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# Effects of Capture, Shearing, and Release on the Ecology and Behavior of Wild Vicuñas

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**ABSTRACT** The goals of sustainable use of wildlife include minimizing long term deleterious impacts of management. We evaluated the ethoecological and demographic responses of wild vicuñas (*Vicugna vicugna*) to capture, shearing, and release in northern Argentina, as well as effects on behavior, by comparing captured and shorn versus non-captured animals for 2 yr after capture events. We observed subtle and short-term changes in the movement behavior of individuals, likely due to thermal and behavioral stress following capture. We did not observe changes in survival and birth rates, social organization, or distribution of animals following capture. Therefore, we concluded that the capture techniques used resulted in low impacts on the wild vicuña population. © 2011 The Wildlife Society.

**KEY WORDS** Andean communities, behavioral impacts, capture and shearing, sustainable use, *Vicugna vicugna*, wild vicuñas.

The wild vicuña is intimately connected with Andean culture; as a result, conservation and management of vicuñas are both complex and risky (Vilá 2006). Vicuñas are adapted to the high Andean environment (Koford 1957), with more than a quarter of a million individuals occupying 5 countries. The fiber from shorn vicuñas is also among the finest (12.5 microns) and highest priced in the world ($300–$770/kg); over 43 tons have been sold in the last 10 yr (Bonacic et al. 2006). The harvest of fiber from vicuñas is an example of the sustainable use of wildlife (Gordon 2009), because these animals can be managed via capture, handling, shearing, and immediate release back into the wild (Lichteinstein and Vilá 2003). Sahley et al. (2007) presented preliminary evidence on the sustainability of live shearing of vicuñas from 2 wild Peruvian populations. They found that the population growth in a wild population that was periodically captured for shearing was similar to that for a non-shorn population. Additionally, birth rates were equivalent.

Nevertheless, capture of wild animals can potentially cause injuries and changes in their normal behavior and physiology (Beringer et al. 1996, Morgan and Tromborg 2007, Swaisgood 2007, Cattet et al. 2008). Previous research on vicuñas demonstrated that captures affected, in the short-term (at time of capture), the physiological, physical, and behavioral parameters relative to baseline values (Bonacic and Macdonald 2003, Bonacic et al. 2006, Arzamendia et al. 2010). To date, we still know little about the ecological and behavioral responses of vicuñas to capture and shearing management in the long-term (months and years after), and problems not detected in the short term can negatively affect

the management system and its sustainability (Williams et al. 2006).

The effect of management on natural behavior can be informative (Sutherland 1998, Gimpel and Bonacic 2006). Any deviation from behavioral homeostasis signals the possibility that the animal perceives a threat and can also be an indicator of a stress response (Swaisgood 2007). Noticeable signs of stress include: alarm or defense responses, avoidance, suppression of feeding and sexual behavior, aggression, stereotypic behavior, apathy, decreased complexity of behavior, and high latency required to resume normal activity after the stressor (Swaisgood 2007).

In a highly social species such as the vicuña, functional family groups are key to reproductive success and population health (Koford 1957, Franklin 1974, Vilá 1992). The family group protects neonates against predators, allows females to graze without disturbance, and provides males the opportunity to mate with females of the group (Vilá and Cassini 1994). Such groups have a mean composition of 1 male, 3 females, and 2 calves and are generally stable (Vilá and Cassini 1994).

We evaluated the behavioral and demographic response of wild vicuñas to capture and shearing by quantifying the responses of vicuñas that had been shorn, and of control animals that had not been captured. Our objective was to investigate and document changes, including individual-levels and population-level changes of wild vicuñas after capture. We hypothesized that capture and shearing could cause changes in behavior, population parameters, and habitat use; these changes could potentially vary from subtle, short-term changes to persistent changes resulting from chronic stress. Some possible effects that might result from captures include changes in: 1) demographic parameters, such as increase in mortality (due to injuries that may

impede escape from predators or inability to cope with extreme temperatures once shorn) and/or decrease in birth rates (due to increased risk of abortion); 2) social behavior (due to decrease in size of family group or unusual composition); 3) habitat use (due to dispersal or avoidance of capture area); and 4) individual behavior (due to increased alarm behavior and movements, decreased parental care, etc.).

## STUDY AREA

The Cieneguillas community was located in northwest Argentina, in the Andes at 3,700 m above sea level. The study area was in the Pozuelos Biosphere Reserve (66° 15′W, 21°50′S). The climate of the region had high diurnal temperature fluctuations and frequent frosts; rainfall is seasonal (Dec to Mar) and sparse (350 mm/yr), and strong, dry winds are frequent. The study area (8,940 ha) had one of the highest densities of vicuñas in Argentina (Arzamendia and Vilá 2006, Baigún et al. 2008) because local inhabitants tolerate vicuñas grazing amongst their livestock (Arzamendia et al. 2008).

## METHODS

Our work followed the Cieneguillas Wild Vicuñas Management Plan (Vilá et al. 2003), developed to guide the capturing, shearing, and releasing of wild vicuñas to ensure compliance with animal welfare standards (Arzamendia et al. 2008). We captured vicuñas in 5 fields (2,414 ha) where they grazed with llamas (*Lama glama*) and sheep (*Ovis aries*; Arzamendia et al. 2006). Capture and handling procedures of vicuñas were approved by the Dirección Provincial de Medio Ambiente y Recursos Naturales de Jujuy, Argentina (DPMAyRN permits no. 038-03, 130-04, and 203-05). Our procedures also complied with the guidelines of the American Society of Mammalogists (Gannon et al. 2007).

We began capturing vicuñas in May 2003, in a pilot study that did not involve shearing. We started shearing captures in November 2003, 2004, and 2005. We used a capture technique that involved herding vicuña groups into a corral; people on foot surrounded the vicuñas while holding colored string ropes to create a barrier and drove the vicuñas slowly down a funnel into an enclosure (Arzamendia et al. 2008, 2010). The funnel ended in a corral divided into sub-corrals. The fenced sides of the funnel were 500 m long, with a mean height of 2 m. We sheared all captured adult male and female vicuñas that had not been shorn the previous year or had fiber long enough for shearing (>2.5 cm). We did not shear young born that year, which we released with the adults when shearing was completed. We blindfolded the vicuñas prior to handling. We recorded data on sex and age (estimated by dental eruption and wear) of the captured vicuñas. We marked vicuñas with a numbered necklace made of flexible plastic and placed a tag on 1 ear.

### Population Parameters
We calculated densities along 14 fixed-width line transects, located in the middle of each field. For each census, we drove at a speed of 10 km/hr and recorded animals within 500 m of

the central line of the transect; the total fixed width surveyed area was 89.4 km$^2$. Because our study area was an open steppe, 500 m visibility was easily achievable, and we were able to identify unmarked, marked, and shorn vicuñas. We calculated the density along each transect and then used the average of the 14 transect densities to calculate mean total vicuña density in the study area for each annual census. We conducted 5 censuses: 1999, 2000, 2002, 2004, and 2005. During our censuses we recorded the following data: 1) group type (i.e., family, bachelor group, solitary, or un-identified); 2) GPS location and distance from group of vicuñas to waypoint; 3) number of individuals per group; 4) composition of family groups (i.e., number of adult females, number of young, presence of adult male); 5) number of carcasses, which we removed; 6) identity of marked and shorn individuals from 2003 onwards; and 7) identity of marked females with calves. We determined the proportion of dead captured and non-captured vicuñas during fixed-width transect censuses. We also observed (on foot and on vehicle) marked animals post-release: daily during the first month and then monthly, while searching for carcasses.

We tested for pre- and post-capture differences on the number of vicuñas in each field, (Friedman test), and number of calves and females per family group (Kruskall–Wallis H test). To determine the effect of shearing on the proportion of young born to females, we used a chi-square test to compare the proportion of young born to captured (marked and shorn females) and non-captured females, pooling data obtained in 2004 and 2005 (Siegel 1991).

We estimated the survival probability of marked individuals in 2003, using Program MARK version 6.x (White and Burnham 1999, Cook and White 2011). We used the joint live and dead model developed by Burnham (1993) to calculate: $S$ (survival probability), $p$ (recapture probability), $r$ (recovery probability; the probability of being found dead and reported), and $F$ (fidelity probability; the probability of remaining in the sample area). We assessed the goodness-of-fit for this model using a parametric bootstrap procedure available in Program MARK. We based the model selection on a quasi-likelihood corrected version of Akaike's Information Criterion (QAIC$_c$) with small-sample correction. We assessed relative strength of each model through QAIC$_c$ weights, and QAIC$_c$ differences ($\Delta$QAIC$_c$; White et al. 2001, Burnham and Anderson 2002).

### Behavioral Study
We collected behavioral data between May 2002 and February 2005 on a vicuña population of about 200 individuals in a 1,145 ha portion of the Biosphere Reserve. We sampled 6–10 days per season (fall, winter, spring, and summer). We increased the sampling intensity after the 2003 captures (i.e., on a daily basis for 2 weeks after capture and 1 week every month for 6 months thereafter). We observed the behavior of marked animals from the first day after their release.

We monitored individuals marked in 2003 ($n = 98$) for up to 2 yr after capture. These vicuñas constituted 2 sampling groups: the captured group, ($n = 43$ vicuñas captured and

marked in May), and the shorn group ($n = 75$ vicuñas captured, shorn and marked in Nov 2003 [55 were marked for the first time in the Nov capture and 20 had been recaptured]). We had a control group of about 100 individuals that we did not capture or shear and which we observed in each season for 3 yr (from Apr 2002 to Feb 2005).

Seasonally (in fall, winter, spring, and summer), we made daily observations between 0800 hr and 2000 hr. We evenly distributed observations among 4 intervals (0800–1100 hr, 1100–1400 hr, 1400–1700 hr, and 1700–2000 hr). We used focal animal sampling (Martin and Bateson 1986) with 1,731 samplings of 15 min. We recorded standardized behaviors (i.e., grazing, standing, alert, walking, running, lying, grooming, suckling, and other) described in Arzamendia and Vilá (2006). We also recorded events, which included vocalization, excretion, and aggression. Each behavioral datum referred to the number of minutes in which a particular behavior occurred during a 15 min sampling period. On each day, we randomly chose the focal animals from the vicuñas that were visible. We classified individuals by sex, age, social group (family male, females, calves, bachelors, and solitary), and the management group (i.e., control, treatment). We did not sample the same individual more than once per day.

We used a log-ratio transformation (Elston et al. 1996) of the response variable (proportion of time spent grazing and walking) to analyze the changes in behavior among seasons and to test for the effects of capture and shearing management. Grazing and walking were the most frequent behaviors observed, and these behaviors contribute importantly to fitness. Therefore, they were useful indicators of possible effects of capture and shearing (Vilá and Cassini, 1994). We used a ratio that relates both behaviors in a log-ratio transformation (LGW; $Log_e$ [proportion of time spent grazing/ proportion of time spent walking]). To deal with zeros in the log-ratio transformation, we replaced them by half the minimum of time recorded in one behavior (0.5 min), and we subtracted the same value from the other term of the ratio (Elston et al. 1996).

We analyzed the effect of season, sex, and management on behavior (LGW) using the Residual Maximum Likelihood (REML) method, which provides efficient estimates of treatment effects in unbalanced designs (Horgan and Hunter 2000). Residual Maximum Likelihood tests each term using the Wald statistic, which has an asymptotic $\chi^2$ distribution with degrees of freedom equal to those of the fixed model term. We performed statistical analyses using GENSTAT 6 (Horgan and Hunter 2000). Our visual inspection of the residuals indicated that the log-ratio transformed data met the criterion of homoscedasticity and normality necessary for this analysis. The model included the following fixed effects: season, sex, management, and the interactions among them. We considered animal ID and samples (at different times of the day) random effects. We identified differences between treatments using least significant differences (LSD) at the $P \leq 0.05$ level (Snedecor and Cochran 1980).

To study the frequency of suckling (proportion of minutes of suckling during each focal observation), we compared shorn and control group mothers using a 2-factor analysis of variance (ANOVA). The factors were: season and management. To evaluate the frequency of the alert behavior in relation to sex, social group, management (control vs. treatment), and the time since the capture event, we conducted an ANOVA where the dependent variable was the number of occurrences of the alert behavior during focal observation, after rank transformation (Shirley 1987). Given that the distance to neighboring groups and group size can influence the behavior of males, we conducted an analysis of covariance (ANCOVA), including distance to other groups and the size of the group as covariates. We also analyzed the variation of lying behavior (proportion of minutes/focal, with rank transformation) with an ANCOVA (Shirley 1987), including the same factors as above.

## RESULTS

### Population Effects of Management
Censuses that took place before the captures occurred (i.e., from 1999 to 2002) indicated a population size of 1,020 vicuñas at a mean density of $11.91/km^2$ (Table 1). Captures took place in fields that initially had a density higher than the average (i.e., maximum 40 vicuñas/$km^2$). In capture areas, pre- (2002) and post-capture (2004 and 2005) censuses were similar ($T^2 = 1$, $P = 0.44$, $n = 3$). The same pattern was evident for non-captured groups ($T^2 = 1.52$, $P = 0.24$, $n = 12$; Table 1).

The social composition of the groups (number of females and calves in the family groups) was similar between pre- and post-capture censuses. In 2003, we observed a mean of 1 male, 2.4 (SE 0.31) females, and 1.8 (SE 0.35) calves in the pre-capture groups and 1 male, 2.3 (SE 0.35) females, and 1.31 (SE 0.2) calves in the post-capture groups (Kruskall–Wallis H test, calf $H = 6.44$, $P = 0.12$, $n = 56$; F $H = 3.75$, $P = 0.41$). In 2004, we observed a mean of 1 male, 2.57 (SE 0.33) females, and 1.43 (SE 0.25) calves in the pre-capture groups and 1 male, 2.67 (SE 0.28) females, and 1.43 (SE 0.23) calves in the post-capture groups (calf $H = 4.32$, $P = 0.09$; F $H = 1.25$, $P = 0.51$, $n = 48$; Fig. 1). There was no difference in the number of young per female between captured and non-captured females (Tables 1 and 2; $\chi_1^2 = 0.01$, $n = 565$, $P = 0.94$). We captured and marked 27 individuals from a group of 27–30 bachelor males in the 2003 capture, and they remained nearby of the capture site. Bachelor groups ($n = 6$) had a similar mean group size of 14.43 (SE 3.33; min = 5; max = 27) individuals before and after the 2004 capture ($H = 0.05$; $P = 0.47$).

We captured 364 vicuñas, marked 266, and recaptured 86 between May 2003 and November 2005. We identified 93% of marked vicuñas, which remained in the same areas where the 2003 and 2004 captures occurred. During the first month after the 2003 shearing, we found 98% of the marked vicuñas in 20 social groups (family, bachelors, and solitary), including some with unmarked vicuñas, which returned to the same

**Table 1.** Population of vicuñas at Cieneguillas, Jujuy, Argentina, 1999–2005. Density/field (vicuñas/km$^2$), total number of vicuñas, survey area, young, and young/female per year.

| Field/transect | 1999 | 2000 | 2002 | 2004 | 2005 |
|---|---|---|---|---|---|
| 1 | | | 7.39 | 7.65 | 7.31 |
| 2 | | | 25.64 | 14.65 | 20.15[a] |
| 3 | 9.09 | 8.56 | 10.16 | 11.10 | 9.63 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | | | 8.71 | 1.72 | 7.48 |
| 6 | 6.64 | 4.29 | 10.52 | 4.70 | |
| 7 | 5.87 | 5.87 | 6.44 | 8.46 | 4.52 |
| 8 | 5.76 | | 10.40 | 4.34 | 4.44 |
| 9 | 8.96 | 20.75 | 31.60 | 39.62 | 55.66[a] |
| 10 | 9.11 | 21.01 | 24.81 | 29.37[a] | 32.66[a] |
| 11 | 13.5 | 14 | 20.88 | 24.13[a] | 18.63 |
| 12 | | | 23.10 | 20.97 | 14.59 |
| 13 | | | 5.89 | 3.37 | 0.00 |
| 14 | | | | 9.26 | 13.76 |
| Total vicuñas/yr | 414 | 406 | 1,020 | 954 | 910 |
| Area | 54.08 | 44.18 | 85.96 | 93.3 | 83.51 |
| Mean density | 7.7 | 9.2 | 11.9 | 10.2 | 10.9 |
| Mortality rate of non-captured vicuñas | | | 0.7 | 1.0 | 0.8 |
| Number of young | 35 | 87 | 179 | 146 | 147 |
| Young/female | 0.71 | 0.70 | 0.59 | 0.53 | 0.51 |

[a] Post-capture census.

territory. The marked animals captured twice (in May and Nov 2003), also returned to their original groups. These animals belonged to 3 family groups (mean size: 1 male, 3 females, 1.33 calves) and 1 group of 27–30 bachelor males. Some marked bachelors (7.5%) dispersed to other areas, up to 20 km away. We registered 12 vicuñas dead between May 2003 and Nov 2005. We found 3 calves (1 marked and 2 probably captured) killed, presumably by a red fox (*Pseudalopex culpaeus*), and 2 marked animals (female and male) killed by a puma (*Puma concolor*). We found 1 marked female dead at a watering site, 2 marked males killed by humans, and 4 marked vicuñas died from unknown causes.

To estimate survival probabilities of marked vicuñas in 2003, we carried out an initial analysis fitting the time-dependent joint live and dead model {S(t) p(t) r(t) F(t)}, in which all parameters are time-specific (Table 3). The parametric bootstrap, goodness-of-fit test provided evidence that the model failed to represent the data adequately ($P < 0.002$); therefore, we based model selection on QAIC$_c$. The top model {S(.) p(t) r(.) F(.)} had approximately 7 times more support in data than the second-ranked model {S(.) p(t) r(.) F(t)} (Table 3). The top 2 models comprised 92% (0.804 + 0.116) of the support, and both had S(.) for survival parameter and a time dependent recapture probability in common (Table 3). Thus, we might conclude there was no considerable evidence of a difference in survival in the time, but recaptured probabilities appeared to vary among sampling occasions (Fig. 2). The monthly survival probability was (0.9973 ± 0.0013) and annual survival was 97 ± 0.002%.

## Capture Effects on Behavior

Season, sex, and management had a significant effect on grazing versus walking behavior (LGW) with no detectable interactions among the 3 factors (Table 4). Males grazed less (62% the activity budget) than females (67%) independently of season, and management (Table 4). We found other differences among seasons (Table 4). For the control group in the second year, we observed the highest LGW value in spring (Fig. 3). Among years, we found differences in the LGW of the control group in the fall of the first and the third years. We also found an interaction between season and management and differences for the management factor (Table 4). In the spring of 2003, the captured group had the lowest LGW, (6 months after capture and before re-capture). Also, the shorn group showed a significant decrease in LGW relative to the control group, in the first survey after shearing, which increased to a similar value in the subsequent seasons (Fig. 3).
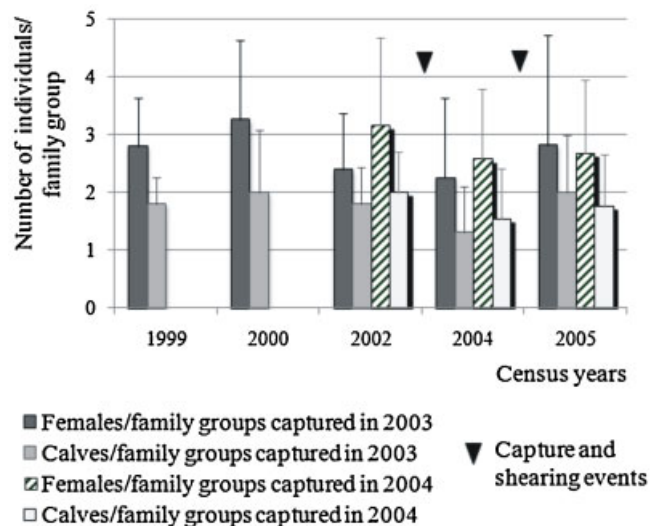


**Figure 1.** Mean number of females and calves of vicuñas per family group before and after capture and shearing events of 2003–2004, in Cieneguillas, Jujuy, Argentina.

**Table 2.** Number of captured and shorn and non-captured female vicuñas with and without young in Cieneguillas, Argentina in 2004 and 2005.

| Management | Without young | Young | Total | Young/female |
|---|---|---|---|---|
| Captured and shorn females | 67 | 73 | 140 | 0.521 |
| Non-captured females | 205 | 220 | 425 | 0.517 |
| Total | 272 | 293 | 565 | |

**Table 3.** Results of analysis of data from vicuñas marked in 2003 in Cieneguillas, Argentina using both live and dead encounters (Burnham) model, and model selection based on quasi-likelihood corrected version of Akaike's Information Criterion (QAIC$_c$).

| Model[a] | QAIC$_c$ | ΔQAIC$_c$ | QAIC$_c$ weights | Model likelihood | $K_i$ | QDeviance |
|---|---|---|---|---|---|---|
| {S(.) p(t) r(.) F(.)} | 672.754 | 0.000 | 0.8028 | 1.000 | 17 | 246.841 |
| {S(.) p(t) r(.) F(t)} | 676.608 | 3.854 | 0.1169 | 0.146 | 29 | 225.466 |
| {S(.) p(.) r(.) F(.)} | 678.250 | 5.496 | 0.0514 | 0.064 | 4 | 278.949 |
| {S(.) p(.) r(.) F(t)} | 679.738 | 6.984 | 0.0244 | 0.030 | 17 | 253.825 |
| {S(.) p(t) r(t) F(.)} | 683.553 | 10.799 | 0.0036 | 0.005 | 29 | 232.411 |
| {S(t) p(t) r(.) F(.)} | 687.962 | 15.209 | 0.0004 | 0.001 | 31 | 232.551 |
| {S(.) p(.) r(t) F(.)} | 689.599 | 16.846 | 0.0002 | 0.000 | 16 | 265.760 |
| {S(t) p(.) r(.) F(.)} | 690.607 | 17.854 | 0.0001 | 0.000 | 18 | 262.617 |
| {S(.) p(t) r(t) F(t)} | 690.974 | 18.220 | 0.0001 | 0.000 | 41 | 213.939 |
| {S(t) p(t) r(.) F(t)} | 693.018 | 20.264 | 0.0000 | 0.000 | 43 | 211.600 |
| {S(.) p(.) r(t) F(t)} | 693.358 | 20.605 | 0.0000 | 0.000 | 29 | 242.216 |
| {S(t) p(.) r(.) F(t)} | 695.370 | 22.617 | 0.0000 | 0.000 | 31 | 239.960 |
| {S(t) p(t) r(t) F(.)} | 696.321 | 23.568 | 0.0000 | 0.000 | 41 | 219.286 |
| {S(t) p(.) r(t) F(.)} | 701.134 | 28.381 | 0.0000 | 0.000 | 29 | 249.992 |
| {S(t) p(t) r(t) F(t)} | 701.840 | 29.086 | 0.0000 | 0.000 | 47 | 211.600 |
| {S(t) p(t) r(t) F(t)} | 701.840 | 29.086 | 0.0000 | 0.000 | 47 | 211.600 |
| {S(t) p(.) r(t) F(t)} | 703.964 | 31.210 | 0.0000 | 0.000 | 35 | 239.960 |

[a] S (survival probability), p (recapture probability), r (recovery probability; the probability of being found dead and reported), and F (fidelity probability; the probability of remaining in the sample area). For each model: $K_i$ is the no. of parameters in the model, ΔQAIC$_c$ is the change in Akaike's Information Criterion with small-sample correction (QAIC$_c$) between the model and the model with the lowest QAIC$_c$ (best model), model likelihood is the QAIC$_c$ weight for the model of interest divided by the QAIC$_c$ weight of the best model.

For alert behavior, we found interactions between season and sex ($n = 1,218$, $F_{14} = 2.74$, $P \leq 0.001$), and season and management ($n = 1,218$, $F_{13} = 1.75$, $P = 0.046$). The males in family groups showed the highest frequency of alert behavior (Fig. 4). The distance between neighboring groups ($n = 103$, $F_1 = 2.22$, $P = 0.14$) and family group size ($n = 398$, $F_1 = 2.01$, $P = 0.16$) did not influence the alert



**Figure 2.** Parameters estimated for survival analyses of vicuñas marked in 2003 using the live and dead model {S(.) p(t) r(.) F(.)} where t represents a time-dependent variable and (.) constant over time variable (SE, corrected for overdispersion with a variance inflation factor $\hat{c} = 1.485$). The sampling occasions occurred in different month–time intervals between May 2003 and November 2005, in Cieneguillas, Jujuy, Argentina.

response of males in family groups. There were interactions between season and management for alert behavior of males ($n = 398$, $F_8 = 2.2$, $P = 0.04$); for the winter and spring of 2004, the control group recorded higher alert frequency (Fig. 4). Alert behavior varied among seasons for female vicuñas ($n = 595$, $F_7 = 9.51$, $P \leq 0.001$), but not with management ($n = 595$, $F_2 = 2.3$, $P = 0.101$); there was no interaction between these factors ($n = 595$, $F_7 = 0.95$, $P = 0.46$; Fig. 4). The bachelors showed seasonal variation in alert behavior ($n = 215$, $F_7 = 2.13$, $P = 0.04$); by fall 2003 the control group recorded higher alert frequency ($\bar{x} = 12$, SE $= 1$) than the captured group ($\bar{x} = 2.56$, SE $= 1.2$; $F_{2,12} = 8.27$, $P = 0.02$), and we observed an opposite trend by summer 2005 (alert for control bachelors: $\bar{x} = 1.25$, SE $= 0.5$, and alert for shorn bachelors: $\bar{x} = 7.17$, SE $= 1.7$, $F_{2,14} = 6.04$, $P = 0.03$).

Lying behavior varied between the sexes, among social groups, and between management treatments. There were also interactions among these factors ($n = 1,218$, $F_4 = 2.5$, $P = 0.04$). The time animals were lying did not vary among seasons for males in family groups ($n = 401$, $F_7 = 0.6$, $P = 0.76$) but it did vary with management ($n = 401$, $F_2 = 5.2$, $P = 0.006$). The control males lay more than the shorn males ($n = 401$, $F_7 = 0.6$, $P = 0.76$; Fig. 5). Bachelors did not show differences in the time spent lying ($\bar{x} = 10.03$, SE $= 1.77$% of activity budget) between management treatments ($n = 222$, $F_7 = 2.7$, $P = 0.07$) or among seasons ($n = 222$, $F_7 = 0.8$, $P = 0.61$). However,
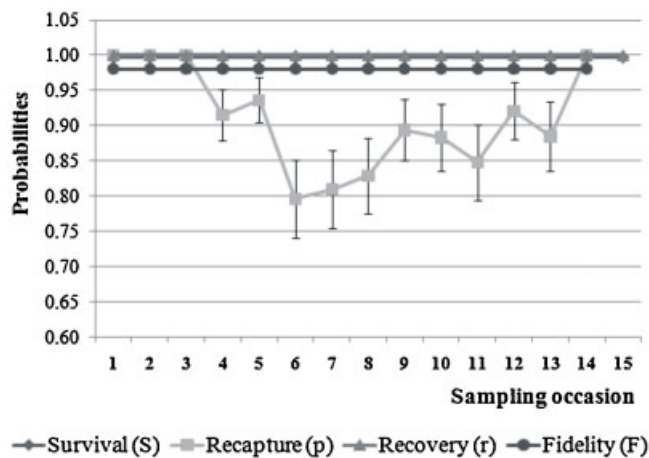
**Table 4.** Results of Residual Maximum Likelihood (REML) analyses testing the effect of seasons, sex, and management (capture and shearing) on the LGW, $\text{Log}_e$ (proportion of time spent grazing/proportion of time spent walking), for a population of vicuñas in Cieneguillas, Jujuy, Argentina in 2003–2005.

| Fixed terms | df | $\chi^2$ | P |
|---|---|---|---|
| Season | 11 | 2.17 | 0.013 |
| Sex | 1 | 14.57 | <0.001 |
| Management | 2 | 4.86 | 0.008 |
| Season × sex | 11 | 1.20 | 0.277 |
| Sex × management | 2 | 1.14 | 0.319 |
| Season × management | 7 | 3.13 | 0.003 |
| Season × sex × management | 7 | 0.79 | 0.599 |

females from the control group lay more during the winter of 2004 ($n = 41$, $F_1 = 11.37$, $P = 0.002$; Fig. 5).

There were seasonal differences in the time assigned to suckling ($F_{6,439} = 14.89$, $P < 0.001$), peaking in summer ($\overline{x} = 18.97$, SE = 5.36% of activity budget) and fall ($\overline{x} = 1.82 \pm 0.83\%$). Suckling was not different between the control group and the shorn group ($F_{2,439} = 0.34$, $P = 0.71$).

## DISCUSSION

### Population Effects of Management

The impact of any manipulation in a wild species is mediated by the way it is performed. Differential animal welfare standards (that include the minimization of animals stress and pain) can explain many of the different outcomes, failures, and successes of most vicuña captures that have occurred across the Andes (Gimpel and Bonacic 2006). We demonstrated some minor impacts of captures, mainly because we worked under a strict animal welfare framework (Vilá 2006, Arzamendia et al. 2010). Vicuñas were not displaced by capture, which can be a nuisance and can prompt erratic movements, as seen in other species. Red deer (*Cervus elaphus*) and moose (*Alces alces*) required up to 1 week to

return to their normal ranges (Jeppesen 1987, Andersen et al. 1996).

Birth rates of the control and shorn vicuñas were similar, and both showed a consistent population increase, reaching a stable density (Arzamendia and Vilá 2006). Sahley et al. (2007) obtained similar results in Peru for the northern vicuña subspecies (*V. vicugna mensalis*).

Social composition was resilient; capture did not affect the size and composition of social groups, which are important factors for population persistence (Caro 1998). However, in other vicuña captures (Gimpel and Bonacic 2006, Sarno et al. 2009), researchers detected pronounced and lasting effects on family group composition that were probably caused by the use of vehicles in the chase, a technique that we chose not to use. (Bonacic et al. 2006, Arzamendia et al. 2010). Bachelor groups that include the future breeding males are a reserve of genetic diversity essential for the population health (Arzamendia 2008). Individual members of these groups showed the greatest dispersal distances. Our results led us to conclude that assuming these males are in excess (e.g., many projects suggest castration or elimination of these individuals; Lichteinstein and Vilá 2003) was not justified.

It is often difficult to discriminate between capture induced mortality and natural mortality, especially relative to predation deaths (Gimpel and Bonacic 2006). Studies on
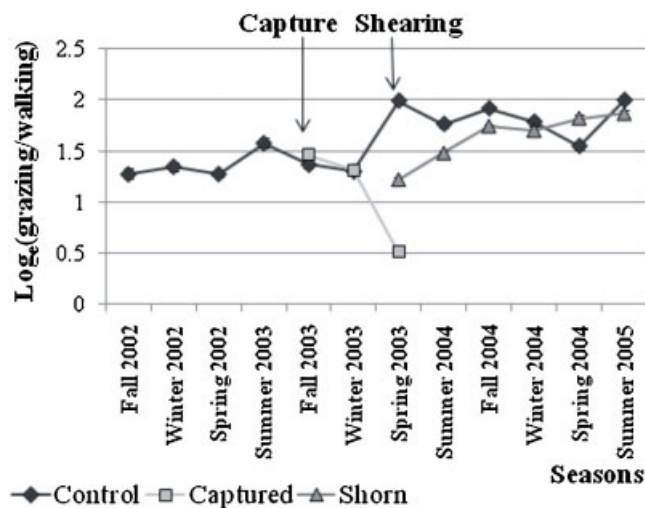


**Figure 3.** Variation in the LGW, $\text{Log}_e$ (proportion of time spent grazing/proportion of time spent walking), for the control group and treatment groups (captured and shorn) of vicuñas, in Cieneguillas, Jujuy, Argentina, 2002–2005.
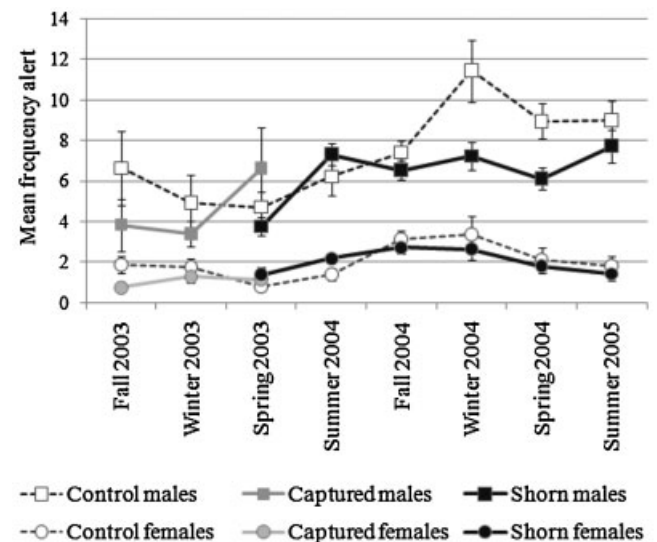


**Figure 4.** Variation of the mean frequency in alert behavior for the control, captured, and shorn family males and female vicuñas, in Cieneguillas, Jujuy, Argentina, 2003–2005.
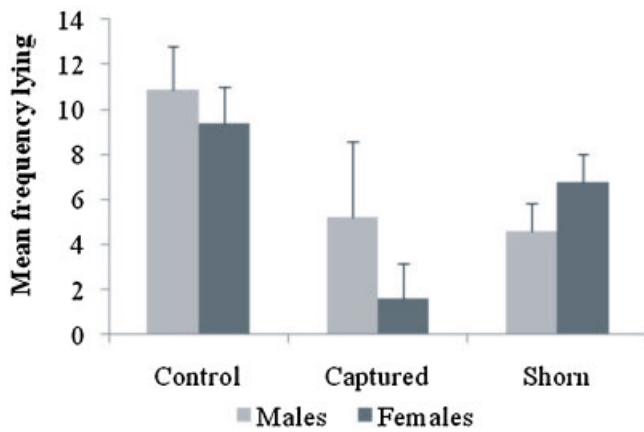
**Figure 5.** Variation of the mean frequency in lying behavior, for the control, captured, and shorn family males and female vicuñas, in Cieneguillas, Jujuy, Argentina, 2003–2005.

white-tailed deer (*Odocoileus virginianus*) hypothesized that capture myopathy was the cause of death within the month following capture (Beringer et al. 1996). Mortalities after capture can also be attributed to other natural factors, rather than to the capture itself (Gimpel and Bonacic 2006). In most reports of wild vicuña management, capture mortality has been underestimated or absent. Based on sparse data, mortality during the captures has varied between 0% and 12% (Bonacic et al. 2006, Gimpel and Bonacic 2006) and has been influenced by the time of year, capture method, and welfare protocols. Strategies to reduce negative capture consequences include reduction in the speed of chase and the total duration of captures (Bonacic et al. 2006), which was the approach we took. Natural mortality of vicuña populations typically varies from 3.3% to 21.4% (Franklin 1982, Hofmann et al. 1983, Glade and Cattán 1987). Therefore, our result with an estimated annual survival rate of 97% constant in time, suggested that capturing and shearing under strict animal welfare protocols did not appreciably increase total annual mortality.

### Effects on Behavior

All the published papers which have measured male and female time budgets, reported that females forage more than males (Koford 1957, Franklin 1974, Bosch and Svendsen 1987, for a review Vilá and Cassini 1994). We found the same pattern regardless of the existence and type of management. Also, sex differences in displacement and feeding behavior were similar in the population relative to management. In the unmanaged vicuñas, we observed an increase in feeding time in 2003 and 2004, relative to 2002, associated with a decrease in vegetative cover (Arzamendia et al. 2006). Some differences between control animals and captured animals might also be explained as the consequence of effects of human infrastructure construction in the same area as the November shearing captures.

Loss of pelage due to shearing and capture impacts can explain most of the observed changes. Camelids have thermal windows in the bare areas of their axillaries and flank regions, and lying behavior modifies the exposure of those areas,

providing a mechanism for these animals to mitigate for changes in wind speed and temperature. As studied in the other wild South American camelid species, the Guanaco (*Lama guanicoe),* lying is one behavioral mechanism for thermoregulation used to decrease convective heat loss (de Lamo et al. 1998). Shorn animals had increased thermal windows, so it would be expected that they would compensate for heat loss by increased movement (Wilson 1989). Even though changes in lying and walking behavior have been characterized as stress indicators (Swaisgood 2007), the duration of the changes we noted were short enough not to mediate substantive additional risk to the vicuñas. Behavioral changes for managed animals were of equivalent magnitude to seasonal changes and other changes produced by stochastic events (such as drought) seen in the control group.

## MANAGEMENT IMPLICATIONS

Our results show that capture, handling, and live shearing of vicuñas in spring and under the application of strict animal welfare conditions can be biologically sustainable. It is important to address that we conducted this study in a period of normal precipitation and in drought times it is probable to have additional thermal and nutritional stresses. If we care enough about precautionary and welfare aspects, we can assume that captures for shearing can be considered a conservation option for vicuña that could maintain ecologically functional populations of wild vicuña in the Puna.

## ACKNOWLEDGMENTS

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