#2 were not observed on Cavern Point after this occurrence.

Although territoriality per se was not observed between H#1 and H#2, if a subordinate horse would pass manure or urine, a more dominant animal (usually a stallion) was observed smelling the excrement and showing a flehmen response. This investigative behavior would be followed by a period of increased activity or excitement, culminating in the passage of manure onto the top of the subordinate's pile. This "male-typical-elimination-marking-response" (S. McDonnell, pers. comm. 1998) has been associated with sexual behavior and territoriality (Rubenstein 1981; Turner and Kirkpatrick 1986).

Consort Behavior

Consort behavior was evaluated by determining genetic microsatellite loci using genetic material from hair follicles and blood collected from the individuals in the herd and comparing these to herd relationships observed in the field. Throughout the study from 1995 until April 1998 when a colt and young mare left to form a third harem, there were two distinct stallion-dominated harems. The stallion in H#2 (Buck Bay) was sired by the stallion in H#1 (El Dorado). Before 1996, the Harem #2 stallion sired all offspring tested during this study for both H#1 and H#2, after which the H#1 stallion sired all foals in H#1 and one foal in H#2 (Blanca's 1997 colt). Each stallion guarded the mares in his harem and their offspring. During our observations, we did not witness sexual posturing (such as thigh nuzzling, licking, genital sniffing, flehmen, or mounting) by a stallion from one herd to a mare of another herd without a protective response (walking between individuals, ear pinning, flexation of chest muscles, striking or rearing behavior). The genetic data show, however, that the alpha mare of H#1 consorted with the alpha stallion of H#2, since the two of her progeny tested were both sired by him. Blanca of H#2 has born foals by the alpha stallions from both H#1 and H#2. Previous to the beginning of the study, the three eldest individuals in H#2 (Buck Bay, Inez, and Tinker) were all sired by the alpha stallion in H#1 (Table 1).

Grazing Patterns

Grazing observations indicated that the herd foraged primarily on grasses. Species of *Avena, Bromus, Hordeum* and *Nassella* appeared to predominate their rangelands although numerous other grasses such as *Phalaris, Koeleria*, *Gastridium, Lolium, Polypogon, Lamarckia, Piptatherum,* and *Poa* were also present and utilized. Forbes such as *Erodium* and *Medicago polymorpha* were also eaten. During the spring (wet season observations), the horses appeared highly selective and targeted the inflorescence of the abundant *Avena*. During the fall (dry season observations), grazing patterns were more diverse. Not only did they feed on stems of dry *Avena*, they also targeted the still green (more nutrious) blades of the perennial grass *Nassella.* Occasionally, during the dry season, they were observed eating and sometimes specifically targeting forbes such as *Brassica, Sonchus* and *Cirsium*. Most foraging behavior took place on the relatively level eastern plateaus. There were no apparent differences in foraging habits between sexes or among ages.

The study area was grazed by both feral sheep (est. 3,500 head) (Channel Islands National Park, pers. comm. 1997) and horses (12 to16 head). Horses grazed primarily the lower, flatter regions along the eastern plateaus. During this survey, these grasslands appeared to be in good condition in both the wet and dry seasons. Bare ground from overgrazing was not apparent in the plateau region. Bare ground occurred as access roads, rock outcrops, areas of feral pig rooting, and animal trails along canyon walls to water sources. During the wet season, grasses formed dense turf. In late fall, residual dry matter was still abundant. The native perennial bunch grasses (*Nassella*) were selectively grazed during the late summer and fall, but did not display any deformities typical of overgrazing.

Migration Patterns

There was an obvious trend for the herd to be found on the plateau (greater San Pedro Point) when local stream or pond water was available. After plateau water sources disappeared during the dry season, the tendency was to graze nearer either Scorpion or Smugglers Canyons where water was provided by a National Park Service watering trough (Figure 1). They were never observed utilizing perennial springs to the south, which were frequented by feral sheep.

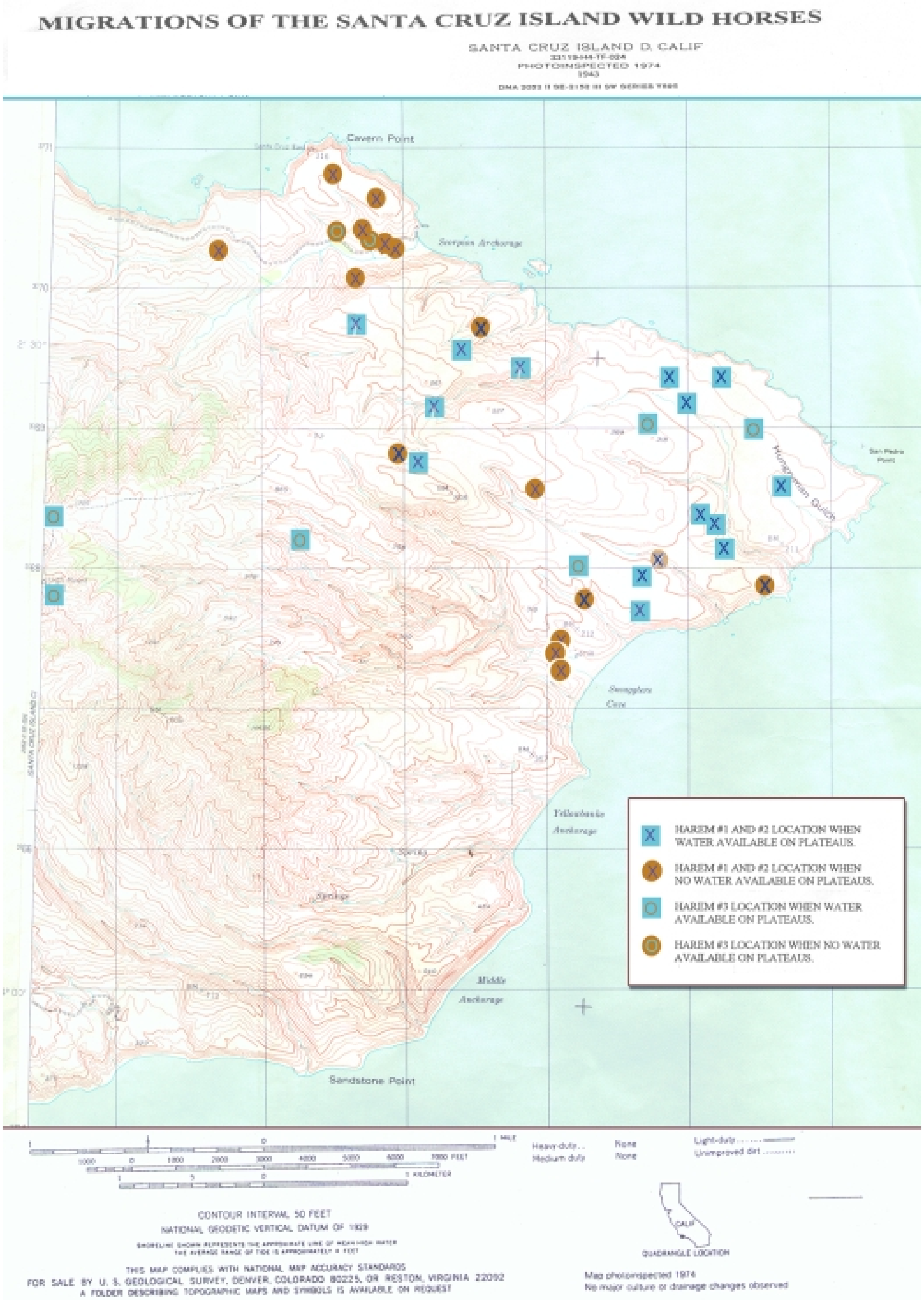

Figure 1. Migratory patterns of the Santa Cruz Island wild horses.

Physical and Physiological Traits

Condition/health of the herd was excellent by all standards. Haircoats were shiny and body scores, a standardized indicator of body weight (Mowrey 1993), were rated at 7 to 8, which is well above average weight. Survival rates (98% for adults and 100% for foals) were remarkable (Table 3). There was a pattern of foaling and breeding between the short photoperiod months of October and February (Table 1). No parasite eggs were seen in any of the fecal examinations and no external parasites were found. (D. Jensen, pers. comm. 1996). The weight bearing surface of the hoof remained remarkably smooth and symmetrical during all seasons, whether the ground was moist or dry. Both hoof length and hoof angle were considered to be within normal limits for domestic horses.

The long bone (metacarpal) length of the deceased SCI mare was greater than four standard deviations below the mean length of the Thoroughbred (TB) population and greater than two standard deviations below the mean of the Quarter Horse (QH) population measured (Table 4). Although the SCI mare metacarpal cross-sectional area was not substantially larger than the areas in the population measured at the University of California Davis (UC Davis) (Table 4), it was greater than three standard deviations above the mean values reported in a mixed-breed population studied at the School of Veterinary Medicine in Gainsville, Florida (Piotrowski et al. 1983).

A remarkable difference was found between the shape of the transverse sections of the metacarpal bone of the SCI wild mare, which had traveled mainly at a walk on basalt and Monterey shale surfaces, and that of domestic breeds which have traveled on various surfaces. While the long-bone cross sections of the SCI mare showed remarkable symmetry, those of the patient population at the Veterinary Medical Teaching Hospital at UC Davis exhibited a marked thickening of the anterior medial cortex.

DISCUSSION

Grazing conditions during our preliminary observations appeared ideal in both quantity and quality and were reflected in the overall healthy condition of both the feral herd and the rangeland (Duncan 1992). Although steeper sheep-dominated regions displayed evidence of overgrazing (i.e., bare ground and erosion), horse-dominated grasslands appeared to be in good condition with dense grass cover in both wet and dry seasons.

The migratory patterns were predominantly influenced by the available water supply. If water was available, the herd was most likely to be found on the coastal plateau.

The pattern of foaling between October and February is distinctly different from that of any United States wild herd reported except for the wild burro herd living in the U.S. Virgin Islands, which breeds and foals all year around. While the difference in photoperiod at that latitude can explain the apparent anomaly in the Virgin Islands (J. Turner, pers. comm. 1997), it cannot explain why the SCI feral herd bred and foaled during the months with the shortest photoperiod, in sharp contrast with nearby mainland domestic horses. Foaling on SCI appeared to coincide with the availability of green grass. Grazing on green grasses increases reproductive success since nutritional levels are then high enough to support a developing fetus and production of milk for the foal (Coates-Markle, in press). This suggests that there may have been some adaptation to island environment. Any conclusions need to be made with caution, however, because of the limited number of animals studied.

Other studies suggest that availability of forage vegetation contributes to harem stability in island herds of feral horses. When forage availability decreased, as much as 30% of adult females left their harems (Stevens 1990). Considering these findings, the high stability (93.8%) of the SCI wild horse harems may have reflected the availability of ample range and suitable vegetation (Table 3).

In previous studies, 25% to 30% of mares in stable consort relations with particular harem stallions have been reported to produce foals sired by stallions from outside their harem (Kasada et al. 1996; Bowling and Touchberry 1990). Analysis of microsatellite variation provided the tool to confirm or rule out suggested relationships in the SCI herd based on coat color and anecdotal information. Preliminary findings in the study indicated that all foals born in H#1 between 1994 and 1996, were sired by Buck Bay (H#2), son of El Dorado (H#2), while those born in 1997 or after were sired by El Dorado (H#1). The 1997 offspring of a mare from H#2 (Blanca) was sired by stallion H#1, but her 1998 offspring was sired by stallion H#2 (Table 1). This resulted in 6.2% harem instability for this herd. In light of the fact that consort behavior was occurring, it is interesting that these harems remained closely affiliated with very little confrontation and competition between stallions, and that only alpha mares produced offspring during most years. This suggests that forage availability may have been a stronger factor than potential mates in conspecific competition in these herds. It also suggests that there may have been some prohibition of mating of subordinate mares by the alpha mares.

Table 3. Survival rates for the Santa Cruz Island wild horses.

Description	1995	1996	1997	1998	Ave. Survival Rate
Adults over 1 year (Survival/Total#)	09/09	11/11	11/12	13/13	98%
First year of age	03/03*	01/01	02/02	03/03	100%

*Adopted colt not included in this data.

Table 4. Comparison of long-bone measurements between SCI horses and domestic breeds.

Breed	Age	Sex	Leg	Length	Ave. CX area	CX/length
TB	15 years	mare	right	27.3 cm	10.72 cm^2	0.39
TB	9 years	gelding	left	25.8 cm	9.28 cm^2	0.36
TB	20 years	stallion	left	25.8 cm	9.96 cm^2	0.39
TB	3 years	gelding	left	27.1 cm	10.10 cm^2	0.37
Mean TB				26.5 cm	10.02 cm	0.38
St. Deviation TB				0.812	0.590	0.591
QH	7 years	mare	right	23.4 cm	8.72 cm^2	0.37
QH	2 years	mare	right	24.6 cm	7.60 cm^2	0.31
QH	6 years	gelding	right	25.5 cm^2	9.34 cm^2	0.37
QH	8 years	gelding	left	24.3 cm	9.29 cm^2	0.38
QH	10 years	gelding	left	24.7 cm	8.58 cm^2	0.34
Mean QH				25.4 cm	8.71 cm^2	0.35
St. Deviation QH				0.758	0.704	0.704
Mean Total #				25.4 cm	9.29 cm^2	0.36
St. Deviation Total				1.283	0.924	0.026
SCI wild mare	15 years	mare	right	22.9 cm	8.94 cm^2	0.36

TB = Thoroughbred; QH = Quarter Horse.

Comparison of the metacarpal length of the deceased SCI mare to that of Quarter Horses is most significant since Quarter Horse stock was reportedly introduced onto the island in the 1980s (M. Daily, pers. comm. 1996). Thoroughbred metacarpi used in the comparison were substantially longer (Table 4), which underscored the diminution of stature of the island sub-species. The marked decrease in long-bone length may have resulted either from island environmental factors affecting selection or from the genetic influences of the horses brought to the island by early European settlers. Although Inez was the only SCI horse to perish during the study, providing only one sample for comparison, it would appear that her long bones were representative since she appeared to be above average in stature for adults in the island herd (Figure 2). These findings substantiate the obvious phenotypic differences between this island sub-species which is shorter in stature in relation to body size than mainland breeds.

The level of heterozygosity in the Santa Cruz Island horses can be regarded as moderately high, particularly considering the small number of animals, their island isolation and likelihood of inbreeding. Average heterozygosity was 0.61 compared to 0.75 average from 16 domestic breeds and 0.72 from seven feral populations (Bowling 1994). No attempt was made to determine genetic similarity to extant breeds since effects such as small population size; non-random mating or natural selection is likely to have produced significant changes in gene frequency from the founder group. The Santa Cruz Island horses should be considered to provide a collection of genes that has been selected for survival under conditions present in this particular habitat.

Figure 2. Phenotypical Santa Cruz Island wild horses (Inez is mare in the foreground guarding foal in grass).

That collection may be a valuable resource in the future for traits presently undefined that may have been lost in the modern studbook of recorded breeds.

The survival rates of the SCI wild horses during this study (adults 98% and first-year foals 100%) were remarkably higher than reported average survival rates in 18 other wild herds in six states (California, Colorado, Idaho, Nevada, Utah, and Wyoming) (Journal of Range Management 1980). Estimates of first-year survival rate ranged from 50 to 70%; adult survival rates ranged from 80 to 85%. The seasonally sparse availability of grasses, harsher climactic conditions, and potential presence of predators in the other herds studied may be responsible for the markedly lower survival rates. In spite of competition of approximately 3,000 feral sheep, the abundant grasslands, relatively mild climactic conditions, and absence of predators on Santa Cruz Island provided an optimal habitat for the horse herd.

CONCLUSIONS

Abundant suitable habitat within an isolated island environment resulted in a wild horse herd remarkable in seven ways: 1) timing of reproductive cycling in winter months in spite of photoperiod, 2) high harem stability of 93.8%, 3) low conspecific competition, 4) high adult (98%) and foal (100%) survival rate, 5) shorter long bone (metacarpal) length, 6) increased cross-sectional area (thickness) of metacarpi and 7) high level of general health.

LITERATURE CITED

de LaGuerra Ord, A. 1956. Occurrences in Hispanic California. MCMLVI Academy of American Franciscan History 5401 West Cedar Ln., Washington, DC.

Anonymous. 1980. Journal of Range Management 33(5):354-360.

Augustine, D. J. and S. J. McNaughton. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. Journal of Wildlife Management 62(4):1165-1183.

Bowling, A. T. 1994. Population genetics of Great Basin feral horses. Animal Genetics 25(1):67-74.

Bowling, A. T., M. L. Eggleston-Stott, G. Byrnes, R. S. Clark, S. Dileanis and E. Wictum. 1997. Validation of microsatellite markers for routine horse parentage testing. Animal Genetics 28:247-252.

Bowling, A. T. and R. S. Clark. 1985. Blood group and protein polymorphism gene frequencies for seven breeds of horses in the United States. Animal Blood Groups and Biochemical Genetics 16:93-108.

Bowling, A. T. and R. W. Touchberry. 1990. Parentage of Great Basin feral horses. Journal of Wildlife Management 54(3):424-429.

Coates-Markle, L. In press. Interactions Between Social Ranch and Forage use in Mainland Feral Horses, Oregon State University, Corvallis, OR 97331.

Duncan, P. 1992. Horses and Grasses: nutritional ecology of equids and their impact on the Camague. Springer-Verlag, New York, NY.

Kaseda, Y., K. Nozawa, 1996 Paternity tests with blood types in Misaki feral horses. Animal Science and Technology 67(2):198-203.

Kirkpatrick, J. F., I. M. K. Liu, J. W. Turner, and M. Bernoco. 1991. Antigen recognition in feral mares previously immunized with porcine zonae pellucida. Journal of Reproduction and Fertility. Supplement 44.

Kirkpatrick, J. F., I. M. K. Liu, J. W. Turner Jr., R. Naugle, and R. Keiper. 1992. Long-term effects of porcine zonae pellucidae immunocontraception on ovarian function in feral horses (*Equus caballus*). Journal of Reproduction and Fertility 94.

McDonnell, S. M., M. M. Lutz, E. H. Ewaskieweiz, and A. Ruducha. 1998. Ontogeny of Sexual Behavior of foals in a Semi-feral Pony Herd (all authors at University of Pennsylvania School of Veterinary Medicine, New Bolton Center, Kennett Square, PA 19348). In press.

Mowrey, R. A. 1993. Mare and Foal Nutrition. North Carolina Cooperative Extension Service. North Carolina State University College of Agriculture & Life Sciences 1-6.

Nunamaker, D. M., D. M. Butterweck, and M. T. Provost. 1989. Some geometric properties of the third metacarpal bone: a comparison between the throughbred and standardbred racehorse. Journal of Biomechanics 22:129-134.

Ovnicek, G., J. B. Erfle, and D. F. Peters. 1995. Wild horse hoof patterns offer a formula for preventing and treating lameness. Pages 258-260 *in* 41st Annual Proceedings of the American Association of Equine Practitioners Convention.

Piotrowski, G., M. Sullivan, and P. T. Colahan. 1983. Geometric properties of equine metacarpi. Journal of Biomechanics 16(2):129-139.

Rubenstein, D. I. 1981. Behavioural ecology of island feral horses. Equine Veterinary Journal13(1):27-34.

Stevens, W. F. 1990. Instability of harems of feral horses in relation to season and presence of subordinate stallions. Behavior 112:3-4,149-161.

Transcript of the Proceedings in Case #176, Andres Castillero *vs* The United States for the Island of Santa Cruz (1852).

Turner, J. W. and J. F. Kirkpatrick. 1986. Hormones and reporduction in feral horses. Equine Veterinary Science 6(5):250-258.

Wayne, Robert K. 1995. Conservation genetics in the Canidae. Pages 75 to 118 *in* Avise, J. C. and J. L. Hamrick (eds.), Conservation Genetics; Case Histories from Nature. Chapman & Hall, New York, NY.

SOURCES OF UNPUBLISHED MATERIALS

Daily, M., Santa Cruz Island Foundation, 1010 Anacapa Street, Santa Barbara, CA 93101. Personal communication 1996.

Gherini, F., 162 South "A" Street, Oxnard, CA 93030. Personal observation 1997.

Jensen, D. H., DVM, P.O. Box 798, Los Alamos, CA 93440. Personal communication 1996.

McDonnell, S.M., University of Pennsylvania School of Veterinary Medicine, New Bolton Center, Kennett Square, PA 19348. Personal Communication 1998.

Channel Islands National Park 1901 Spinnaker Dr., Ventura, CA 93001-4354, Personal Communication 1997.

Owens, J., 308 Lion Street, Ojai, CA 93023. Personal Communication 1997.

Turner, J.W., Medical College of Ohio, Department of Physiology and Molecular Medicine, 3000 Arlington Avenue, Toledo, OH 43699-0008. Personal Communication 1997.