

# Mortality Date Estimation Using Fetal Pronghorn Remains

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**ABSTRACT** Pronghorn (*Antilocapra americana*) fetal remains are sometimes recovered from archaeological contexts. Pronghorn have consistent reproductive schedules so their remains may provide information on seasonality of site occupation and number of mortality events. To investigate the reliability of fetal remains for seasonality and mortality event assessment, bone size and tooth eruption were measured in a sample of modern fetal pronghorn remains with known mortality dates. Results indicate a strong correlation between bone size and mortality date, but no significant correlation between tooth eruption level and mortality date. Fetal bone size was used to estimate a late April or early May mortality date at both the Oyster Ridge (48UT35) and Trappers Point (48SU1006) archaeological sites. The number of mortality events at Trappers Point was also investigated. Copyright © 2007 John Wiley & Sons, Ltd.

*Key words:* pronghorn antelope; fetus; mortality event; Trappers Point; Oyster Ridge

## Introduction

Pronghorn (*Antilocapra americana*) bones are commonly included in faunal assemblages from archaeological sites in western North America (Walker, 2000; see also Faunmap, 2006). Occasionally, remains of fetal pronghorn are recovered. Modern pronghorn have consistent, predictable reproductive cycles, with birth occurring around the same dates every year (Byers & Hogg, 1995; Byers, 1997: 26; O'Gara, 2004: 291). Therefore, assuming consistent fetal growth rates, the size of recovered fetal remains should correlate with mortality dates of the fetuses and their mothers. These mortality dates provide insight into site occupation seasonality and perhaps the number of mortality events included in the assemblage.

Currently, estimation of archaeological pronghorn fetus mortality dates relies on either visual or quantitative comparisons with a limited sample of modern pronghorn fetuses or newborns (Davis & Fisher, 1990; Miller, 1999; Davis *et al.*, 2000). This report provides quantitative assessments of relationships between bone size, tooth eruption and mortality dates based on a sample of 153 modern fetal pronghorn remains with known mortality dates. These assessments are used to investigate season of occupation at the Oyster Ridge (48UT35) and Trappers Point (48SU1006) sites in Wyoming. The number of mortality events at Trappers Point is also analysed.

## Pronghorn gestation

Day of year calculation from fetal remains relies upon a consistent mating period and fetal growth rate. Unfortunately, these are difficult parameters to measure in wild animal populations. Birth date,

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on the other hand, is relatively easy to collect and is necessarily correlated with both date of conception and fetal growth rate. Therefore pronghorn parturition research will be reviewed to assess the consistency of calendar day/fetal size correlations. However, it is important to keep in mind that variation in birth date involves more than conception date and fetal growth rate variability. In particular, it includes variability in the length of gestation, which in ungulates is correlated with both neonate body mass and fetal growth rate (Sæther & Gordon, 1994). This suggests that some of the variability in birth date is due to gestation length differences that occur after a particular pre-natal calendar day. For instance, on a particular day in April two pronghorn may have fetuses with identical size characteristics, but they still may have differing parturition dates because one mother is able to carry her fetuses to a larger size and a later date. Thus variability in parturition dates probably overstates the variability in pre-natal size/date correlations.

Birth synchrony in pronghorn is thought to be a response to predation on neonates (Gregg *et al.*, 2001; O'Gara, 2004: 290). The simultaneous birth of many pronghorn limits the number which predators can attack before the neonates develop sufficient strength to outrun them. A number of researchers have investigated the synchrony and duration of the pronghorn birthing season. O'Gara (2004: 290) indicated that throughout most of the pronghorn's range 'the majority are dropped within a 10-day period'. Twenty-five birth dates recorded by Autenrieth & Fichter (1975: 16) from 1959 to 1973 in Idaho varied from 21 May to 5 June, a 15-day period. Gregg *et al.* (2001) found that pronghorn on the Oregon plains had 12- or 13-day birthing seasons, with peak fawn drop occurring over four or five days in late May. Fairbanks (1993) studied pronghorn parturition in Middle Park, Colorado, from 1988 to 1990. She found 17-day fawning seasons in 1988 and 1989, and a 21-day season in 1990. Finally, Hoover *et al.* (1959) studied pronghorn on Colorado's plains, and found the fawning season to vary from seven to 24 days, with an average of 11 days on the southern Colorado plains and 15 days on the northern Colorado plains. They found the average birthing start date in the

northern plains is 29 May, with an average end date of 11 June.

These studies suggest a fairly tight two- to three-week fawning season beginning in late May or early June. However, caution is needed when applying this to archaeological remains. Firstly, July and even August births occasionally occur due to fawn or yearling pregnancies or a second oestrus in females that did not conceive during their normal oestrus period (O'Gara, 2004: 291). While these births are unusual, they could result in a misleadingly early fetal development date if found in archaeological contexts. Therefore, single outliers should be treated with caution.

A second caution is applicable when the analysis involves pronghorn remains from the Pleistocene or early Holocene. It is possible that pronghorn size has diminished since the end of the Pleistocene epoch. Adams *et al.* (1999) suggested that adult Early Archaic pronghorn from Trappers Point may have been 3–8% larger than modern pronghorn. Chorn *et al.* (1988), however, found few significant size differences between modern pronghorn and Late Pleistocene *A. americana* from Wyoming's Natural Trap Cave. Thus pronghorn size reduction remains an open issue; furthermore, it is not clear whether post-natal adult size differences would imply a pre-natal size change. It is likely that much of the size difference would be due to post-natal growth differences and extended gestation length. While a temporal size difference would increase uncertainty in using modern samples to estimate Pleistocene or early Holocene archaeological mortality dates, it seems unlikely that small differences in adult size would significantly affect fetal sizes.

A final concern is that the fawning season appears to be correlated with precipitation and temperature. Byers & Hogg (1995) found pronghorn gestation length to be correlated with amount of precipitation during the previous summer; wetter summers resulted in faster prenatal growth and reduced gestation length. However, the longest mean gestation length was only five days longer than the shortest mean gestation length. A more serious concern for our purposes is temperature-related variability. Pronghorn living in the southern end of their range exhibit earlier and longer fawning seasons.

Canon & Bryant (1997) found that pronghorn in Trans-Pecos Texas had a fawning season that lasted from April to June, with most births occurring in May. In the Sonoran desert, Bright & Hervert (2005) found that fawning begins in late February and lasts until mid-April. Therefore the date estimation equations developed in this study, which are based on pronghorn samples from Wyoming, are likely to be both late in the calendar year and less precise when applied to samples from much warmer and drier climates.

Nevertheless, the consistency of pronghorn birthing seasons within the northern portion of its range suggests that most pronghorn in that area are born within 21 days starting in late May. As previously discussed, this period likely over-estimates pre-natal size variability. The issue of date estimation precision is revisited following presentation of the estimation technique and results.

## Samples and methods

The modern fetal pronghorn sample mortality dates (Table 1) span the calendar period from 11 January to 16 May, although most are concentrated in late April and early May. Some samples were collected in 1981 and 1993, but most date from 2000 and 2001. Sample locations include eastern and central Wyoming, and represent a range of High Plains grass and sage ecosystems. These fetal pronghorn remains are curated in the

Table 1. Modern fetal pronghorn sample mortality locations and dates

Mortality location (Wyoming)	Mortality day <sup>a</sup>	<i>n</i>
Cheyenne area	26 April 2000	5
	9 May 2001	32
Como Ridge	22 February 1993	2
Gillette area	16 May 2000	16
	7 May 2001	25
Horse Creek area	11 January 1981	2
	10 May 2000	29
Rawlins area	4 May 1981	7
Shirley Basin	5 May 2000	16
	13 May 2001	19
Total		153

<sup>a</sup>For most locations, the mortality day is the later of two consecutive days recorded as the mortality date. The Como Ridge date is an estimate based on circumstances surrounding discovery of the remains.

University of Wyoming Comparative Osteology Museum. No animals were sacrificed specifically for this study.

Long bones, scapulae, mandibles and calcanei of modern fetal pronghorn specimens with known mortality dates were measured by the senior author using digital callipers (Table 2, Figure 1). Damaged bones were excluded. The  $R^2$  correlation coefficients and F-statistic significance of the regression between mortality date and fetal size were assessed. Measures with  $R^2$  values less than 0.60 or F-statistic significance estimates above 0.05 were rejected. Measures with  $R^2$  values between 0.60 and 0.80 (and significant F-statistic values) were accepted, but should be considered marginal due to the apparent

Table 2. Measurements performed on modern fetal pronghorn bone samples

Element	Measurement <sup>a</sup>	Abbreviation <sup>b</sup>
Calcaneus	Maximum length	LCML
Femur	Maximum length	LFML
	Minimum width	LFMW
	Length from proximal end to first foramen	LFFL
Humerus	Maximum length	LHML
	Minimum width	LHMW
	Length from proximal end to first foramen	LHFL
Mandible	Eruption of premolar 1 (similar for premolars 2 and 3)	LDP1
	Maximum width	LMMW
	Maximum tooth row width	LMMTW
	Maximum tooth row length	LMMTL
	Maximum length	LRML
Radius	Minimum width	LRMW
	Maximum length	LSML
Scapula	Maximum width (proximal 'fan' surface)	LSMW
	Distal articulation surface maximum length	LSDL
	Distal articulation surface maximum width	LSDW
	Minimum neck width	LSMNW
Tibia	Maximum length	LTML
	Minimum width	LTMW

<sup>a</sup>Lengths include the articulation surfaces present on fetal bones, but exclude the unattached epiphyses. Because bones are not perfectly cylindrical, width measurements often required rotating the bone and performing several measures to ensure a minimum value was obtained. The scapula distal articulation surface is roughly oval; lengths were measured across the long axis of the surface, and widths across the shorter axis.

<sup>b</sup>Abbreviation shown for the left element. To obtain the abbreviation for right elements, substitute an 'R' for the initial 'L'.

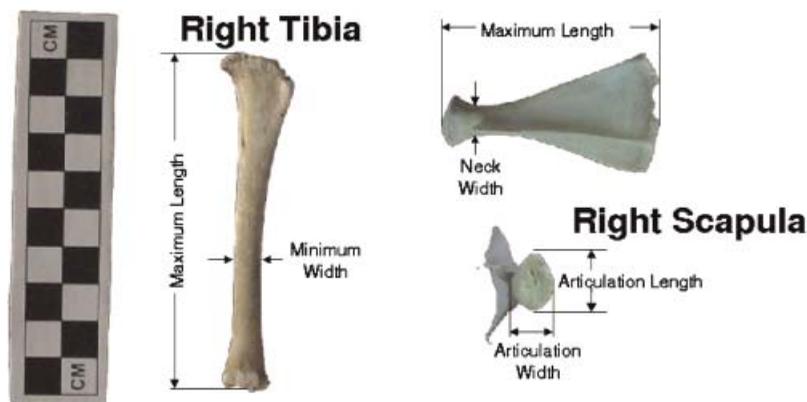


Figure 1. Example measurements: both the tibia and scapula are from a pronghorn fetus collected on 7 May 2001, near Gillette, Wyoming. This figure is available in colour online at [www.interscience.wiley.com/journal/oa](http://www.interscience.wiley.com/journal/oa).

influence of non-date-related size influences. Measures with  $R^2$  values above 0.80 and significant F-statistic values are considered fully acceptable. For acceptable measurements, regression equations were estimated using the curve fit function of SPSS version 14. As described in the results section below, the internal accuracy of these equations were investigated using nonparametric bootstrap resampling to establish the 95% confidence interval for various subsample sizes. Intraobserver error was assessed by blind repeat measurements on all elements of five fetuses. Overall, intraobserver error was  $0.18 \pm 0.34$  mm. As expected, more variation is present on length measurements ( $0.20 \pm 0.31$  mm) than on the smaller width measurements ( $0.06 \pm 0.08$  mm).

Tooth eruption patterns are often used to estimate pronghorn post-natal age (e.g. Nimmo, 1971; Lubinski, 1997, 2001; Miller, 1999; Frison, 2000). Deciduous teeth begin to form and emerge before birth, so deciduous eruption patterns may correlate with gestation age, and therefore with mortality date. To investigate this, eruption levels of the three deciduous premolars present in the fetal pronghorn mandible were recorded for the modern fetal pronghorn sample, using a slightly modified version of Lubinski's (2001: 221) eruption scoring system.<sup>1</sup> Missing or broken

<sup>1</sup>Lubinski's (2001: 221) code 'Z' was modified to include the case where the dental crypt is open but the tooth is not present and the socket has not formed. This is the case early in fetal pronghorn life. To aid quantitative analysis, Lubinski's codes of Z, C, V, 1, 2, 3 and 4 were converted to numerical values 0 to 6, respectively.

teeth were excluded. As with bone size data, the  $R^2$  correlation coefficients and F-statistic significance level of mortality date versus eruption level were then assessed.

## Results of analysis of the modern fetal sample

Boxplots of humerus length for each mortality date sample set (Figure 2) show a pattern typical for each of the measures. There is considerable overlap of bone sizes among fetuses. This is expected for samples with mortality dates separated by only a few days. The Day 127 specimens (a 4 May 1981 sample of seven pronghorn fetuses from the Rawlins area) seem slightly larger than expected given their mortality date and the pattern seen in other samples. The size difference may be an artefact of the relatively small Day 127 sample size, or could be environmentally or genetically based. The general overlap and this out-of-pattern sample indicate that caution should be applied when assigning mortality dates to archaeological samples, particularly when only small sample sizes are available (see discussion below). Nevertheless, the overall pattern clearly supports a correlation between mortality date and bone size.

Size versus day-of-year  $R^2$  correlations for 24 element measures exceeded 0.80, and an additional four measures had marginally accep-

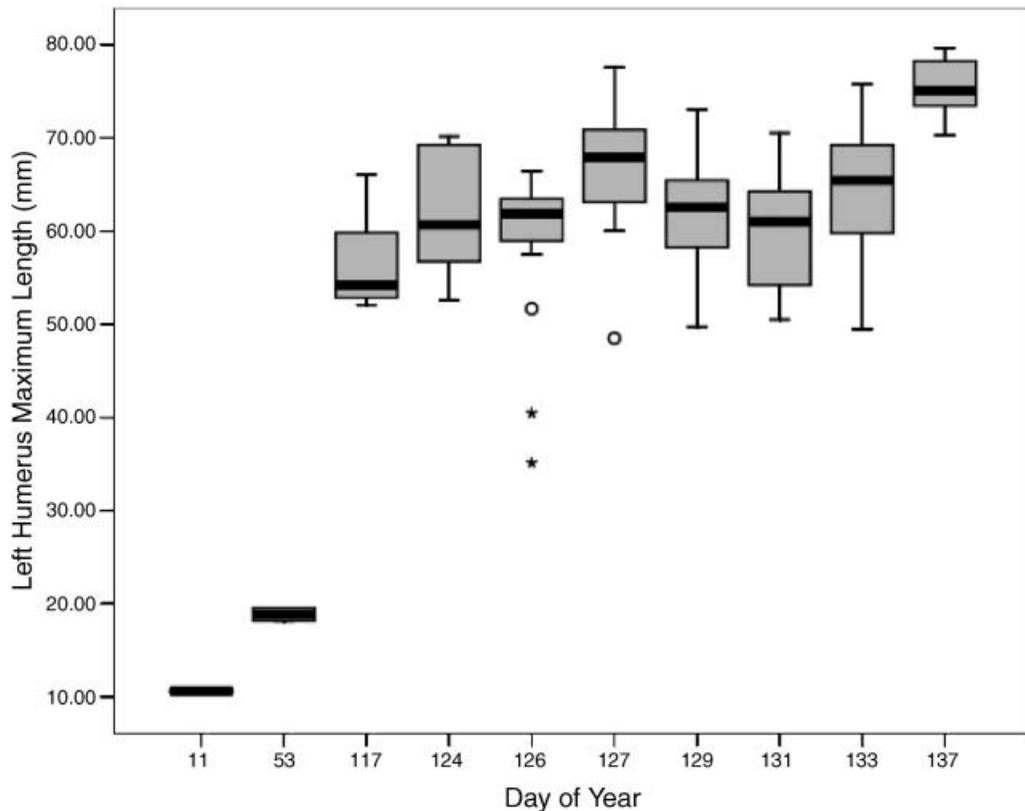


Figure 2. Boxplots showing left humerus maximum length measurements for ten sample sets. Note that the Day of Year axis is not to scale. Day 1 = 1 January. Circles indicate outlier values (at least 1.5 box lengths from the box edge) while asterisks indicate extreme values (at least 3 box lengths from the box edge).

table correlations between 0.60 and 0.80 (Table A in the Appendix). Ten size measurements were rejected as too poorly correlated with calendar date for use as mortality date estimators. Mortality day-of-year/bone size regression equations were determined for the 28 acceptable element measurements. A variety of equation relationships were computed, and the inverse relationship provides the best fit to the data. The resulting equations derived in this analysis are presented in Table A in the Appendix, and an example is graphed in Figure 3. These equations are based on a large sample ( $n = 149$ ) of pronghorn with April and May mortality dates, but only four specimens with January and February mortality dates. Therefore the equations are likely to produce more accurate dates for late spring than for earlier mortality events.

To investigate the precision of the mortality date estimate, a nonparametric bootstrap analysis

was performed. This technique uses repeated random subsamples to determine confidence intervals in circumstances where the population distribution function is unknown and is not assumed to follow the normal distribution (Buntinas & Funk, 2005: 479–85). Nonparametric bootstrapping uses the distribution of the sample itself to establish the confidence interval. Briefly, a measurement is randomly selected with replacement from all modern fetal pronghorn measurements, its estimated mortality date is computed using the appropriate equation, and the difference between the estimated and known mortality dates computed. This is repeated  $k$  times, where  $k$  is the subsample size of interest. These  $k$  values are then averaged. This process is repeated 1000 times for each subsample size. The 95% confidence interval is the range of values remaining after the top and bottom 2.5 percentile values are discarded.

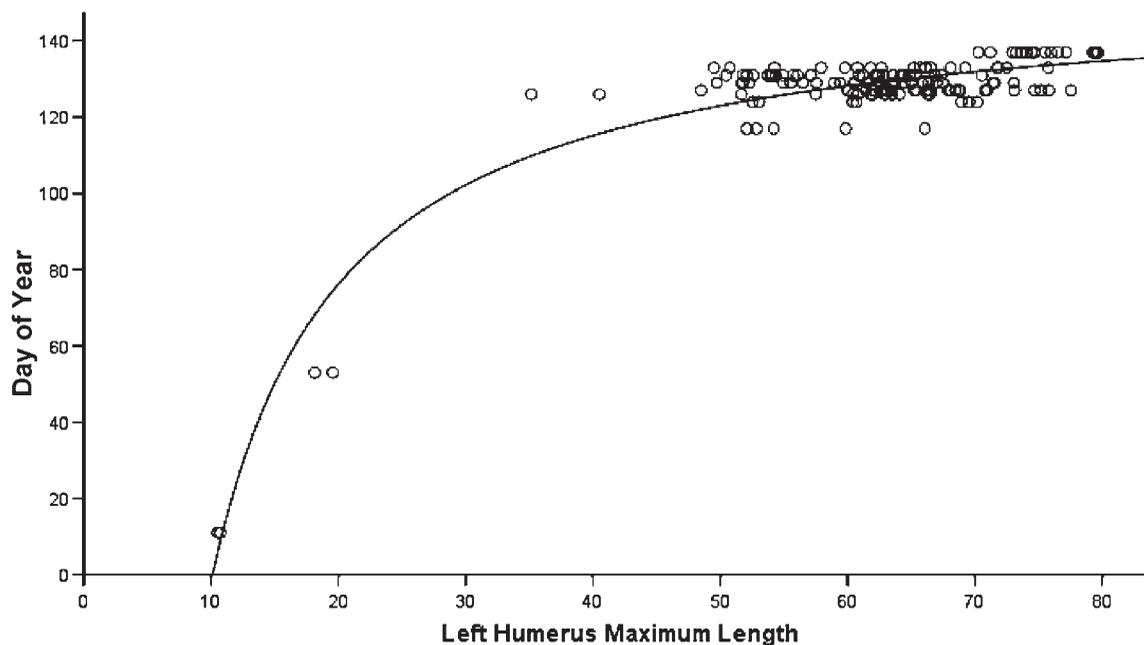


Figure 3. The relationship between Day of Year and left humerus maximum length. Day 1 = 1 January.

Based on this method, the average difference between the computed mortality date and the known correct date is very close to zero; it ranges from 0.06 to 0.33 days for various subsample sizes (Figure 4). This is to be expected, since the residuals are evenly distributed above and below the regression equations. The small but consistently positive value suggests that the equations slightly overestimate the mortality date (or may be an artefact of rounding to even day estimates). For a subsample size of one (that is, a single randomly selected measurement) the confidence interval ranges from  $-10.0$  to  $+12.0$  days. This indicates that, for a sample with population characteristics identical to those of the modern sample used in this analysis, the estimated mortality date should be accurate within  $-10/+12$  days, 95% of the time. For a subsample size of two, the corresponding confidence interval is  $-8.0/+8.5$  days, and the interval converges towards  $-1.5/+2.0$  days with increasing subsample sizes. If absolute values of the date differences are used (so that the computation disregards whether the estimated date is too low or too high), the average difference is consistently very close to 4.0 days (data not shown).

This bootstrap analysis suggests that the accuracy of a single mortality date is  $-10/+12$  days, or 22 days, and with increasing sample sizes it decreases rapidly to about 4 days. However, these values assume the sampled population's characteristics exactly match those of the modern sample. As previously discussed, pronghorn fawning season duration and centroid vary with environmental parameters. Although the modern sample includes pronghorn from several regions within Wyoming, the entire range of potential environmental variation is not included. This adds additional, unknown uncertainty when the mortality date estimates are computed for archaeological samples. For samples from conditions approximating those of modern Wyoming, it seems appropriate to assign a four-week confidence interval to single samples and two to three weeks for the average of eight or more samples. Investigators working with specimens from sites with substantially different environmental conditions – particularly hot desert regions – should assume additional uncertainty.

In addition to bone size, tooth eruption is a potential mortality date indicator. However, prenatal mandibular tooth eruption level was

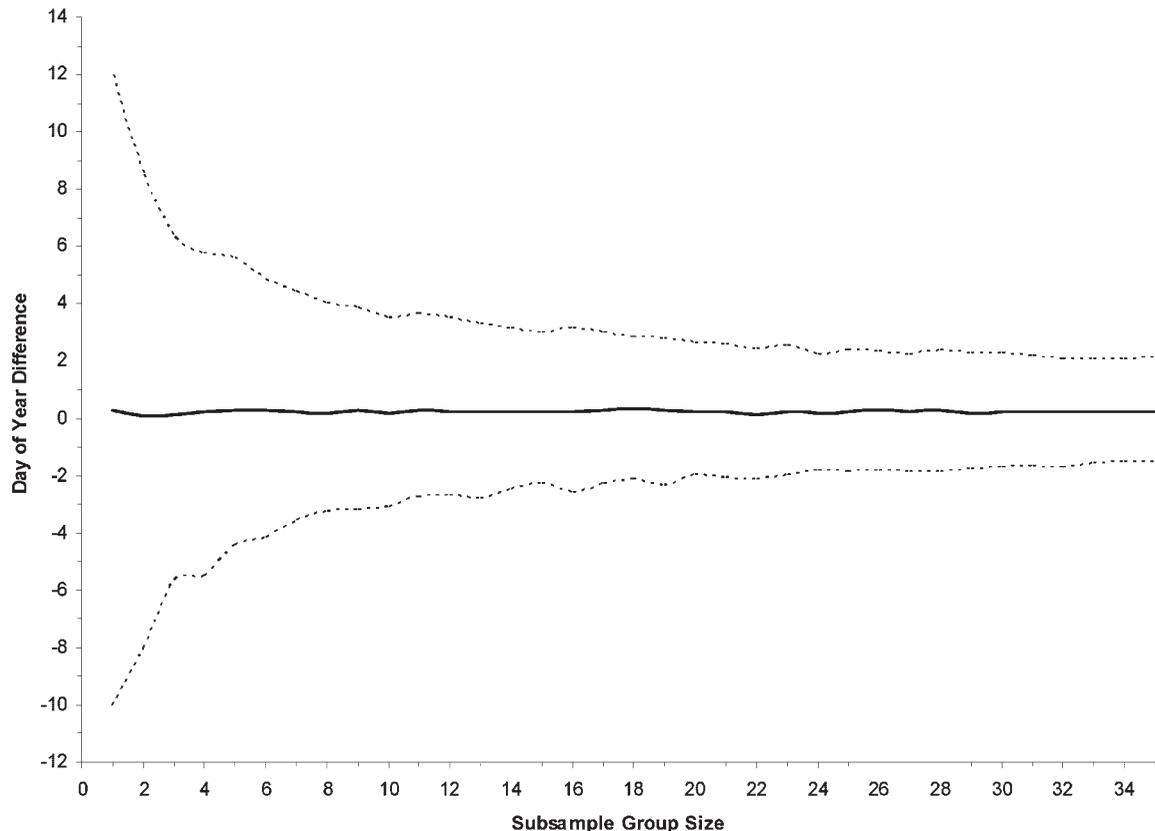


Figure 4. Difference between the computed and true day of year for modern pronghorn fetal measurements. A positive value indicates that the computed day of year is later than the true mortality date. The area inside the dotted lines is the 95% confidence interval. Computed via nonparametric bootstrap resampling; see text for additional discussion.

found to be a poor predictor of mortality date (Table A). The April and May samples show little variation regardless of date; 108 of 119 second deciduous premolar (DP2) teeth are in Lubinski's (2001) stage 1 (with the remainder in stage 'V'), all 135 DP3 teeth are in stage 1, and 106 of 141 DP4 are in stage 'V' (with 34 others in stage 1 and one in stage 'C'). The eruption level and day-of-year  $R^2$  correlation coefficients for these samples are not significant (all have a significance probability much greater than 0.05). The January and February samples have small mandibles in which tooth sockets, let alone teeth, had yet to form. Fetal pronghorn tooth eruption patterns are thus not sufficiently correlated with mortality date to provide a useful seasonality indicator. This is consistent with earlier work (Lubinski &

O'Brien, 2001; Lubinski, 2001) showing that tooth eruption patterns in post-natal pronghorn are insufficiently precise to provide more than a rough season-of-death estimate.

Fetal pronghorn bone size thus provides a reasonable estimate of mortality date, while tooth eruption level does not. Therefore mortality date estimates for archaeological fetal pronghorn remains from archaeological sites should be computed using bone sizes only.

### Archaeological samples

To demonstrate the technique, the mortality date estimation equations in the Appendix are applied to fetal pronghorn remains from two archae-

ological sites. The Oyster Ridge (48UT35) site is located in southwestern Wyoming, about 40 km northeast of Evanston. It has been the subject of several Cultural Resources Management investigations, most recently in 2001 (Zier, 1977, 1982; Backer *et al.*, 2001; Reed & Gansemer, 2001). The site is thought to date to the Late Prehistoric period and contains a 'moderately dense scatter of chipped stone, ground stone and faunal remains' (Reed & Gansemer, 2001: 4). The original investigators assigned all identifiable large mammal bone to pronghorn, including 13 fetal remains (Zier, 1982; Reed & Gansemer, 2001). These fetal remains were inspected by the senior author of this study and confirmed to be consistent with pronghorn. No substantial comparative collection of fetal deer or other large ungulates is available, so the possibility that one or more of the fetal remains are not pronghorn cannot be ruled out. Nevertheless, given the specimens' morphological match with modern fetal pronghorn and the lack of adult ungulates other than pronghorn, the Oyster Ridge fetal remains can be confidently assigned to pronghorn. Only two of the 13 fetal specimens (specimen numbers 6B and 6C) are appropriate elements and sufficiently well preserved for mortality date analysis; both are right scapula fragments with preserved bone sufficient for RSMNW measurement.

Trappers Point (48SU1006) is located just west of Pinedale, Wyoming. It is a large, multi-component site partially excavated by the Office of the Wyoming State Archaeologist during the 1990s (Miller *et al.*, 1999; Miller & Sanders, 2000). A large quantity of faunal remains was recovered, with pronghorn dominating the assemblage. A total of 1811 specimens were identified by the original investigators as pronghorn, including 101 fetal pronghorn specimens (Eckles, 1999). The only other ungulate specimens identified were two deer (*Odocoileus* sp.), 52 elk (*Cervus elaphus*) and 9 bison (*Bison bison*) specimens. The fetal pronghorn remains were inspected by the senior author and confirmed to be consistent with pronghorn. With this match and the overwhelming abundance of pronghorn at the site, these remains can also be confidently assigned to pronghorn; 30 of these specimens (providing

34 measurements) are sufficiently well preserved and are appropriate elements for this study.

Twenty-nine of these specimens (accounting for 33 measurements) were from Stratum V, the most extensive bone-bed at Trappers Point. This stratum dates to 5900 to 5700 BP (Eckerle, 1999: 65; Francis & Sanders, 1999: 42). The single remaining specimen is from Stratum VI, which is considered non-cultural and has not been directly dated but stratigraphically dates from 5700 to 5000 BP (Eckerle, 1999: 65).

The mortality dates of the fauna from Trappers Point are of particular interest because the site lies along a modern pronghorn migration corridor. Pronghorn today migrate north through the Trappers Point area during March and early April, and return during their southward migration in autumn (Sawyer & Lindzey, 2000). Miller (1999: 241–2; see also Sanders & Miller, 2004) noted that the Trappers Point Stratum V seasonality analysis is compatible with a scenario in which hunters intercepted migrating herds of pronghorn. That work is often interpreted as demonstrating that pronghorn have used the Trappers Point migration corridor for thousands of years, with implications for modern wildlife management and proposed development in the Trappers Point area (e.g. Sawyer & Lindzey, 2000; K. Berger, 2003; Gearino, 2003; J. Berger, 2004; Sawyer *et al.*, 2005; Boomerang Staff, 2005). However, an alternative scenario in which hunters targeted resident pronghorn is also feasible. Archaic foragers may have specifically targeted local pregnant does during spring for their fetuses, perhaps via drives or surrounds. There are historical and ethnographic accounts of North American cultures who regularly consumed fetal animal remains, often considering them to be a great delicacy (e.g. Hearne, 1795; Clark, 1885; Grinnell, 1923; Wilson, 1984; Williamson & Railsback, 1988; Fowler, 1989; Douglas, 1999). Fetal animal hide was also used for specialised purposes, such as small bags (Rides-at-the-Door, 1980).

Unfortunately, historical and ethnographic accounts do not specify the month during which fetal remains were targeted. It would seem optimal to wait until the fetuses were close to full term and therefore as large as possible. In the

case of pronghorn, this would usually occur during May. However, other considerations such as taste or texture of the fetal (or adult) pronghorn may be more important than size.

Beyond their relevance in assessing ancient pronghorn migration behaviour, these interception and local procurement scenarios also have implications for Archaic hunter aggregation and communal behaviour. Therefore the spread and clustering of fetal mortality dates are investigated for insight into the number and timing of pronghorn mortality events at Trappers Point.

### *Oyster Ridge mortality date estimate*

The two Oyster Ridge fetal specimens are scapulae whose RSMNW measurements are 3.93 and 4.67 mm. Using the RSMNW regression equation parameters from Table A in the Appendix, these measures correspond to mortality dates of 27 April and 4 May respectively. The average of these two dates is 1 May.

This date should be treated with caution. Firstly, as shown in Figure 4, estimates based on only two specimens have a confidence interval in excess of  $\pm 8$  days. Secondly, RSMNW size has only a marginal correlation with mortality date; its  $R^2$  value is 0.63 (Table A). Therefore estimates based only on RSMNW have a greater uncertainty than those using stronger correlations. An appropriate estimate, incorporating these uncer-

tainties, is that at least one mortality event occurred in the second half of April or the first half of May at Oyster Ridge.

### *Trappers Point mortality date estimate*

As previously noted, 30 fetal pronghorn specimens from Trappers Point yielded 34 measurements. Because multiple measurements on a single bone should yield identical mortality dates, the four specimens which supported two measurements apiece provide an opportunity to assess day estimate accuracy (Table 3). Three of the measurements involve RSMNW, which as previously discussed has only a marginal correlation with mortality date and therefore increased uncertainty. The average difference between measurements was nevertheless only 1.9 days, with a range of 3.1 to 0.4 days. This is well within proposed accuracy confidence intervals. When used in calculations with other measurements, the average of the two date calculations is used for each of these four specimens.

The 29 Trappers Point Stratum V fetal specimens produce an average mortality date of 30 April, with a range of 13 April to 11 May (Figure 5). Most fetal pronghorn died between 24 April and 11 May, with two earlier-April outlying specimens.

Miller (1999) performed a comparison of Trappers Point fetal specimens against a small set of modern fetal specimens with known mortality date. He concluded that Stratum V fetal bone 'size and development more closely

Table 3. Trappers Point specimens with two measurements apiece

Specimen	Measurement	Value	Estimated mortality day	Difference (days)	Average day per specimen	Average calendar day
SU1006-10160	RSMNW	5.04	127.1	3.1	125.6	May 06
	RSDL	10.38	124.0			
SU1006-5150	RSMNW	4.76	125.0	2.0	124.0	May 04
	RSDL	10.02	123.0			
SU1006-6007	RRML	68.9	128.8	2.0	127.8	May 08
	RRMW	5.25	126.8			
SU1006-7784	RSMNW	5.19	128.1	0.4	127.9	May 08
	RSDL	12	127.7			
Average difference				1.9		

The estimated mortality day and average day per specimen are Julian days, with Day 1 = January 1.

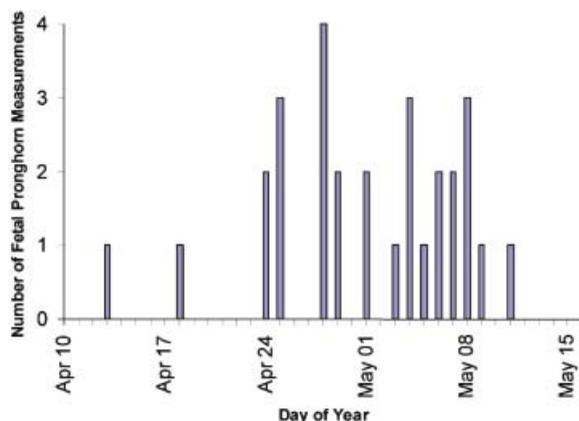


Figure 5. Computed mortality dates for Trappers Point Stratum V fetal pronghorn. See Fenner (2007) for specific date/specimen values.

resembles May 1 than late February, suggesting an April (ca. 6.5–7.5 months in utero) rather than a March mortality' (Miller, 1999: 211). The analysis in this study supports his assessment, although it suggests a slightly later date of very late April or early May.

The average date of 30 April assumes that the Trappers Point fetal pronghorn represent a single mortality event. However, there are hints of structure within the mortality date data which might indicate that multiple mortality events are represented in the assemblage. This will be explored in the next section.

The single Trappers Point Stratum VI specimen is a fragmentary fetal pronghorn right tibia with a minimum width measurement corresponding to a 13 April mortality date. While based on only a single sample, this suggests Stratum VI mortality – presumably natural, since the layer is considered non-cultural – may have occurred at roughly the same time of year as the earliest Stratum V mortality event. Alternatively, this specimen could be intrusive from Stratum V.

## Discussion

The archaeological evidence from Trappers Point Stratum V is compatible with a single mortality event (Sanders, 1999). Fetal mortality date analysis offers another means of assessing the

number of mortality events; structure within the mortality date data may indicate different mortality dates and therefore multiple kill events. Two such data structures will be investigated.

The specimens with outlying dates of 18 April (RSMNW) and, particularly, 13 April (LTMW) are outside the confidence interval expected for a large sample and may represent an earlier mortality event than do the remaining specimens. However, there are other potential explanations for these specimens. Severely stressed pronghorn may carry dead, mummified or partially resorbed fetuses internally for extended periods (Barrett, 1982; Zimmer, 2004: 23). Alternatively, they could be late fetuses borne by fawns, yearlings, or adults who conceived during a second oestrus (O'Gara, 2004: 291). These are all unusual events but could explain the presence of more immature fetal specimens within the assemblage.

There is also a hint of additional structure within the late April/early May data. This data shows a potentially bimodal shape, with clusters from 24 April to 1 May and from 3 May to 11 May. These may be merely random cluster accumulations from a single kill event, or they may represent separate kill events with different mortality events. Additional insight into this question may be obtained by considering the spatial distribution of fetal remains.

Previous analysis of all Stratum V pronghorn remains by Sanders (1999) shows a concentration of bones in the northeast quadrant and scattered bone throughout the site. Sanders (1999: 376) attributed differential bone weathering in the northern and southern portions of the site (north and south of grid line 1057N) to differences in depositional or sediment characteristics rather than differences in exposure duration. Fetal remains likewise do not appear to be spatially distributed by cluster period or kill event (Figure 6), but instead conform to the overall pronghorn bone distribution described by Sanders (1999). If multiple kill events occurred, bone from earlier events must still have been exposed on the surface and influenced subsequent bone disposal location. The number of years required to completely cover large bones in the Trappers Point region is unknown, but Sanders (1999: 370) suggested it may take about ten years. That being the case, if there is more than one fetal

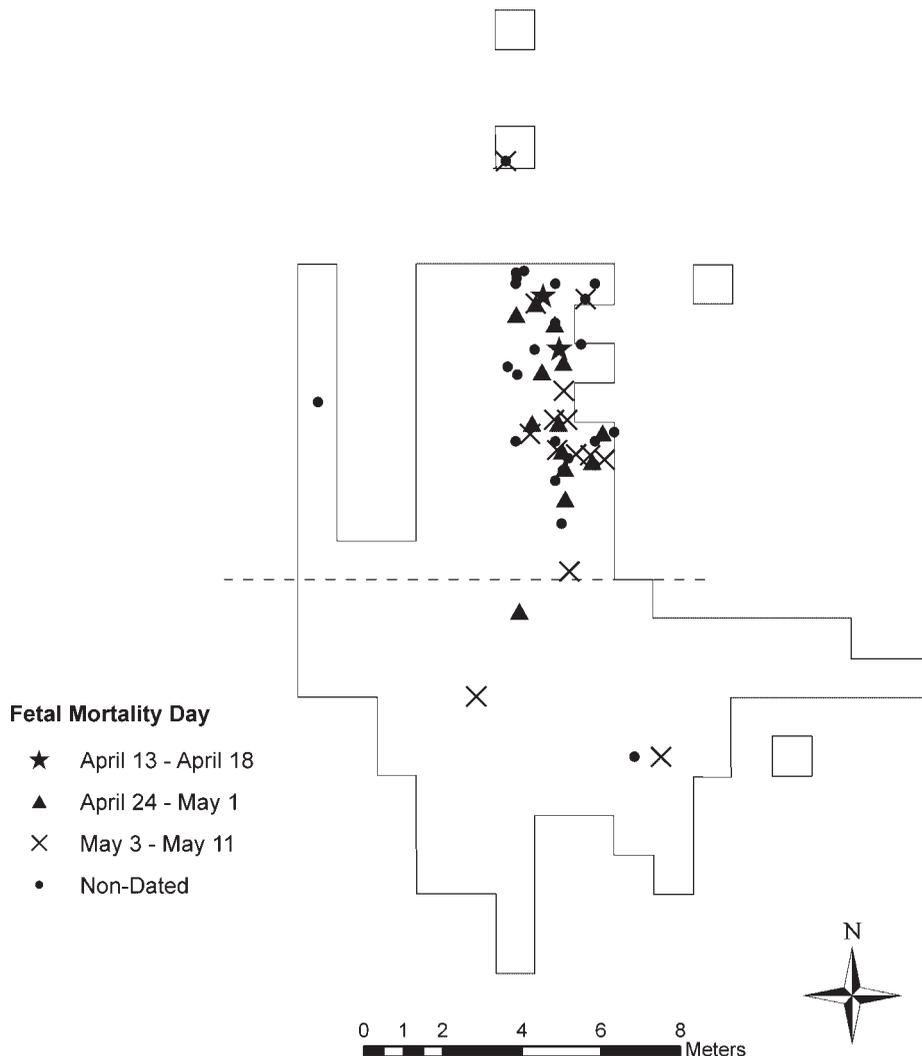


Figure 6. Locations of fetal pronghorn remains within Trappers Point Stratum V. Note that there is no clear spatial organisation by mortality event period. The dashed line indicates grid line 1057N, which Sanders (1999) uses to separate the north and south portions of the site.

pronghorn mortality event included in Trappers Point Stratum V, then less than a decade must have separated each of them.

Fetal size analysis therefore indicates that remains from one (or possibly two) late April or early May mortality events may be included in Trappers Point Stratum V. Two specimens also tentatively support an early April event. Wildlife managers tracing modern pronghorn movements show that pronghorn migrated north through Trappers Point in April 1999, while in 2000 the

migration was in late March (Sawyer & Lindzey, 2000). At least the early April kill event is therefore compatible with a strategy of intercepting migrating pronghorn. The late April/early May kill event(s) are less compatible with modern migration patterns, but – considering the small number of modern migrations surveyed – cannot be ruled out. A particularly late snowmelt could perhaps postpone the migration into early May (Sawyer *et al.*, 2005). The effects of modern development are also unknown. The Stratum V

mortality dates are thus most compatible with the killing of locally resident pronghorn, but the migration-interception scenario cannot be ruled out.

The number of pronghorn remains within Stratum V in relation to seasonal pronghorn grouping behaviour suggests multiple mortality events. A minimum of 27 post-natal pronghorn individuals were recovered from excavations covering only 28% of Trappers Point Stratum V (Sanders & Miller, 2004: 165). The total kill may have been over a hundred pronghorn (as well as lesser amounts of other animals; see Eckles, 1999). Modern pronghorn in Wyoming form large groups – sometimes consisting of more than 100 individuals – during fall and winter, but by April break into smaller groups averaging fewer than 13 individuals per group (Mitchell, 1980: 103; O'Gara, 2004: 154–63; Beckmann & Berger, 2005). However, characteristics of the Trappers Point area may alter this general pattern. Trappers Point is located at a pronghorn migration bottleneck. Multiple modern pronghorn groups often gather together in the open areas south and north of the site before and after movement through the area (Sanders & Wedel, 1999; Sawyer & Lindzey, 2000), so groups with more than 13 individuals may be present during migration seasons. As Sanders & Wedel (1999: 308) noted, it is unknown if this gathering is related to the highway and fencing that must be crossed when moving through the Trappers Point bottleneck. Nevertheless, if one assumes all pronghorn were killed during the late April/early May season as indicated by fetal remains, then the Trappers Point Stratum V kill size is more likely the result of multiple kills of small groups than a single mass kill of a very large group.

It should be noted that because Trappers Point site seasonality has been based upon analysis of fetal remains, it is unknown whether the post-natal pronghorn were killed during the March-to-May timeframe. Some or all of the post-fetal pronghorn at Trappers Point may have been killed at other seasons. Miller (1999) analysed Trappers Point adult pronghorn dentition and considered it compatible with a spring mortality event, but pronghorn dentition is quite variable and cannot be relied on for secure seasonality indications (Lubinski, 2001;

Lubinski & O'Brien, 2001). The site could therefore represent one or more large fall or winter kills mixed with relatively small spring kills. In this circumstance, the case for a scenario involving hunters intercepting migrating pronghorn is weaker.

## Conclusion

Bone sizes of modern fetal pronghorn remains of known mortality date were used to develop regression equations for estimating mortality day of archaeological specimens. While environmental and within-sample variation indicates that the resulting values should only be used as estimates, with a precision of perhaps two or three weeks, archaeologists can use size data to investigate seasonality and the number of mortality events at sites containing ancient fetal pronghorn remains. Fetal mandible tooth eruption was found to correlate poorly with mortality date and should not be used in estimating mortality dates.

Analysis of two fetal samples recovered from the Oyster Ridge site indicates a late April or early May mortality event. Bone size of fetal samples from the largest component at the Trappers Point archaeological site indicates that one to three pronghorn mortality events occurred during April and May. If more than one mortality event occurred, they must have been fairly closely spaced in time. The data are compatible with both interception of migratory pronghorn and procurement of resident local pronghorn, but the hints of structure within the mortality data and the number of individuals procured lend some support to multiple kill events. Multiple kill events processed at exactly the same location imply an ability to predict pronghorn location at specific times, which tentatively supports the migration interception scenario.

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## APPENDIX

**Mortality day of year versus bone size equations**

The following equations may be used to estimate mortality day of year based on size measurements for specific fetal pronghorn elements. See Table 2 for element measurement abbreviations, and the text for discussion about development and use of these equations.

The equations are of the form:

$$\text{Calendar day of year} = b_1/x + k$$

where  $x$  is the measured size (in mm), and  $b_1$  and  $k$  are constants given in the following table.

Table A. Fetal pronghorn mortality day estimation parameters

Measure	Number of samples	R <sup>2</sup>	F statistic	Significance	Acceptable correlation?	Inverse parameter (b <sub>1</sub> )	Constant (k)
LCML	141	0.107	16.659	0.000	No		
LDP2	124	0.003	0.358	0.551	No		
LDP3	140	n/a			No		
LDP4	146	0.004	0.443	0.507	No		
LFFL	141	0.046	6.636	0.011	No		
LFML	149	0.903	1369.264	0.000	Yes	-1618.175	152.459
LFMW	151	0.912	1548.354	0.000	Yes	-252.248	164.504
LHFL	147	0.655	274.776	0.000	Marginal	-704.158	149.714
LHML	151	0.910	1506.186	0.000	Yes	-1560.611	154.211
LHMW	152	0.911	1542.479	0.000	Yes	-218.318	161.074
LMMTW	141	0.002	0.185	0.668	No		
LMMW	142	0.005	0.529	0.468	No		
LMTRL	116	0.016	1.783	0.185	No		
LRML	150	0.901	1345.290	0.000	Yes	-1811.880	155.144
LRMW	152	0.879	1090.301	0.000	Yes	-215.780	167.741
LSDL	140	0.908	1365.719	0.000	Yes	-304.640	153.146
LSDW	123	0.913	1269.618	0.000	Yes	-208.587	151.909
LSML	31	0.939	449.464	0.000	Yes	-1733.217	159.549
LSMNW	149	0.611	230.540	0.000	Marginal	-191.671	165.001
LSPW	26	0.926	302.281	0.000	Yes	-1188.943	165.242
LTML	147	0.906	1394.786	0.000	Yes	-2197.997	153.760
LTMW	149	0.897	1277.499	0.000	Yes	-230.213	164.258
RCML	143	0.112	17.810	0.000	No		
RFFL	138	0.033	4.586	0.034	No		
RFML	150	0.905	1405.185	0.000	Yes	-1627.807	152.604
RFMW	151	0.915	1602.410	0.000	Yes	-250.504	164.216
RHFL	144	0.710	346.861	0.000	Marginal	-703.666	150.166
RHML	153	0.911	1551.217	0.000	Yes	-1577.990	154.497
RHMW	153	0.911	1536.380	0.000	Yes	-230.343	162.795
RDP2	115	0.021	2.003	0.160	No		
RDP3	140	n/a			No		
RDP4	144	0.035	4.121	0.045	No		
RMMTW	139	0.000	0.020	0.887	No		
RMMW	143	0.005	0.584	0.446	No		
RMTRL	101	0.004	0.343	0.560	No		
RRML	152	0.903	1396.916	0.000	Yes	-1833.198	155.413
RRMW	153	0.882	1132.882	0.000	Yes	-215.683	167.929
RSDL	141	0.905	1319.822	0.000	Yes	-289.204	151.821
RSDW	124	0.909	1224.066	0.000	Yes	-215.840	152.669
RSML	35	0.956	708.938	0.000	Yes	-1727.002	157.581
RSMNW	151	0.634	257.658	0.000	Marginal	-181.805	163.174
RSPW	32	0.939	463.828	0.000	Yes	-1149.801	163.154
RTML	148	0.905	1388.266	0.000	Yes	-2184.362	153.595
RTMW	149	0.891	1201.344	0.000	Yes	-231.572	164.421

See Table 2 for element measurement abbreviations. A value of n/a indicates that the measurement did not vary, so a correlation coefficient could not be computed.