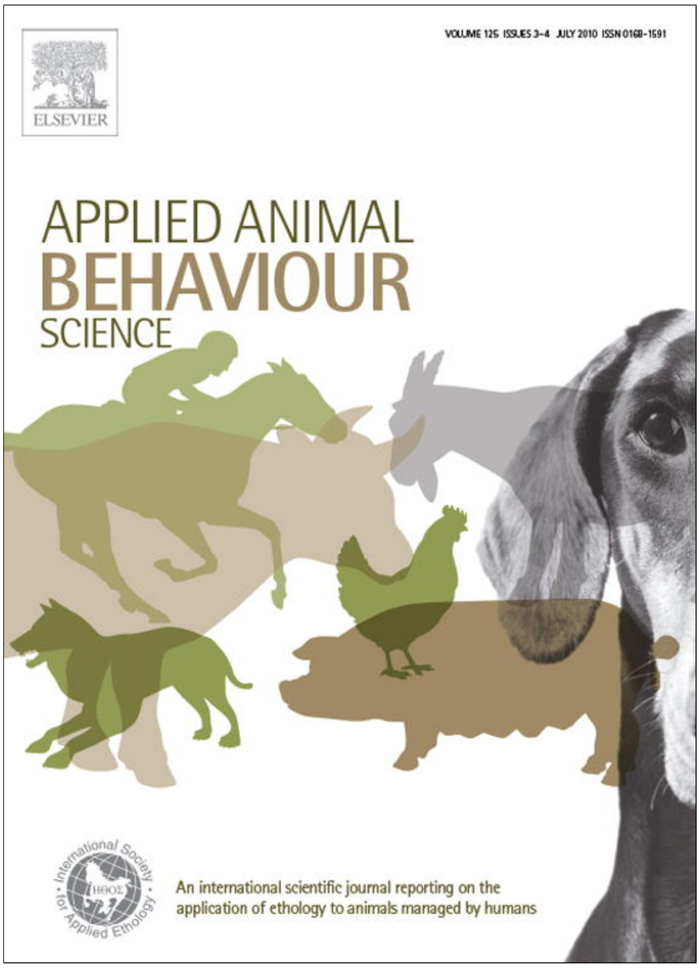
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Behavioural and physiological consequences of capture for shearing of vicuñas in Argentina

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ABSTRACT

Behavioural, physical and physiological responses of Argentinean vicuñas to capture, handling and shearing were studied for the first time. The research was undertaken in a study area of 2414 ha with a mean density of 12–40 vicuñas/km^2. Captures were conducted on groups of wild vicuñas that had not received any prior management. Groups were herded into a funnel system that ended in a corral with several internal subdivisions. Three distinct capture methods were compared, according to the method by which the animals were herded into the corral (vehicles system: vehicles only; mixed system: people on foot and vehicles; and Chaku system: people on foot only). Attempts to escape, alarm calls, increased vigilance, vocalizations, and kicking were measured to quantify the stress response. A total of 478 vicuñas were captured between May 2003 and November 2005. Vicuñas captures by mixed system showed alert and active behaviours and vocalized more in the handling corral. The most active animals inside the corrals showed higher respiratory and heart frequency during handling ($r = 0.44$, $P < 0.05$ and $r = 0.58$, $P < 0.001$, respectively) and the heart rate increase was inversely proportional to blood glucose and creatin kinase (CK levels) ($r = -0.31$, $P = 0.05$ and $r = -0.4$, $P = 0.05$, respectively). Females captured by people on foot showed greater concentrations of cortisol (174 ± 10.5 nmol/L), compared to vicuñas captured by people and vehicles (127.38 ± 12.5 nmol/L) ($F_{(1,21)} = 7.22$, $P < 0.05$). Cortisol levels peaked between 90 and 120 min post-capture (♀ = 177.13 ± 7.67 nmol/L; ♂ = 135.11 ± 13.23 nmol/L). CK (ln) increased significantly according to time spent in captivity. The system that caused the fewest stress responses in vicuñas was capture by people on foot.

1. Introduction

Current policies for vicuña management in the South American Andes include the use of different capture methods for the shearing of wild animals, farming, ranching and translocation and/or reintroduction (Lichtenstein and Vilá, 2003; Bonacic et al., 2006). It has been demonstrated that vicuñas become stressed by human contact in a similar way to other wild ungulates (Bonacic et al., 2006). Previous studies have reported that as a result of capture a number of physiological parameters including rectal temperature, heart rate, respiratory rate, creatin kinase (CK), and plasma cortisol concentration increased beyond the normal baseline range seen in captive animals (Bonacic and Macdonald, 2003; Bonacic et al., 2003, 2006). For example, plasma cortisol concentrations were 41% higher in captured animals than levels recorded in previous studies and under similar conditions of the altiplano of Chile and Bolivia suggesting that capture is stressful (Bonacic et al., 2006). Despite the recognised effects that capture

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causes in wild ungulates (Beringer et al., 1996; Morgan and Tromborg, 2007; Swaisgood, 2007), little is known about the behavioural responses of vicuñas to management. Less-known is the relationship between physiological and behavioural changes in this wild species. Assessment of stress and discomfort should include both behavioural and physiological measures (Morgan and Tromborg, 2007; Swaisgood, 2007). A number of methods has been proposed to identify and quantify anthropogenic stressors that impact wildlife negatively (Tarlow and Blumstein, 2007), among them are the physiological parameters studied by Bonacic and Macdonald (2003) and Bonacic et al. (2006), which might provide a standard quantitative measure of a vicuña's response to stress. Behavioural changes as a consequence of capture and handling are likely to be reflected in these physiological parameters if they are stressful. Grandin (1997) defines attempts to escape, alarm calls, increased vigilance, vocalizations, and kicking as behavioural responses to stress in other ungulate species, and the relationship between behavioural and physiological responses are well-described in farmed animals such as pigs and poultry (Morrison et al., 2007; Rodenburg and Koene, 2007; Schütz et al., 2009), laboratory animals and wild animals in captivity (Swaisgood et al., 2001; Fox and Millam, 2007; Watters and Meehan, 2007). Sahley et al. (2007) stated that in certain circumstances the capture, handling, and live shearing of vicuñas can be biologically sustainable with no ecological consequences for the species. They found consistent population growth in a wild population that was periodically captured for shearing compared to a non-shorn population. However the paper by Sahley et al. (2007) is the only published account of the population consequences of vicuña capture, and it was only based in the long-term response of raising calves. It is not yet known if there are short- and medium-term effects on wild vicuña populations that are utilised for economic gain in remote areas. In these areas there is an emphasis on obtaining economic benefits for poor rural communities. The aim of this study is to determine the effect of different capture methods on vicuñas' behaviour before release and how this was related to physiological parameters of vicuñas that are live-shorn in a community-based project in the high plateau of the Argentinean Andes. We expect greater values of stress indicators when vehicles are used in the capture process because it includes stronger stimulus than the Chaku method.

2. Materials and methods

2.1. Capture methods

Vicuñas were captured in the north of Argentina, close to the Bolivian–Argentinean border at 3700 m above sea level (66° 15′W, 21° 50′S) (see Arzamendia and Vilá, 2006; Arzamendia et al., 2006, 2008). The climate of the area is harsh with severe high diurnal temperature fluctuations and frequent frosts. Rain is seasonal (December to March) and scarce (350 mm/year) (Tecchi and Garcia Fernandez, 1998). Strong, dry winds are frequent. Soils are stony, sandy or saline and the terrain is mostly soft plains. A total area of 2414 ha with a mean density of 12–40 vicuñas/km^2 was chosen as the management area. Capture was conducted on wild groups of vicuñas that had never been subject to management before. Groups were herded into a funnel system that ended in a corral divided into four sub-corrals: reception, pre-handling, handling-shearing and pre-release. Gates connected sub-corrals and plastic covers impeded sight among them. Fenced sides of the funnel were 500 m long with a mean height of 2 m with posts every 10 m. A strong and semi-transparent net (10 cm × 10 cm) impeded the escape of vicuñas from the funnel. Two extra nets were buried across the entrance of the funnel system and 250 m away from the corral to close the trap securely during the phase before vicuñas entered the corral. Three contrasting capture methods were compared at the same location and season to evaluate how behavioural, physical and physiological variables were affected by the capture procedure.

The three capture methods differed in the herding system employed. One method used vehicles only (vehicles system: two pickups, two motorcycles and one quad bike), the second employed a combination of vehicles and people (mixed system: same number of vehicles and 25–70 people on foot) and the third method used people only (Chaku system: with approximately 70 people on foot). The capture of vicuñas with vehicles only used a small team of people in vehicles to herd animals into a corral where they were held and unrestrained, until shearing. The vehicles used were Ford pickups and motorbikes, all with noise levels below 80 dB during chase. Capture with vehicles and people consisted of vehicles chasing the animals until they reached the entrance of the funnel, then people on foot and people in vehicles herded the animals into the corral by walking behind (in silence), holding a rope with coloured plastic strips as a visual barrier. The Chaku system followed the same procedures as in the mixed system but only utilising people on foot.

The main effects considered were (1) capture method, (2) herding distance and (3) duration of capture or restraint, on a range of physiological and behavioural variables.

Each animal was handled by two to three people who blindfolded the vicuña before further handling. Each animal was restrained and placed on a carpet to allow a blood sample to be collected, the age and sex were determined and the animal shorn. The heart rate, respiratory rate and rectal temperature were monitored manually throughout the handling process and the recorded values at the start of restraint were compared to those at the end of shearing restraint.

The duration of each handling event was recorded and any reaction from the animals was registered by a dedicated observer. A total of 478 animals were studied. Tagged animals (n = 266) were monitored in the study area for up to 24 months after capture.

Blood samples (5 mL) were collected by jugular venepuncture. Standard blood tubes (vacutainers) were used containing EDTA for haematological assays and heparin for plasma cortisol. Proteins and blood glucose concentrations were measured in the field, by refractometry using a portable glucometer (Elite, Bayer, Germany). Its accuracy was then validated using the hexoquinase test in the IACA haematology laboratory (Bahía Blanca, Argentina). Heparin tubes were centrifuged immediately at approximately $1500 \times g$ for 15 min at 4 °C. The plasma was subsequently decanted into separate 1.5 mL microtubes and frozen at −18 °C until analysis. EDTA tubes were kept refrigerated in a portable cooler for a maximum of 4 h before being analysed. Cortisol concentration was measured from blood plasma using a validated radioimmunoassay for the species (Bonacic and Macdonald, 2003). These values were chosen for the comparisons of blood parameters using the baseline for captive wild vicuñas (Bonacic et al., 2003), captive-born vicuñas taken from private collections and reference values in the published literature for vicuñas and other South American Camelids (Bonacic, 2000; Bonacic et al., 2003; Sarno et al., 2009).

2.2. Behavioural records during capture and handling

Scan sampling was used to observe animals in pre-handling and pre-release corrals every 5 min ($n = 365$ scans in pre-handling and 84 in pre-release corral). In the handling-shearing corral, focal sampling was used to observe each individual animal continuously during handling and shearing ($n = 355$ samples) (Martin and Bateson, 1986). Scans and focal sampling utilised the following behavioural states: (1) Alert, the animal standing with the head raised high and ears erect, (2) walking, or low displacement with head up, (3) running, (4) lying, or resting on the ground (5) auto-grooming and allo-grooming, included scratching with fore or hind feet and biting and chewing the fur, (6) others, all other observed activities, like mounting another vicuña, suckling, etc. The behavioural events recorded were abrupt movements (jumping, attempts to escape from handling), vocalisations, urination, defecation, kicking, fighting and aggressions, and all.

2.3. Data analysis

Capture methods were compared by GLM considering chase distance, duration and chase speed as independent variables.

ANCOVA was used to: (1) compare the mean proportion of animals for each behaviour category between corrals (pre-handling and pre-release) and capture methods using as covariables the time in corral (total time since captivity began) and total number of vicuñas in the corral. (2) Compare the mean frequency of movements and vocalisations per minute, rectal temperature and respiratory rate between capture methods with sex and age (excluding calves, animals <1-year old) as explanatory variables and the time in corrals (total time since captivity began) as a covariable. (3) Compare the heart rate, cortisol, glucose, creatin kinase, aspartate aminotransferase and protein concentrations between capture methods and sex, with time in corral as covariables. Age was excluded from this analysis because the heart rate and the blood samples were not obtained from all the captured animals in the handling-shearing corral.

ANOVA was utilised to compare the behaviour in the handling-shearing corral (body movements and vocalisations) and physiological variables (cortisol, glucose, total proteins) of two groups of animals that differed in their time of sampling (24 h interval).

Each behavioural, physical and blood parameter was checked for normality with Shapiro–Wilks test and homocedasticity graphically (Gurevitch and Scheiner, 1993; Underwood, 1997). Transformed values (ln) were used for aspartate aminotransferase (AST) and creatin kinase (CK) (Zar, 1999; Bonacic et al., 2006). The behavioural variables were transformed to ranks (Shirley, 1987). Likely relationships between physiological variables and behavioural variables were analysed by non-parametric correlations (Grandin, 1997).

3. Results

3.1. Capture events

A total of 478 vicuñas were captured between May 2003 and November 2005. All three capture methods were tested during the first year. The vehicle system was unsuccessful (no vicuñas captured) because vehicles necessarily leave spaces between them and therefore the vicuñas could escape. The Chaku system was the method by which most vicuñas were captured (43 ± 15 vs. 10 ± 3 for the mixed system, $n = 22$; $t = 2.24$, $P < 0.001$). The speed of capture differed between methods; motorised captures had an average chase speed (mean speed 30 ± 10 km/h) in comparison with mixed system (mean speed 13.7 ± 3.53 km/h) and the significantly slower Chaku method (mean speed 3.5 ± 0.34 km/h, $F = 6.28$, d.f. = 2, $P < 0.05$). No significant differences were found between the duration of capture between the two successful methods (mixed and Chaku) when both the chase and final enclosure in the main corral were considered (mean 41.22 ± 6.57 min, $n = 23$; $F = 1.78$, d.f. = 2, $P = 0.19$). Similarly no difference was seen in the mean distance of chase (mean 2.62 ± 0.11 km, $n = 23$, $F = 1.76$, d.f. = 2, $P = 0.2$). Waiting time before shearing was longer in the Chaku system ($H = 24.23$, $P < 0.0001$; Chaku system: 65.08 ± 2.99 min, mixed system: 47.43 ± 4.92 min), but no differences were detected in handling and shearing time (7–11 min).

3.2. Behavioural and physiological responses during capture and pre-release

Mixed captures resulted in more animals walking, fighting and kicking inside the corrals compared to captures by the Chaku system (Fig. 1 and Table 1). Kicking was more frequent in the pre-handling corral than in the pre-release corral.

The frequency of behaviours categorized as alert, lying and grooming occurred with statistically different frequency inside the corral and between capture methods (corral × capture method interactions were: alert: $F_{(1,449)} = 24.5$, $P < 0.0001$; lying: $F_{(1,449)} = 28.1$, $P < 0.0001$; grooming: $F_{(1,449)} = 15.91$, $P < 0.001$) (Fig. 1). Animals waiting to be handled stayed alert for a longer period of time ($F = 5.39$, $P < 0.05$) and less time lying ($F = 3.34$, $P = 0.05$) when captured with the mixed system, compared with those captured without the use of vehicles. The number of animals in the corral increased the number of alert events

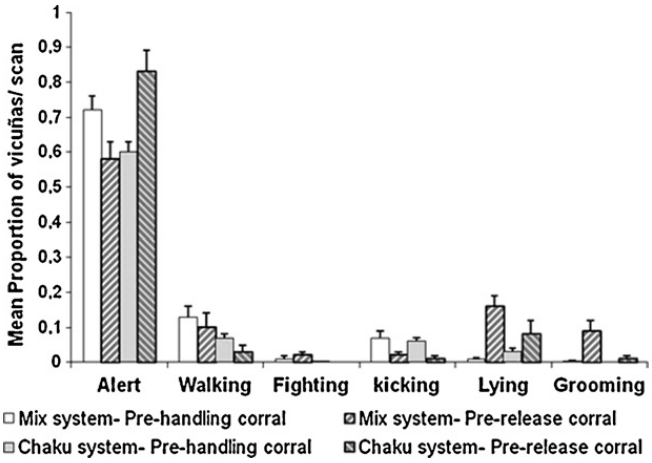

Fig. 1. Mean proportion of vicuñas performing each behavior per scan (standard error) in the pre-handling and pre-release corrals in the two different capture methods (mixed and Chaku).

($F = 9.8$, $P < 0.01$) and, decreased the number of animals lying on the ground ($F = 6.8$, $P < 0.5$). Grooming was more frequent (9%) after handling and shearing ($F_{(1,449)} = 36.85$, $P < 0.0001$), additionally in the pre-release corral the time in captivity increased the number of grooming events ($F_{(1,84)} = 7.41$, $P < 0.01$). Vicuñas captured by the mixed method showed more activity (movements/min and vocalizations/min) during handling (Table 3), for females and calves, respectively ($F_{(1,100)} = 6.8$, $P = 0.01$ and $F_{(1,27)} = 13.60$, $P < 0.01$), and adult vicuñas vocalized more ($F_{(1,109)} = 4.9$, $P < 0.05$).

Cortisol levels, CK, respiratory frequency and rectal temperature were higher in captured animals than previously reported in reference values (Tables 2 and 3). The most active animals inside the corrals showed higher respiratory and heart frequency during handling ($r = 0.44$, $P < 0.05$ and $r = 0.58$, $P < 0.001$, respectively) and heart rate was inversely proportional to blood glucose and CK levels ($r = -0.31$, $P = 0.05$ and $r = -0.4$, $P = 0.05$, respectively). We found an interaction method × sex (Table 2) in the case of females captured by people on foot, which showed higher levels of cortisol (174 ± 10.5 nmol/L) compared to the ones captured by people and vehicles (127.3 ± 12.5 nmol/L) ($F_{(1,21)} = 7.22$, $P < 0.05$); but in the case of males that was the other way round. Cortisol levels peaked between 90 and 120 min post-capture (♀ = 177.13 ± 7.67 nmol/L; ♂ = 135.11 ± 13.23 nmol/L). CK (ln) increased linearly with

Table 1
Comparison of the mean proportion of animals for each behaviour category between corral and by capture methods.

Statistical model	Walking		Kicking		Fighting-aggression		Vocalizing	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Corrals (PH and PR)	0.88	0.35	4	**0.047**	0.25	0.614	0.22	0.642
Capture methods	4.05	**0.045**	4	**0.045**	11.2	**0.0009**	0.25	0.618
Corrals × capture methods	0.2	0.655	0.4	0.533	0.67	0.415	1.08	0.308
Time in corral	0.04	0.845	0	0.917	0.18	0.672	2.23	0.146
Vicuñas/corral	0.1	0.754	17	**<0.0001**	0.59	0.444	1.52	0.227
Dif. between capture methods	M > CH	M > CH	M > CH					
Dif. between corrals		PH > PR						

Note: Behavioural categories; walking, kicking, fighting-aggressions and vocalizing.
Between corrals (pre-handling: PH and pre-release: PR) and, capture methods (M: mixed; CH: Chaku) using as covariable the "time in corral" (the total time since captivity began), and "vicuñas/corral" (the number of vicuñas in the corral). The bold values, indicate significant difference for $p < 0.05$.

Table 2
Effects of two capture methods and sex on blood parameters with time in corral as a covariable, in the handling-shearing corral.

Parameter	Sex	Capture methods		Statistical model								
		Mixed	Chaku		Methods		Sex		Methods × sex		Time	
		Mean ± SE parameter		Statistical significance								
				N	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Cortisol (nmol/L)	♂	138.2 ± 11.4	>112.8 ± 6.5	54	1.4	0.237	6.3	**0.02**	12.6	**0.001**	0.5	0.47
	♀	127.3 ± 12.5	<174 ± 10.5									
Glucose (mg/dL)	♂	107.5 ± 6.5	<128 ± 5.91	46	7.5	**0.009**	0.8	0.38	0	0.88	0	0.87
	♀	112.8 ± 8	<136 ± 4.91									
AST (ln)	♂	5.33 ± 0.14	5.41 ± 0	27	0	0.921	1.6	0.22	0.3	0.57	2.8	0.11
	♀	5.22 ± 0.07	5.08 ± 0.29									
CK (ln)[a]	<♂	5.47 ± 0.36	3.89	24			7.61	**0.01**			30.6	**<0.001**
	>♀	5.5 ± 0.29	5.68 ± 0.58	14	0.8	0.39					5.2	**0.04**
Proteins (g/dL)	<♂	4.37 ± 0.2	<5.46 ± 0.05	25	8.2	**0.007**	4.8	**0.04**	7.2	**0.01**	1.6	0.22
	>♀	5.18 ± 0.2	<5.41 ± 0.23									

Note: Reference values for vicuñas are cortisol 18–24 nmol/L, glucose 95–150 mg/dL; aspartate aminotransferase (AST) 128–450 IU/L (ln AST 4.85–6.11); creatin kinase (CK) 0–137 IU/L (ln CK 1–4.9); proteins 4.8–7.0 g/dL (Bonacic et al., 2003; Bonacic and Macdonald, 2003; Fowler, 1989). The bold values, indicate significant difference for $p < 0.05$.
The sign (>, <) indicates significant differences between sex and methods.
[a] ln CK: comparisons between sex for the mixed method, and between methods only for the females.

Table 3
Effects of two capture methods, sex and age on behavioural and physical parameters in the handling-shearing corral, with time in corral as a covariable.

Parameter	Sex	Capture methods		Statistical model																
		Mix (2)	Chaku (3)		Methods		Sex		Age		Methods × sex		Methods × age		Sex × age		Methods × sex × age		Time	
		Mean ± SE parameter		Statistical significance																
				N	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Initial rectal temperature	♂	40.24 ± 0.1	>39.8 ± 0.15	85	4.5	**0.03**	3.4	0.07	3.45	0.07	1.92	0.17	0.001	0.97	0.4	0.56	0,09	0.76	0.1	0.79
	♀	39.74 ± 0.1	>39.6 ± 0.14																	
Final rectal temperature	♂	40.20 ± 0.1	39.6 ± 0.2	66	3.8	0.06	2.2	0.14	1.42	0.24	2.33	0.13	0.73	0.39	0.3	0.6	0.18	0.68	3.9	0.05
	♀	39.79 ± 0.1	39.5 ± 0.2																	
Initial respiratory rate	♂	38.07 ± 2.0	>32.9 ± 2.4	82	3.7	**0.05**	0.04	0.84	0.02	0.88	1.04	0.31	0.08	0.78	3.1	0.08	0.38	0.54	1.3	0.27
	♀	41.43 ± 3.0	>32.5 ± 2.5																	
Final respiratory rate	♂	61.60 ± 5.6	46.7 ± 4.1	44	1.9	0.18	1.13	0.29	1.72	0.19	1.69	0.2	0.14	0.71	0	1	0.1	0.76	2.7	0.11
	♀	53.71 ± 8.0	46.0 ± 3.3																	
Initial heart rate	♂	79.93 ± 3.9	>59.8 ± 3.5	76	6.2	**0.015**	3.1	0.08			1.4	0.242							7.3	**0.01**
	♀	83.14 ± 5.6	>72.5 ± 4.9																	
Final heart rate	<♂	67.20 ± 6.1	>56.6 ± 2.7	41	9.3	**0.004**	4.8	**0.04**			1.7	0.203							4.7	**0.04**
	>♀	86.29 ± 8.6	>58.4 ± 3.5																	
Mov/min	<♂	108.11	116.09	231	5.7	**0.018**	6.2	**0.01**	0.4	0.69	4	**0.047**	5.9	**0.003**	1.3	0.27	0.1	0.87	7.8	**0.01**
	>♀	150.21	>114.42																	
Vocal/min	♂	128.42	>106.31	231	5.8	**0.017**	0.6	0.44	0.3	0.78	0.2	0.648	3.9	**0.02**	0.5	0.63	0.8	0.47	4.4	**0.04**
	♀	146.46	>111.25																	

Reference values for vicuñas are heart rate 30–90, respiratory rate 10–30 mov./min, rectal temperature 37.5–38.9 °C (Fowler, 1989; Bonacic et al., 2003; Bonacic and Macdonald, 2003). The sign (>, <) indicates significant differences between sex and methods. The bold values, indicate significant difference for $p < 0.05$.

Table 4
Comparisons between handling day (1 and 2) and sex on behavioural variables in the pre-handling corral, as well as in cortisol, glucose and proteins.

Factor	Parameter										
		Mov./min		Vocal./min		Cortisol		Glucose		Proteins	
		n: 326		n:326		n:75		n:64		n:53	
	d.f.	F	P	F	P	F	P	F	P	F	P
Handling day	1	0.05	0.82	0.3	0.58	0.6	0.44	4.4	**0.04**	6.58	**0.01**
Sex	1	1.11	0.29	2.22	0.14	5.81	**0.02**	1.58	0.21	0.004	0.95
Handling day × sex	1	0.63	0.43	1.83	0.18	0.004	0.95	0.03	0.86	1.35	0.25
Result		NS		NS		F > M		2 > 1		2 > 1	

Note: NS: no significance, 1: animals handled the same day; 2: animals handled the day after. F: females, M: males. The bold values, indicate significant difference for $p < 0.05$.

the time spent in captivity, and was higher in females (Table 2).

One group of vicuñas remained in a large corral (approximately 6 ha) for 24 h before they were handled and shorn. No major behaviour differences were found between the first day and the second day of handling. In both days cortisol levels were higher than baseline values (♀ = 157.9 ± 9.79 nmol/L and ♂ = 127.9 ± 5.75 nmol/L) (Table 4). The highest cortisol value for a captured animal was found in this group (day 2) with 286.94 nmol/L.

4. Discussion

This study considers some behavioral and physiological parameters of vicuñas captured by two different methods. Traditional capture, or Chaku, showed the slowest chase speed, but similar total handling time, compared to the mixed method. Total handling time was similar to other studies in Chile and Bolivia (1:38 h, Bonacic et al., 2006), and it is connected to the size of the group captured. The number of vicuñas captured did not influence the mean handling time of each animal (below 12 min/animal). Behavioural observations from vicuñas waiting in a corral were clearly linked to an acute stress response (see Morgan and Tromborg, 2007). An increased frequency of alarm calls, vigilance time and attempts to escape have been described as acute stress traits (Grandin, 1997; Giralt, 2002; Morgan and Tromborg, 2007; Swaisgood, 2007). The movements and vocalizations in the handling-shearing corral, as well as walking, alert, aggressive interactions and kicking behaviours in other corrals were more frequent in animals captured by chases using vehicles. After handling, the alert, lying down and grooming behaviours were affected. Indeed, grooming increased up to 10 times the normal baseline value observed in free-living vicuñas (Arzamendia, 2008). All of these behaviours were described before as acute stress responses (Giralt, 2002; Swaisgood, 2007). Alert and kicking increased with more animals in a corral and grooming with longer waiting time, as a consequence of the crowding and longer holding time prior to release, respectively. Considering this, we suggest releasing the animals after shearing in small groups so as to decrease the overall capture time. It is recommended to release males as soon as possible, after handling and shearing to avoid possible aggressive behaviours towards females and calves, which are more vulnerable to aggressions because of their pregnancy and their size, respectively.

The mixed method of capture generated, in some parameters, more stress signs than captures by Chaku method. In both groups, blood and clinical parameters were altered compared to baseline levels. Bonacic and Macdonald (2003) and Bonacic et al. (2006) also reported increases in rectal temperature, cortisol, as well other parameters as glucose, CK and AST levels, as a consequence of chase and handling in wild vicuñas. Longer times in captivity affected these parameters more than shorter times, as reported in previous studies (Bonacic and Macdonald, 2003; Bonacic et al., 2003, 2006). However, this study did not show glucose and AST increases as previous studies did show. More responsive animals during shearing showed higher heart rate and respiratory rate after handling, and CK levels increased in relation to the time in captivity after shearing. Cortisol mean values and the range of responses were similar to previous studies. However, in this study females responded with higher levels of cortisol after capture; and a higher peak was reached after 24 h in captivity by a female indicating a distress response (286.94 nmol/L compared to previous studies that reported 219.4 nmol/L; Bonacic et al., 2003). Higher levels of CK in females may suggest that they are more likely to respond with capture myopathy and death (Chapple et al., 1991). However, AST did not follow a similar pattern suggesting that whether no muscle damage occurred or that samples were taken before enzyme release occurred (see Giralt, 2002; Bonacic and Macdonald, 2003 for AST release dynamics).

Harris et al. (1999), Bonacic et al. (2006) and Gimpel and Bonacic (2006), suggested that time in captivity is the most important factor that increases the risk of myopathy. Longer chases causing higher levels of CK, increased packed blood cell volume and higher glucose levels have been observed in red deer and other species (Chapple et al., 1991; Bradshaw and Bateson, 2000). In addition, when longer times in captivity are linked to longer waiting times, total cortisol values also increase (Bonacic et al., 2006). Moreover, when animals were kept in captivity for 24 h, cortisol values were maintained high and increased in some animals and vigilance and alertness remained high, probably as a consequence of distress caused by people, lack of access to their natural territories and the effect of mixed groups. Large-scale Chaku management in Salinas Aguada Blanca, Arequipa, Peru (Wheeler and Hoces, 1997; Sahley et al., 2004), and partially in the Argentinean province of Catamarca and Bolivian Ulla-Ulla National Reserve, usually involves leaving groups enclosed for one day or more, however the results of this study suggest higher stress for the vicuñas in this condition.

High levels of glucocorticoids could increase reproductive failure and mortality (Tarlow and Blumstein, 2007). However, the results of the post-capture monitoring in the study area, showed similar birth and mortality rates between shorn and control animals (Arzamendia and Vilá, 2006; Arzamendia, 2008). Chakus in Arequipa, Perú have been evaluated from the point of view of reproductive success without finding negative effects (Sahley et al., 2007). Improvement in handling and chasing techniques (welfare standards) and post-capture monitoring programs, including new monitoring techniques of group stability, calf survival, and fiber production, may aid the detection of medium- and long-term impacts.

5. Conclusion

The traits monitored in this study suggested that the Chaku (capture by people on foot) system causes less stress and fewer changes in vicuñas' welfare than capture involving motor vehicles. Chaku was also the most successful capture system in terms of the total number of animals captured per event. Captures of vicuñas by people on foot is an Andean tradition with at least 500 years of history, and seems to be the least detrimental of the two in relation to animal welfare, provided the animals are handled and released back into the wild in a short time period within the same day.

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