

A Comparison of Pronghorn Body Measurements Throughout Western North America

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Abstract: Biologists use mammalian body measurements to make taxonomic, behavioral, and ecological comparisons within and among species. Another application of these comparisons is promulgation of several “rules” to explain intraspecific variation in morphology over broad environmental gradients. We examined body measurements of 223 pronghorn (*Antilocapra americana*) collected from throughout North America to determine whether body measurements varied consistently among biotic communities, ecoregions, and subspecies. We also evaluated variation in pronghorn measurements with annual temperatures (Bergmann’s rule), forage productivity as measured by precipitation (“Geist’s” rule), and latitude (Allen’s rule). Pronghorn showed little sexual dimorphism other than in body weight, and morphological similarities among populations were more apparent than differences. Pronghorn size varied little ($P=0.003$) with mean annual temperature, and pronghorn from areas receiving greater rainfall were only slightly larger ($P=0.001$) than animals in desert areas. Horn size increased slightly ($P=0.0003$) from north to south, but did not increase ($P=0.035$) with precipitation. Body measurements, however, varied little from north to south ($P=0.001$) although pronghorn from Arizona and New Mexico had longer ears ($P=0.001$) than other populations, and pronghorn from the Great Plains had shorter hind feet and longer tails ($P=0.0001$) than other populations. Analyses of designated “subspecies” revealed few differences, and the species is remarkably monotypic. A possible exception is *A. a. peninsularis*, which tended to be smaller ($P=0.005$) than other subspecies. Further investigations into morphological variation among pronghorn populations should examine specific environmental characteristics across spatial and temporal scales and should measure body size using other morphometrics.

Proceedings Pronghorn Antelope Workshop 22: 125-137

Key Words: *Antilocapra americana*, ecoregion, latitude, morphology, precipitation, pronghorn, sexual dimorphism, temperature.

Morphological variation within a species can provide biologists with a wealth of information. Although recent analyses have focused on molecular techniques, most mammalian species and subspecies originally were described on the basis of morphological characteristics (Feldhamer et al. 2004). Historically, recognition of large-scale patterns of change suggested relationships between an animal’s environment and its morphology, which in turn led to the promulgation of ecological “rules.” Bergmann’s rule recognized the tendency for mammals to increase in size in colder environments (Bergmann 1847), whereas Allen’s rule reflected a

pattern in which mammals experiencing cold climates tend to have smaller appendages (i.e., ears, tails) than closely related forms in warmer environments (Allen 1877). Similarly, Geist (1998) noted that body size in cervids tends to decrease with declining forage availability. Although biologists have studied these relationships for >100 years, application of these rules remains equivocal and controversial (e.g., Stevenson 1986, Geist 1987, Ashton and Feldman 2003).

As in other mammals, regional variation in pronghorn (*Antilocapra americana*) body measurements have been used as 1 criterion to differentiate subspecies (Merriam 1901, Nelson 1912, Bailey 1932, Goldman 1945), and biologists have long suspected that local variation in pronghorn morphology might depend upon environmental factors (Powell 1953). In a previous paper (Brown and Mitchell 2006), we discussed statewide differences in pronghorn horn size and correlated variation in trophy size to winter temperature. We reasoned that similar comparisons in standard body measurements such as total length, hind foot length, tail length, ear length, and weight might be equally informative and provide insights into regional adaptations and applicability of subspecies designations. Such an exercise also could be used to further evaluate Bergmann's, Allen's, and Geist's rules.

Methods

Tables of pronghorn measurements presented in O'Gara (2004a) provided the initial basis for our data search and stimulated us to request additional data. We searched the literature to obtain mammalian measurement data (total length, hind foot length, tail length, ear length, horn length, and weight) for individual pronghorn from the following sources: Elliot (1907), Mearns (1907), Nelson (1912), Murphy (1917), Bailey (1931, 1932), Knipe (1941, 1942, 1944), Goldman (1945), Buck (1947), Einarsen (1948), Büchner (1950), Mason (1952), Carr (1971), Tinker (1978), Menzel (1980), Smith and Beale (1980), Arizona Game and Fish Department (1981), Wright and deVos (1985), Hepworth (2004), and Meeker (2004). In addition, the senior author and his colleagues collected measurements from pronghorn in southern New Mexico (33.18°N, 107.03°W) in October 2005, southwestern Arizona (32.4°N, 112.9°W) in December 2005, and Sonora, Mexico (31.4°N, 113.5°W) in January 2006.

We also contacted museums listed in the Mammal Networked Information System and queried them about availability of pronghorn measurements in their collections. Although a disappointingly small amount of measurement data were available for some larger collections, we obtained useable measurements from Burke Museum of Natural History in Seattle, California Academy of Sciences, Field Museum of Natural History in Chicago, University of Kansas, Los Angeles County Museum, Michigan State University, Museum of Southwestern Biology at the University of New Mexico, Museum of Vertebrate Zoology at the University of California at Berkeley, National Museum of Natural History, Texas Tech University, University of New Mexico, and the U. S. National Museum.

We included only measurements from adult pronghorn collected prior to translocations from other states or countries. However, we used measurements of pronghorn from the National Bison Range (Dow 1952) even though these animals descended from translocated stock because all translocations originated from areas within intermountain grassland (Reichenbacher et al. 1999). These measurements represent the largest database for pronghorn yet gathered.

We gathered data for 223 individual pronghorn ≥ 2 years old, although we could not obtain every measurement for every animal. We used actual weights when provided and avoided field-dressed weights. We assigned each animal to a biotic community (Reichenbacher et al. 1998) and to an ecoregion (Bailey et al. 1994). Each animal also was assigned to a subspecies based on the original description and map provided in Hall and Kelson (1959). The exception was *A. a. oregona*, which has been replaced by *A. a. americana* (O’Gara and Janis 2004). We obtained mean annual precipitation and mean annual temperature data from the climate station closest to the collection locale having summarized climatic data.

We used *t* tests to compare sexes and analysis of variance (ANOVA) to examine differences in morphology across biotic communities, ecoregions, and subspecies. Linear regression analyses were used to examine relationships between body measurements and mean annual temperature (Bergmann’s rule), productivity as indexed by mean annual precipitation (Geist’s rule), and latitude (Allen’s rule). We analyzed all data in JMP (SAS Institute, 2004), with significance levels of $P \leq 0.05$. When ANOVA results were significant, we ran *post hoc* pairwise comparisons. Due to the large number of statistical tests conducted on the same dataset, we also used sequential Bonferroni corrections for multiple comparisons (Rice 1989).

Results

We initially compared measurements and weights of 150 male and 73 female pronghorn collected from 44 locations within 8 biotic communities and 11 ecoregions ranging from Alberta southward to Coahuila, and westward from western Nebraska to Baja California Sur. Males and females did not differ in any standard measurements ($P \geq 0.23$, Figure. 1a). Female lengths averaged only 0.01% shorter than males, and male hindfoot lengths were within 2% of those for females. Males, however, weighed significantly more than females ($t = -4.88$, $df = 32$, $P \leq 0.0001$; Figure. 1b). Thus, in subsequent analyses, we combined males and females except when comparing body weights.

Comparisons of body measurements across biotic communities showed a range of values (Table 1). Pronghorn did not differ in total length across communities ($P = 0.05$, NS after sequential Bonferroni correction). However, they differed in tail length ($F = 22.4$, $df = 3, 51$, $P < 0.0001$), hind foot length ($F = 49.9$, $df = 4, 33$, $P < 0.0001$), ear length ($F = 16.0$, $df = 4, 133$, $P < 0.0001$, male horn length ($F = 18.3$, $df = 4, 16$, $P < 0.0001$), and male weights ($F = 147.2$, $df = 2, 27$, $P < 0.0001$). Although mean lengths of animals in different biotic communities fell within 10% of each other, other measurements varied more widely. Pronghorn from Chihuahuan Semidesert and Plains Grassland had longer tails than animals from Sonoran Desertscrub or Great Basin Shrub Steppe communities. Pronghorn from Plains Grassland also had shorter hindfoot lengths, smaller horns, and weighed less than animals from other communities. Although sample sizes were small, pronghorn from Intermountain Grassland on the Coconino Plateau had longer ears than animals from other areas, which did not differ in this respect (Table 1).

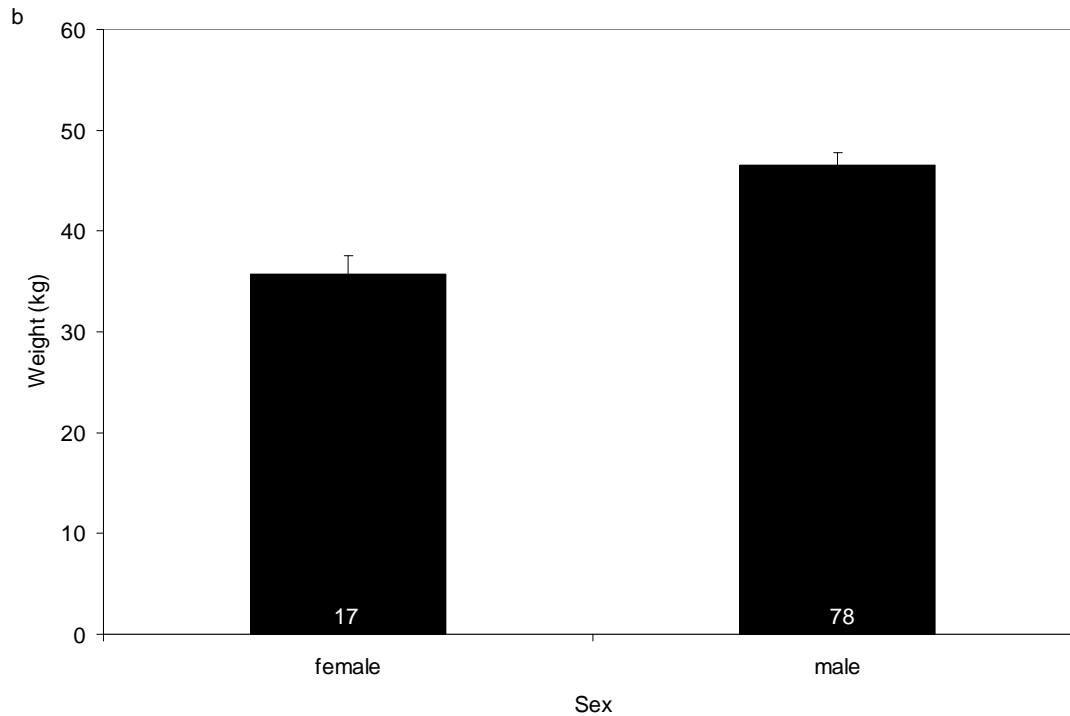
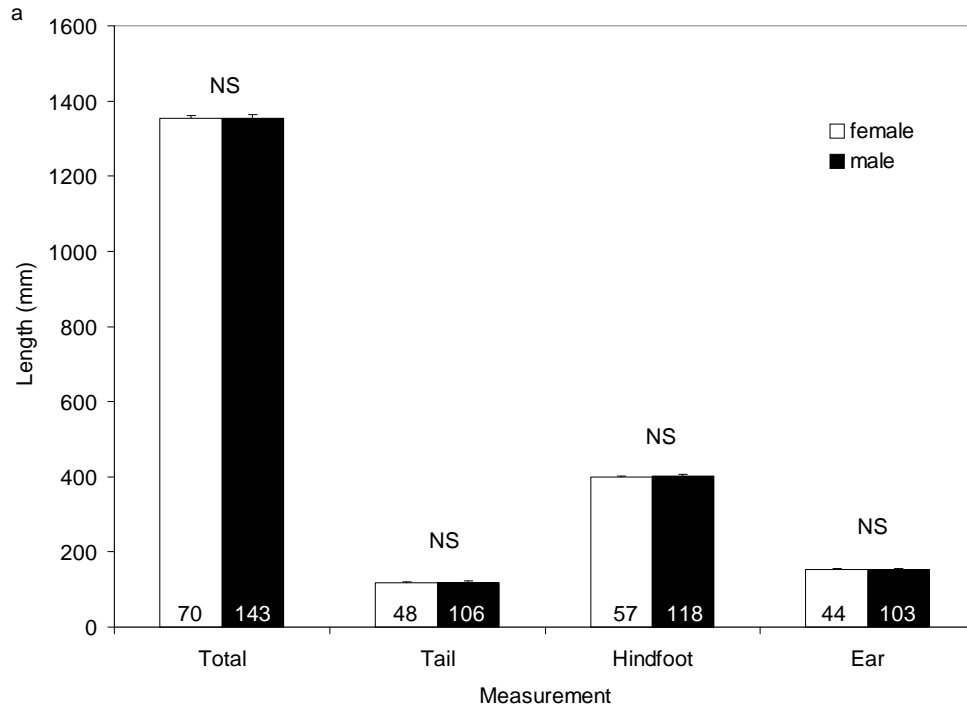


Figure 1. Mean (+ SE) (a) morphological measurements (mm) and (b) body weight (kg) of male and female pronghorns collected throughout western North America between 1890 and 2006. Sample size is indicated at the base of each bar. NS = not significant ($P > 0.05$).

Analyses based on ecoregions varied somewhat from those based on biotic communities (Table 2). Pronghorn differed in total length ($F = 4.81$, $df = 6, 36$, $P = 0.001$), tail length ($F = 27.7$, $df = 4, 42$, $P < 0.0001$), hind foot length ($F = 34.5$, $df = 6, 34$, $P < 0.0001$), ear length ($F = 51.1$, $df = 5, 17$, $P < 0.0001$), male horn length ($F = 14.1$, $df = 4, 20$, $P < 0.0001$), and male weights ($F = 45.1$, $df = 3, 25$, $P < 0.0001$). Pronghorn from the Middle Rocky Mountains were longer than those in the Great Basin (Table 2). Animals from the Northern Great Plains Steppe had longer tails, shorter hindfoot lengths, and weighed less than those from other ecoregions. Pronghorn from the Arizona-New Mexico Mountains had the longest ears, whereas those from the Middle Rocky Mountains had the shortest ears (Table 2).

In our test of Bergmann's rule, we found no relationship between body length and either latitude or temperature ($P = 0.05$). Male weights declined as latitude increased ($r^2 = 0.16$, $P = 0.0003$; Figure. 2), however, the opposite of what is predicted.

In our test of Geist's rule, using mean annual precipitation as an index to plant productivity (Sneva and Hyder 1962), we found that pronghorn were significantly longer in areas receiving more precipitation ($P = 0.0001$, Figure. 3). Precipitation, however, only explained 12% of variation in the data.

Per Allen's rule, hind foot and male horn lengths increased at lower latitudes, although relationships were weak (hindfoot: $r^2 = 0.08$, $P = 0.0003$; horn: $r^2 = 0.15$, $P = 0.0003$; Figure. 4a). Ear lengths did not vary ($r^2 = 0.039$, $P = 0.0189$, NS after sequential Bonferroni corrections). In contrast to Allen's Rule, tail length weakly decreased with increasing temperatures ($r^2 = 0.09$, $P = 0.0002$; Figure. 4b), but the relationship did not hold true for latitude ($P = 0.03$, NS after sequential Bonferroni correction). No other variables varied significantly with temperature ($P > 0.003$, NS after sequential Bonferroni corrections).

Finally, we analyzed body measurements across 4 subspecies. Only tail length differed significantly among subspecies ($F = 16.8$, $df = 2, 51$, $P < 0.0001$, Table 3). Sonoran pronghorn had significantly shorter tails than *A. a. americana* or *A. a. mexicana*, which did not differ significantly from each other. Specimens of *A. a. peninsularis* tended to be shorter than other subspecies, but differences were not statistically significant ($P = 0.05$, NS after sequential Bonferroni correction; Table 3).

Discussion

We conducted these analyses on data collected by many people, over more than a century, and across 3 countries. Therefore, we cannot account for accuracy or precision of original measurements or for any errors made in transcription from field notes to other databases. In addition, despite the relatively large overall database, sample sizes for some locations were small.

Not all significant relationships we found are biologically meaningful. Most pronghorn measurements varied within populations as much as between populations, and mean measurements appeared similar across time and space, and between sexes. Weights were the most variable measurements, probably due to variations in stomach contents, and changes in seasonal and sex-related physiology such as pregnancy, lactation, and rutting behavior.

Table 1. Body measurements (mm) and weight (kg) of male and female pronghorn in different biotic communities (as defined in Reichenbacher et al. 1998) for western North America, 1890-2006. Horn length and weight are included for males only.

Biotic community	Total length			Tail length			Hindfoot length			Ear length			Horn length			Weight		
	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE
Sonoran Desertscrub	23	1,349.1	21.6	14	98.7A ^a	4.0	12	417.3AB	11.5	13	157.4A	2.4	5	293.2BC	32.1	---	---	---
Great Basin Shrub-steppe	46	1,368.5	13.2	36	108.0A	3.2	44	424.6A	2.2	31	149.8A	1.8	25	316.5B	8.3	28	56.5A	1.3
Chihuahuan Semidesert	44	1,355.1	12.2	39	120.7B	4.4	40	402.0B	4.0	40	155.1A	1.6	14	376.7A	8.5	11	53.2A	1.2
Plains Grassland	51	1,348.8	6.6	51	131.5B	2.2	52	375.8C	2.7	51	148.8A	1.8	36	280.2C	10.0	36	36.3B	0.59
Coconino Plateau	8	1,419.4	21.8	---	---	---	8	422.6AB	4.9	3	197.7B	2.7	---	---	---	---	---	---
Vizcaino Desert	23	1,325.7	20.4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

^a Means within columns with different letters are significantly different ($P < 0.001$)

Table 2. Body measurements (mm) and weight (kg) of pronghorn males and females in different ecoregions (as defined in Bailey et al. 1994) across western North America, 1890-2006. Horn length and weight are included for males only.

Ecoregion	Total length			Tail length			Hindfoot length			Ear length			Horn length			Weight		
	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE
Middle Rocky Mountains	12	1,440.9AB ^a	28.7	11	101.5A	3.7	12	419.1AB	5.5	7	138.9A	3.0	4	341.3A	5.6	9	56.2A	2.9
Arizona-New Mexico Mountains	8	1,419.4A	21.8	---	---	---	8	422.6AB	4.9	3	197.7C	2.7	---	---	---	---	---	---
Chihuahuan Desert	44	1,355.1BC	12.2	39	120.7B	4.4	40	402.0B	4.0	40	155.1B	1.6	14	376.7A	8.5	11	53.2A	1.2
Columbia Plateau	24	1,353.9BC	14.7	22	104.4A	1.6	22	430.1A	2.3	24	153.0B	1.6	21	311.8B	9.5	19	56.6A	1.4
Northern Great Plains Steppe	51	1,347.5BC	6.1	51	133.1C	2.5	52	376.5C	2.9	48	149.5AB	1.8	36	280.2B	10.0	35	36.0B	0.53
Sonoran Desert	46	1,337.4BC	14.8	14	98.7A	4.0	12	417.3AB	11.5	13	157.4B	2.4	6	312.7AB	32.6	---	---	---
Great Basin	7	1,285.4C	20.2	---	---	---	7	417.1AB	5.0	---	---	---	---	---	---	---	---	---

^a Means within columns with different letters are significantly different ($P < 0.001$).

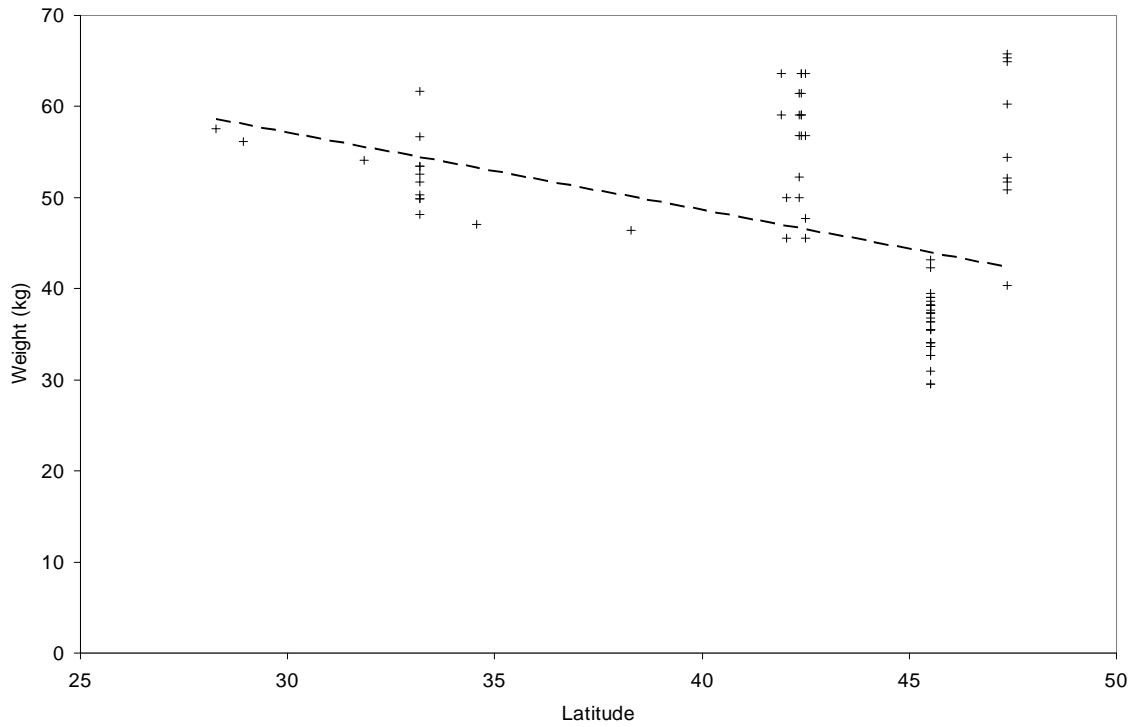


Figure 2. Relationship between male weight (kg, $n = 78$) and latitude for pronghorns collected throughout western North America, 1890-2006.

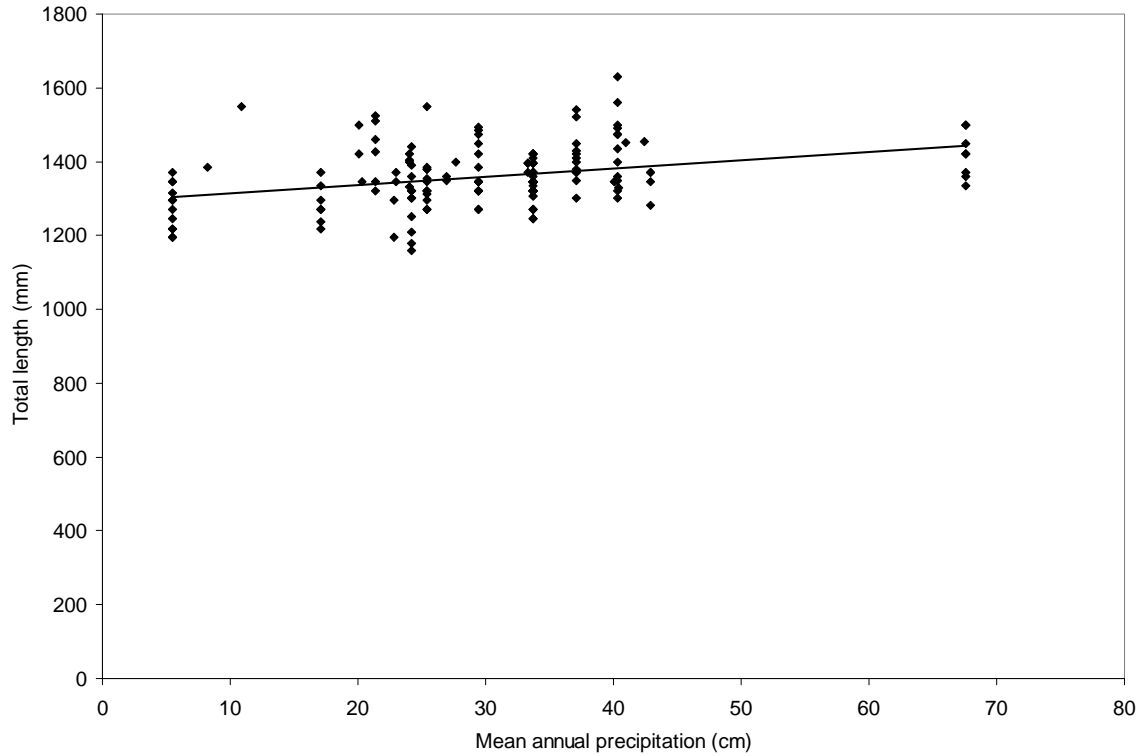


Figure 3. Relationship between total length (mm, $n = 172$) and mean annual precipitation (cm) for male and female pronghorns across western North America, 1890-2006.

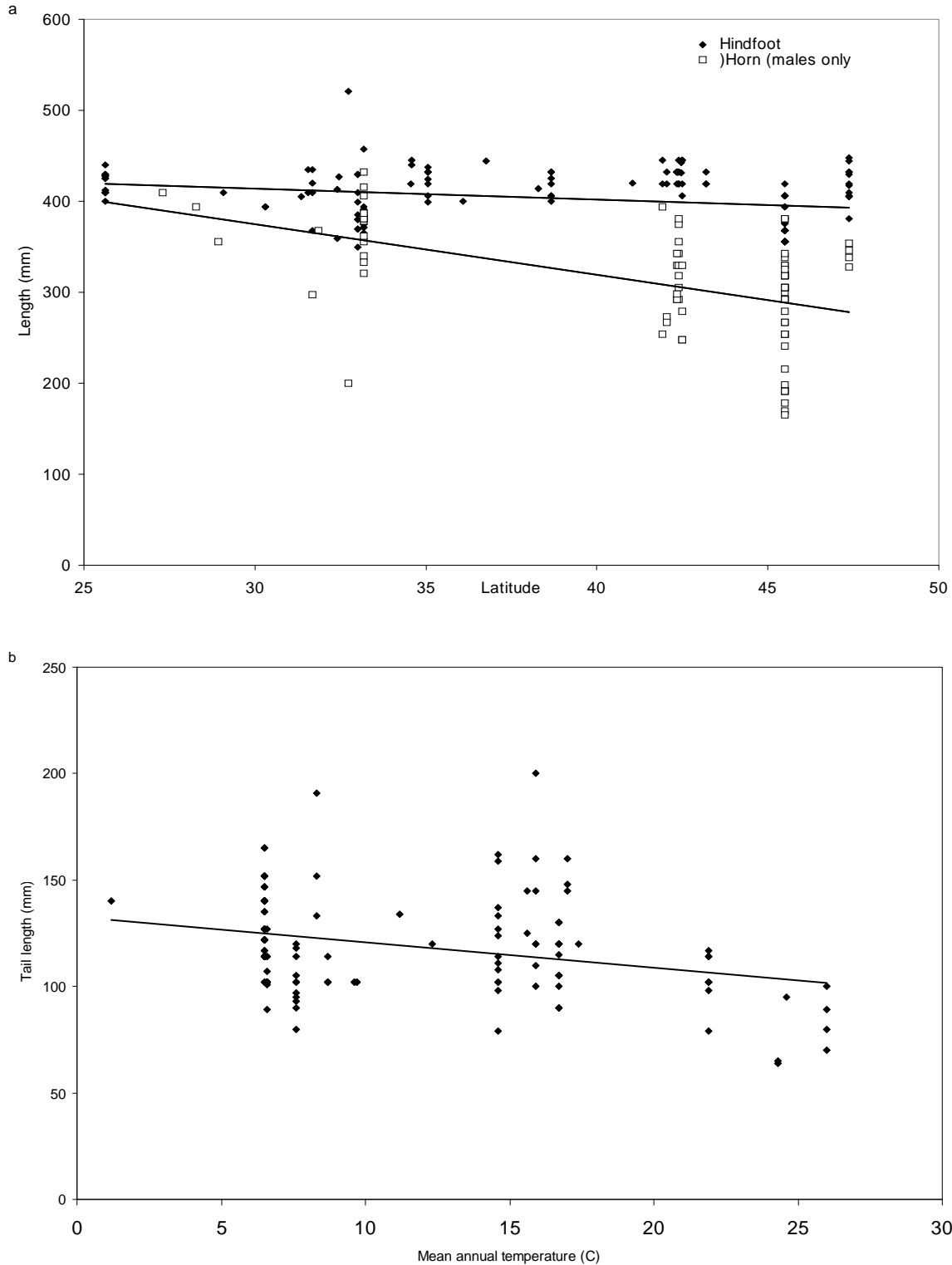


Figure 4. Relationship between length (mm) of (a) hindfoot ($n = 158$) and male horns ($n = 84$) and latitude and (b) tail ($n = 141$) and mean annual temperature ($^{\circ}\text{C}$) for pronghorns collected throughout western North America, 1890-2006.

Table 3. Standard body measurements (mm) for 4 subspecies of pronghorn males and females collected throughout western North America, 1890-2006.

Subspecies	Total length			Tail length			Hindfoot length			Ear length		
	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE	<i>n</i>	<i>x</i>	SE
<i>americana</i>	119	1,369.2	6.9	99	120.9A ^a	2.1	120	402.4	2.7	93	149.5	1.2
<i>sonoriensis</i>	23	1,347.5	22.5	14	99.0B	4.3	12	417.1	12.6	13	157.3	2.6
<i>mexicana</i>	20	1,394.9	13.3	19	115.6A	6.0	18	414.2	4.2	18	161.3	4.4
<i>peninsularis</i>	23	1,325.7	20.4									

^a Means within columns with different letters are different ($P < 0.001$)

In addition, we were not surprised to find differences in pronghorn from different biotic communities, which are classified by climate and vegetation. Temporal and spatial variation in weather, plant productivity, and subsequent nutrition can have major impacts on physical growth. Thus, pronghorn in desert communities, with lower mean productivity, tended to be slightly smaller than pronghorn from Intermountain Grassland communities.

Analysis by ecoregions also revealed some effects of productivity. We found slight differences among pronghorn populations in the Columbia Plateau, Northern Great Plains Steppe, Great Basin, Middle Rocky Mountains, Arizona-New Mexico Mountains, Chihuahuan Desert, and Sonoran Desert (Table 2).

Pronghorn may be the least variable North American ungulate, with the exception of mountain goats (*Oreamnos americanus*). Male and female mountain goats measurements vary by < 5% (Côté and Festa-Bianchet 2003). Pronghorn populations appear more uniform in size and color than those of bighorn sheep (*Ovis canadensis*, McTaggart-Cowan 1940), elk (*Cervus canadensis*, Murie 1951), mule deer (*Odocoileus hemionus*, Taylor 1956), and white-tailed deer (*O. virginianus*, Taylor 1956).

We found little support for Bergmann’s rule in our analysis because we found no significant relationship between body length and latitude. Male weights actually declined with increasing latitude. A better explanation for the slight variation in body lengths is provided by Geist’s rule in that pronghorn in wetter, and presumably more productive, habitats had significantly longer body lengths than those in more arid areas. This relationship is weak, however, and better tests examining measurements and productivity at more specific levels are needed.

Horn length was supportive of Allen’s rule, because animals at lower latitudes displayed significantly longer horns than that farther north. Although hind foot lengths weakly increased in warmer areas at lower latitudes, ear and tail lengths did not.

Morphologically, pronghorn “subspecies” did not differ significantly from each other. Variation within subspecies was as great as that between subspecies. For example, measurements of Baja California animals within the range of *A. a. sonoriensis* resemble *A. a. peninsularis*. If we compare only Arizona and Sonora examples of *A. a. sonoriensis*, non-peninsular or continental pronghorn are remarkably uniform in size. Such similarity suggests that

current subspecies designations, based primarily on morphology, are invalid or inaccurately delineated, particularly because various pronghorn subspecies were named on the basis of very few specimens (Merriam 1901, Nelson 1912, Bailey 1932, Goldman 1945).

Phenotypes are an expression of genetic characteristics, modified by environmental condition, and variance in both genetics and environment may affect phenotypic variance (Bull 1987). Because pronghorn size and extremities do not vary much across the species' range, pronghorn presumably have differentiated very little since Holocene times. These similarities in pronghorn morphology, coupled with universal similarity in pelage markings and color (Brown 2006), suggest a recent separation of populations. According to Allen (1877), the largest animals within a species are located near that species' evolutionary center. If so, morphometrics suggest *Antilocapra americana* evolved in the Intermountain West during Pleistocene times, expanding eastward and southward during Recent times.

We believe additional research on pronghorn body size might provide useful insights into local patterns of growth (e.g., Geist's rule) and changes over time. In addition to standard measurements, we suggest future studies also employ alternate measurements such as head length, incisor arcade, metatarsus:tarsus:femur ratios, and hind limb:body length ratios. Such measurements might not only serve to help identify unique populations, but also provide insights into ongoing regional adaptations.

Management Implications

This exercise and recent genetic studies (O'Gara 2004b, Stephen et al. 2005) suggest most pronghorn managers should be concerned more with adaptations of individual animals than with subspecies designations. Most pronghorn conservation efforts should concentrate on habitat rehabilitation and enhancement and should emphasize population rather than subspecies restoration. As such, any translocation stock should be composed of wild-trapped individuals taken from populations adapted as much as possible to conditions similar to the relocation area. Our work indicates populations of *A. a. mexicana*, *sonoriensis*, and *peninsularis* do not differ morphologically from each other or from *A. a. americana*. However, additional genetic work could determine if genetic differences are due to long-term selection or to more recent geographic separation, population bottlenecks, and genetic drift (Stephen et al. 2005).

Acknowledgments

We thank E. Anthonise, Arizona State University; G. D. Bills, Museum of Southwestern Biology; J. Dines, Los Angeles County Museum; E. D. Edwards, Armendaris Ranch; R. D. Fisher, National Museum of Natural History; J. Hervert, A. Munig, J. Wegge (retired), and J. Wills, Arizona Game and Fish Department; H. Garner, Texas Tech University; J. Gillette, Museum of Northern Arizona; D. J. Long, California Academy of Sciences; B. Patterson, Field Museum of Natural History; J. Patton, Museum of Vertebrate Zoology; J. Vargas, University of North America; and all of the museum curators who assisted us in our requests for morphological data.

Literature Cited

- Allen, J. A. 1887. The influence of physical conditions in the genesis of species. *Radical Review*. 1:108-140.
- Arizona Game and Fish Department. 1981. The Sonoran pronghorn. Arizona Game and Fish Department Special Report 10:1-55.
- Ashton, K. G., and C. R. Feldman. 2003. Bergmann's rule in nonavian reptiles: turtles follow it, lizards and snakes reverse it. *Evolution* 57:1151-1163.
- Bailey, R. G., P. E. Avers, T. King, and W. H. McNab, editors. 1994. Ecoregions and subregions of the United States (map). 1:7,500,000. With supplementary table of map unit descriptions, compiled and edited by W. H. McNab and R. G. Bailey. U.S. Forest Service, Washington, D.C., USA
- Bailey, V. 1931. Mammals of New Mexico. *North American Fauna* 53:1-412.
- Bailey, V. 1932. The Oregon antelope. *Proceedings Biological Society of Washington* 45:45-46.
- Bergmann, C. 1847. Ber die kverhältnisse der wärmeökonomie der thiere zu ihren grösse. *Göttinger Studien* 1:595-708.
- Brown, D. E. 2007. An evolutionary history of pronghorn habitats and its effect on species differentiation. *Proceedings 22nd Biennial Pronghorn Workshop* 22.
- Brown, D. E., and C. D. Mitchell. 2006. A preliminary analysis of pronghorn horn size in relation to environmental factors. Pages. 50-55. In *Managing Southwest wildlife*. The Wildlife Society, Southwest Section, Alpine, Texas, USA.
- Buck, P. D. 1947. The biology of the antelope (*Antilocapra americana*) in Montana. Thesis, Montana State College, Bozeman, USA.
- Büchner, H. K. 1950. Life history, ecology, and range use of the pronghorn antelope in Trans-Pecos Texas. *American Midland Naturalist* 43:257-354.
- Bull, J. J. 1987. Evolution of phenotypic variance. *Evolution* 41:303-315.
- Carr, J. N. 1971. Endangered species investigation—Sonoran pronghorn. Federal Aid Progress Report, Project W-53-21, WP-8, Job 1. Arizona Game and Fish Department, Phoenix, USA.
- Côté, S. D., and M. Festa-Bianchet. 2003. Mountain goat. Pages 1061-1075 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. *Wild mammals of North America: biology, management and conservation*. Johns Hopkins University Press, Baltimore, Maryland, USA.
- Dow, S. A., Jr. 1952. An evaluation of some criteria for age determination of the pronghorn (*Antilocapra americana* Ord). Thesis, University of Montana, Missoula, USA.
- Einarsen, A. E. 1948. The pronghorn antelope and its management. The Wildlife Management Institute, Washington, D.C., USA.
- Elliot, D. G. 1907. A catalogue of the collection of mammals in the Field Columbian Museum. *Field Columbian Museum Zoological Series* 115:1-694.
- Feldhamer, G. A., L. C. Drickamer, S. H. Vessey, and J. F. Merritt. 2004. *Mammalogy: adaptation, diversity, ecology*. McGraw Hill, Boston, Massachusetts, USA.
- Geist, V. 1987. Bergmann's rule is invalid. *Canadian Journal of Zoology* 65:1035-1038.
- Geist, V. 1998. *Deer of the world: their evolution, behavior, and ecology*. Stackpole, Mechanicsburg, Pennsylvania, USA..
- Goldman, E. A. 1945. A new pronghorn antelope from Sonora. *Proceedings Biological Society of Washington* 58:3-4.

- Hall, E. R., and K. R. Kelson. 1959. *The mammals of North America*. Roland Press, New York, NY, USA.
- Hepworth, W. G. 2004. Cited in *Physical characteristics*, Pages 109-143, in B. W. O’Gara, in B. W. O’Gara and J. D. Yoakum, editors. *Pronghorn ecology and management*. Wildlife Management Institute, Washington, D.C., and University Press of Colorado, Boulder, USA.
- Knipe, T. 1941. *The Anderson Mesa antelope hunt*. Project 9-R, Special Report, Arizona Game and Fish Commission, Phoenix, USA.
- Knipe, T. 1942. *Statistical report on the 1942 antelope hunt in northern Arizona*. Project 9-R, Special Report: antelope. Arizona Game and Fish Commission, Phoenix, USA.
- Knipe, T. 1944. *Statistical report on the 1943 antelope hunt*. Project 9-R, Special Report: antelope. Arizona Game and Fish Commission, Phoenix, USA.
- Mason, E. 1952. *Food habits and measurements of Hart Mountain antelope*. *Journal of Wildlife Management* 16:387-389.
- McTaggart-Cowan, I. 1940. *Distribution and variation in the native sheep of North America*. *American Midland Naturalist*. 24:505-580.
- Mearns, E. A. 1907. *Mammals of the Mexican boundary of the United States: a descriptive catalogue of the species of mammals occurring in that region; with a general summary of the natural history, and a list of trees*. U.S. National Museum Bulletin 56:1-530.
- Meeker, J. O. 2004. Cited in *Physical characteristics*, Pages 109-143 in B. W. O’Gara in B. W. O’Gara and J. D. Yoakum, editors. *Pronghorn ecology and management*, University Press of Colorado, Boulder, USA.
- Menzel, K. 1980. *Weights and horn measurements of Nebraska pronghorns—first seasons and twenty years later*. *Proceedings Pronghorn Antelope Workshop* 16:11-12.
- Merriam, C. H. 1901. *Two new bighorns and a new antelope from Mexico and the United States*. *Proceedings Biological Society of Washington* 14:29-32.
- Murie, O. J. 1951. *The elk of North America*. Stackpole, Harrisburg, Pennsylvania, USA.
- Murphy, R. C. 1917. *Natural history observations from the Mexican portion of the Colorado Desert with a note on the Lower Californian pronghorn and a list of the birds*. *Proceedings Linnaean Society of New York* 29:43-101.
- Nelson, E. W. 1912. *A new subspecies of pronghorn antelope from lower California*. *Proceedings Biological Society of Washington*. 25:107-108.
- O’Gara, B. W. 2004a. *Physical characteristics*. Pages 109-143 in B. W. O’Gara and J. D. Yoakum, editors. *Pronghorn ecology and management*. University Press of Colorado, Boulder, USA.
- O’Gara, B. W. 2004b. *Physiology and genetics*. Pages 231-273 in B. W. O’Gara and J. D. Yoakum, editors. *Pronghorn ecology and management*. University Press of Colorado, Boulder, USA.
- O’Gara, B. W., and C. M. Janis. 2004. *Scientific classification*. Pages 3-25 in B. W. O’Gara and J. D. Yoakum, editors. *Pronghorn ecology and management*. University Press of Colorado, Boulder, USA.
- Powell, L. E. 1953. *1952 antelope hunt information*. Project W-53R-3, Work Plan 2, Job 1, Completion Report. Arizona Game and Fish Commission, Phoenix, USA.
- Reichenbacher, F., S. E. Franson, and D. E. Brown. 1998. *North American biotic communities*. Map, scale 1:10,000,000. U.S. Environmental Protection Agency, Washington, D.C. and University of Utah Press, Salt Lake City, USA.

- Rice, W. R. 1989. Analyzing tables of statistical tests. *Evolution* 43:223-225. SAS Institute. 2004. JMP IN. Version 5.1.2. Cary, North Carolina, USA.
- Smith, A. D., and D. M. Beale. 1980. Pronghorn antelope in Utah: some research and observations. Utah Division of Wildlife Resources Publication 80-13:1-88.
- Sneva, F. A., and D. N. Hyder. 1962. Estimating herbage production on semiarid ranges in the Intermountain Region. *Journal of Range Management* 15:88-93.
- Stephen, C. L., J. C. deVos, Jr., T. E. Lee, Jr., J. W. Bickham, J. R. Heffelfinger, and O. E. Rhodes, Jr. 2005. Population genetic analysis of Sonoran pronghorn (*Antilocapra americana sonoriensis*). *Journal of Mammalogy* 86:782-792.
- Stevenson, R. D. 1986. Allen's rule in North American rabbits (*Sylvilagus*) and hares (*Lepus*) is an exception, not a rule. *Journal of Mammalogy* 67:312-316.
- Taylor, W. P., editor. 1956. *The deer of North America*. Stackpole, Harrisburg, Pennsylvania, USA.
- Tinker, B. 1978. *Mexican wilderness and wildlife*. University of Texas Press, Austin, USA.
- Wright, R. L., and J. C. deVos, Jr. 1985. Final report on Sonoran pronghorn status in Arizona. Arizona Game and Fish Department, Phoenix, USA.