The Holocene history of bighorn sheep (Ovis canadensis) in eastern Washington state, northwestern USA

R. Lee Lyman

The Holocene 2009; 19: 143
DOI: 10.1177/0959683608098958

The online version of this article can be found at:
http://hol.sagepub.com/cgi/content/abstract/19/1/143

Published by:

http://www.sagepublications.com

Additional services and information for The Holocene can be found at:

Email Alerts: http://hol.sagepub.com/cgi/alerts

Subscriptions: http://hol.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.co.uk/journalsPermissions.nav

Citations http://hol.sagepub.com/cgi/content/refs/19/1/143
The Holocene history of bighorn sheep (Ovis canadensis) in eastern Washington state, northwestern USA

R. Lee Lyman*

(Department of Anthropology, 107 Swallow Hall, University of Missouri-Columbia, Columbia MO 65211, USA)

Abstract: Historical data are incomplete regarding the presence/absence and distribution of bighorn sheep (Ovis canadensis) in eastern Washington State. Palaeozoological (archaeological and palaeontological) data indicate bighorn were present in many areas there during most of the last 10,000 years. Bighorn occupied the xeric shrub-steppe habitats of the Channeled Scablands, likely because the Scablands provided the steep escape terrain bighorn prefer. The relative abundance of bighorn is greatest during climatically dry intervals and low during a moist period. Bighorn remains tend to increase in relative abundance over the last 6000 years. Bighorn were present in eastern Washington in the nineteenth century, but were largely locally extirpated by the twentieth century. A collection of prehistoric bighorn astragalii that likely includes specimens spanning the terminal Pleistocene and the entire Holocene consists of specimens that are, with one exception, the same size as a collection of modern bighorn astragalii from Wyoming. The single exceptionally large specimen falls in the middle of the size range of specimens from the late Pleistocene of northern Wyoming, suggesting that Washington’s prehistoric bighorn, like those from other areas, were larger than modern bighorn.

Key words: Biogeography, bighorn sheep, chronocline, Holocene, northwestern USA, Ovis canadensis cat-clawensis

Introduction

When Taylor and Shaw (1929: 31) produced their provisional list of land mammals of Washington State (USA), they noted that bighorn sheep (Ovis canadensis) were at that time ‘nearly extirpated’ within the state but that this unglulate had ‘apparently [once occurred] not only in the mountains and foothills of the Cascade Range, but also on the plains nearby’. They could add no evidence to confirm Dice’s (1919: 20) earlier report that bighorn were thought to have previously occurred in the Blue Mountains of the southeastern portion of the state. Booth (1947: 605) later indicated that bighorn still occurred in the Wallowa Mountains of geographically adjacent northeastern Oregon, and though none had been seen in the Blue Mountains ‘in recent times, their former occurrence [there] is well substantiated’. He plotted two locations of bighorn sheep in Columbia County but failed to indicate the type and source of the data for those locations. Booth (1947: 607) also suspected that bighorn may have once ‘been common on the plains of [the Columbia Basin]’ (Douglas, Lincoln, Grant, Adams, Franklin and Benton Counties; Figure 1) but could offer no evidence to validate his suspicion.

Whereas Booth (1947) suggested bighorn had once occupied the ‘plains’ west of the Columbia River (the Yakima Valley?), Dalquest (1948: 405) speculated that bighorn had ‘in the past [occupied] the cliffs of the Columbia River Valley in eastern Washington’, including ‘the eastern or Columbia Plateau side of the [Columbia] river and therefore probably occupied the cliffs of Moses Coulee and Grand Coulee’. (Moses Coulee extends south-west through the centre of Douglas County. Grand Coulee is at the border of northwestern Grant County and the northeastern border of Douglas County.) Unique for his time, Dalquest (1948: 405) reported that ‘in caves along the Columbia River in [western] Grant County, bones of sheep [had been] found in association with stone arrowheads and other human artifacts’. Dalquest likely was referring to archaeological work taking place in the 1940s (eg, Collier et al., 1942; Osborne et al., 1952; Swanson, 1962).

Dalquest and Hoffmeister (1948) described 37 skulls collected in 1889 near Mount Chopaka in northernmost central Okanogan County (Figure 1). Perhaps it was this large sample that prompted Buechner (1960: 14) to report that bighorn ‘do not seem to have been exceptionally abundant’ in Washington except along the British Columbia border. He suggested that bighorn were likely absent from the lower Yakima Valley (in central Benton County) and virtually all of the southeastern fourth of Washington (Buechner, 1960). D.R. Johnson (1972) questioned a historic report of bighorn in the extreme northeastern portion of Pend Oreille County. In his synopsis of bighorn sheep in Washington, R.L. Johnson (1983: 115–16) listed 18 locations where bighorn sheep or their remains – typically an
isolated skull someone had collected – were known to occur or had been found. One of the locations Johnson (1983) listed was an archaeological record (Thomson, 1962), but he did not report all such records. The most recent synopsis of Washington State mammals does not include any reference to pre-1900 bighorn (Johnson and Cassidy, 1997).

In sum, the biogeographic record for bighorn in eastern Washington is of uneven quality; some of it is based on observed individuals, some on fortuitously collected specimens, some on hearsay. It is unlikely that the historic record will improve. Dalquest (1948) and Johnson (1983) identified another data source that continues to improve – the palaeozoological (palaeontological and zooarchaeological) record. Subsequent to their reports of archaeological materials, excavations by professional archaeologists have resulted in the recovery of numerous bighorn sheep remains from many archaeological deposits in eastern Washington. The prehistoric and early historic remains of animals recovered from palaeozoological excavations provide unprecedented data for studying historic biogeography.

In this paper I summarize the palaeozoological evidence for bighorn distribution and relative abundance in eastern Washington during the Holocene, or approximately the last 10,000 years in order to answer four questions. Were bighorn sheep present in Washington State in pre-Columbian (pre-sixteenth century) times? If so, did their relative abundance shift coincident with climate change, as did that of bison (*Bison* sp.) and wapiti (*Cervus elaphus*) (Lyman 2004a, b)? Third, why were bighorn rare in eastern Washington in the late nineteenth and early twentieth centuries? Finally, are prehistoric bighorn bones from eastern Washington larger than those of modern bighorn, as has been observed elsewhere in North America?

**Methods and materials**

I consulted all reports known to me concerning the Holocene palaeozoology of eastern Washington, a politically defined geographic area bounded on the north by British Columbia, the east by Idaho and the south by Oregon. I chose the crest of the Cascade Range as the western boundary, and used county lines that follow or approximate the east–west drainage divide to define that boundary (Figure 1). I recorded the number of identified specimens (NISP) (Grayson, 1984; Lyman, 2008b) of bighorn sheep at each archaeological site location when such data were reported; sometimes only the presence and not abundance of such remains was reported. A specimen is a bone or tooth or fragment thereof. Only those archaeological remains that were not modified into artefacts were recorded to avoid including bones and teeth that had been transported long distances from where animals were procured (Lyman, 1994); no palaeontological remains were recorded as none have been reported. Age of the remains was determined using stratigraphically associated radiocarbon ages, temporally diagnostic artefacts that were stratigraphically associated in the absence of the radiometric ages, or temporally distinct strata such as radiometricly dated volcanic tephra (eg, Lyman 2000a). For analytical purposes, standard zooarchaeological procedure was followed and the mid-point of the age range of deposits was used for statistical analysis (Lyman, 2003). Geographic locations of deposits that produced remains of bighorn were recorded by legal description (township, range) and also plotted on a map.

Because sampling of eastern Washington deposits that contain mammalian remains has not been probabilistic across geographic space (Lyman, 2002, 2004b), efforts to determine the prehistoric range of bighorn or to monitor changes in the distribution of bighorn must be tempered by knowledge that available samples may not be representative. The presence of remains of bighorn, particularly those of low socioeconomic value (minimal food value or useless as tool material) such as phalanges that are unlikely to have been transported far by prehistoric hunters (Lyman, 1994), may be viewed as evidence of relatively local origin (<10 km). The absence of remains may reflect local absence of the species, lack of preservation of bighorn remains or lack of recovery of bighorn remains as a result of minimal sampling (eg, Grayson, 1981; Lyman, 1994, 2002, 2004b, 2008a). Because bighorn were likely acquired by prehistoric hunters within several kilometres of the site of bone and tooth deposition, locations where bighorn remains have been recovered were mapped by township – a rectangular unit, usually 9.65 km × 9.65 km, used for legal geographic descriptions – rather than by individual recovery site. Each unique township that has produced remains of bighorn is noted regardless of how many locations or sites within that township have produced remains.

In general, the older a deposit in eastern Washington, the less intensively and extensively it has been sampled (Lyman, 2000a, b, 2004b). Thus I follow standard palaeozoological procedure (Grayson, 1984) and track abundances of bighorn remains relative to abundances of remains of other taxa across time and space. This analytical protocol circumvents potential depositional, preservational and sampling biases that may skew results (Lyman, 2008b). Nevertheless, detection of the influence of sample size gives reason to be cautious. All ages are given as radiocarbon years before present (RCYBP).

**Palaeoecology and ecology**

Analysis of recent crania of bighorn (Wehausen and Ramey, 2000) suggests the distributions of bighorn subspecies postulated by Cowan (1940) are incorrect. During the nineteenth and twentieth
centuries (the likely time when specimens studied by Wehausen and Ramey (2000) were deposited) all of eastern Washington State was, apparently, occupied by *Ovis canadensis canadensis* rather than *O. c. californiana*). Because modern subspecies designations tend to be based on characters that do not preserve in the palaeozoological record, I do not explore the issue of which subspecies was present prehistorically, with one notable exception.

Eastern Washington witnessed changes in climate during the Holocene that might account for variation in the relative abundance of bighorn during that time; forage quality and quantity have a direct bearing on the size of bighorn populations (Festa-Bianchet, 1988a, b, c). As the Pleistocene ended and the Holocene began about 10 000 RCYBP, summers became warmer and drier (because of evaporation) and winters became extremely cold (climatic history from Chatters, 1998). There was more grass and less shrub vegetation in the Columbia Basin than today. About 8500 RCYBP winters became warmer and wetter, but there was greater aridity overall and grass decreased and sagebush increased in abundance. Between 5500 and 3500 RCYBP climates cooled and moisture increased after 4500 RCYBP. After 3500 RCYBP climates remained cool and with abundant moisture, ground cover increased. After 2500 RCYBP climates warmed and some shrub steppe in the southeastern portion of the basin became more grassy.

Where the archaeological record of upland habitats is well known, such as in western Wyoming and adjacent areas (eg, Grant, 1981; Frison et al., 1990; McGuire and Hatoff, 1991; Frison, 2004), bighorn sheep were regularly exploited by American Indians. Bighorn were procured by interception and ambush along seasonal migration routes, and by communal hunts that utilized artificial drive lines that guided herds into elaborate enclosures and traps constructed of logs and boulders. Where sufficiently well preserved, it is apparent that drive lines and enclosures were constructed in such a way as to indicate intimate knowledge of bighorn behaviour, taking advantage of typical predator-escape behaviour on a particular area of landscape (Frison et al., 1990). These observations indicate two things pertinent to this study. First, indirect (non-faunal) evidence of bighorn may exist in the archaeological record. Second, archaeological remains of bighorn resulting from drives likely represent non-selective demographic cross-sections of bighorn populations.

### Results

Collier *et al.* (1942) and Osborne *et al.* (1952) were the first to report the recovery of bighorn remains from archaeological sites in eastern Washington. Collier *et al.* (1942) listed two sites that produced remains of bighorn and Osborne *et al.* (1952) listed two other sites, but both research teams had only a vague notion of the age of the remains. In the subsequent four decades 87 (of 91 total) more archaeological sites have produced remains of bighorn (see Lyman, 1995 and Parks, 2000, for partial summaries). These sites tend to be concentrated along the Columbia and Snake Rivers where the majority of archaeological excavations in eastern Washington have taken place (Lyman, 2002). As of mid-2007, archaeological and palaeontological deposits in 206 townships had been sampled (Figure 1). Not all sampled townships have produced mammalian remains, and the remains collected from some townships have never been identified or described in the literature (Lyman, 2004b). The studied and published record indicates that individual sites in 55 townships have produced remains of bighorn (Figure 1).

The historic records reported by Johnson (1983) and Johnson and Cassidy (1997) are largely restricted to mountainous terrain (Figure 1). Archaeological excavation has to date been limited in the boreal, subalpine and alpine habitats of the mountain ranges of eastern Washington. When faunal remains have been recovered from such settings, such as in Yakima, Chelan and Stevens counties, bighorn remains are not unusual (Figure 1). The prehistoric record thus supplements the historic record for this species in mountainous areas. Perhaps more interesting is the fact that, as conjectured by Dalquest (1948), bighorn remains found in the central Columbia Basin east of the Columbia River indicate that bighorn sheep once roamed this part of the state. In this case the prehistoric record markedly expands the historic record.

The oldest known bighorn remains in Washington State come from two sites. Seventeen bones and teeth (Lyman, unpublished data, 2003) of bighorn recovered from Sentinel Gap (official state archaeological site number: 45KT1362) in eastern Kittitas County date to 10 200 RCYBP (Galm and Gough, 2000). A single humanly butchered bighorn bone was recovered from an undated stratum at Marmes Rockshelter (45FR50) in northeastern Franklin County (Figure 1). It was recovered from deposits stratigraphically below a stratum dated to about 10 000 RCYBP (Gustafson and Wegener, 1999: 84). This specimen was likely deposited between 11 200 and 10 000 RCYBP as the oldest known artefacts from the site fall in this time span (Hicks, 2004). Bighorn remains have been recovered from other deposits dating to the last 7500 years (Table 1). The absence of bighorn remains dated between 7500 and 10 000 RCYBP is likely a result of inadequate sample sizes.

Artiodactyl remains present in palaeozoological collections under study here represent not only bighorn but deer (*Odocoileus virginianus* and *O. hemionus*), pronghorn (*Antilocapra americana*), wapiti (*Cervus elaphus*) and bison (*Bison antiquus* and *B. bison*). All of these taxa of large mammal were frequent prey of prehistoric human hunters (Lyman, 2003); some taxa represented in palaeozoological collections were not exploited by prehistoric humans. The frequency of bighorn remains per 500 yr interval correlates with the frequency of non-bighorn artiodactyl remains per 500 yr interval (Pearson’s *r* = 0.702, *P* < 0.005), suggesting that the frequency of bighorn remains at any given time is a function of sampling and analytical effort. Similarly, the frequency of bighorn remains per 500 yr interval correlates with both the frequency of radiocarbon dates (*r* = 0.656, *P* < 0.01) and the frequency of radiocarbon-dated sites (*r* = 0.702, *P* < 0.005) per 500 yr

### Table 1: Abundance (NISP, number of identified specimens) of bighorn sheep remains and other artiodactyl remains in deposits containing bighorn sheep remains per 500 yr time interval in eastern Washington State

<table>
<thead>
<tr>
<th>Age (RCYBP)</th>
<th>Bighorn NISP</th>
<th>Other Artiodactyl NISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–500</td>
<td>299</td>
<td>2705</td>
</tr>
<tr>
<td>501–1000</td>
<td>1221</td>
<td>3262</td>
</tr>
<tr>
<td>1001–1500</td>
<td>144</td>
<td>704</td>
</tr>
<tr>
<td>1501–2000</td>
<td>390</td>
<td>726</td>
</tr>
<tr>
<td>2001–2500</td>
<td>33</td>
<td>513</td>
</tr>
<tr>
<td>2501–3000</td>
<td>137</td>
<td>3152</td>
</tr>
<tr>
<td>3001–3500</td>
<td>395</td>
<td>1337</td>
</tr>
<tr>
<td>3501–4000</td>
<td>55</td>
<td>290</td>
</tr>
<tr>
<td>4001–4500</td>
<td>78</td>
<td>589</td>
</tr>
<tr>
<td>4501–5000</td>
<td>19</td>
<td>97</td>
</tr>
<tr>
<td>5001–5500</td>
<td>335</td>
<td>1441</td>
</tr>
<tr>
<td>5501–6000</td>
<td>12</td>
<td>127</td>
</tr>
<tr>
<td>6001–6500</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>6501–7000</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>7001–7500</td>
<td>1</td>
<td>164</td>
</tr>
<tr>
<td>7501–8000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8001–8500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8501–9000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9001–9500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9501–10000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10001–10500</td>
<td>18</td>
<td>29</td>
</tr>
</tbody>
</table>
interval (data from Lyman, 2000b). The frequency of radiocarbon dates and the frequency of dated sites are both good proxy measures of archaeological sampling intensity (Lyman, 2000a, b). Thus it would be unwise to infer anything about the absolute abundance of bighorn on the landscape, though the abundance of bighorn remains relative to the abundance of remains of other taxa can be monitored (Grayson, 1984; Lyman, 2008b).

All artiodactyl remains in assemblages of known age (N = 100) were lumped into temporal bins of 500 yr duration and the relative (percentage) abundance of bighorn remains among all artiodactyl remains was calculated (Table 1, Figure 2). The abundance of bighorn remains increases slightly over time relative to the total number of artiodactyl remains (Cochran’s test of linear trends Chi-squared = 35.26, P < 0.0001). Causes of this increase are unclear. It may relate to the warmer and drier climate of the last 2500 years. The relative abundance of bighorn remains is greater after 2500 RCYBP (21.5%) than between 4500 and 2500 RCYBP (11.0%) when climates were cooler and more moist. Deep snow (>45 cm) is avoided by some bighorn populations today (Titon and Willard, 1982). If much of the moisture between 4500 and 2500 RCYBP was snowfall, it may account for low bighorn abundances at that time.

Assemblages in which bighorn remains are abundant (>50% of the total artiodactyl remains) are located in or adjacent to rugged terrain such as the deeply incised Snake River canyon (one collection), Columbia River canyon between Douglas and Okanogan counties (four collections) and between Douglas and Chelan counties (one collection), Grand Coulee (two collections) and Moses Coulee (one collection) (between Douglas and Grant counties). Only one collection (in southeastern Kittitas County) with abundant bighorn remains is not in such a topographic location. The distribution of sites with abundant bighorn remains is significantly associated with rugged terrain (Chi$^2$ = 6.4, P < 0.025). It is likely that the assemblages with relatively high abundances of bighorn remains have those high abundances precisely because of the locations of the sites that produced the remains. The settings of those sites include predator escape terrain, a favoured variable of bighorn sheep habitats (Shackleton, 1985).

All archaeological collections in eastern Washington that contain remains of bighorn sheep derive from habitation sites rather than procurement or kill sites. Thus far no clear evidence of drive lines or enclosure corrals or traps have been reported in uplands adjacent to the sites (but see Lothson, 1998), or elsewhere for that matter, but that is likely the result of sampling error. Virtually no archaeological research has, for example, been done in the Blue Mountains of southeastern Washington, and very little has been done in the uplands adjacent to the river canyons of the northeastern portion of the state. Discovery of big game drive features such as those that have been found elsewhere (eg, Frison et al., 1990) would be indirect evidence for the prehistoric presence of bighorn in the area, as might prehistoric depictions of bighorn in the form of rock art (pictographs, petroglyphs) (eg, Keyser, 1992; Lothson, 1998).

Eight assemblages of faunal remains containing bighorn sheep are post-Columbian in age (< 500 RCYBP). Of these, four seem to date to the nineteenth century (< 150 RCYBP). One of the latter is adjacent to lower Grand Coulee, and two others are in southeastern Kittitas County. These are areas where historic records indicate bighorn were found in the last 200 or so years. Why were bighorn not more abundant and more ubiquitous at the end of the nineteenth century and beginning of the twentieth century? Archaeologists have often suggested several reasons for the historic low abundances of bighorn (Pippin, 1979; Frison, 2004). These include overhunting by American Indians equipped with rifles, overhunting by Euroamerican settlers, harsh winters and disease transfer from early historic livestock (Stelfox, 1971; Ebert, 1978). There were several harsh winters near the end of the nineteenth century that virtually wiped out local stockmen (Oliphant, 1932). These winters could have impacted local bighorn populations as well, and if those populations were already depleted and isolated from firearm hunting, then those winters may have been the final cause of their extirpation.

**Size of bighorn**

During the late Pleistocene the high rugged mountainous terrain of western North America was occupied by a now extinct form of bighorn sheep. Originally given species status by the palaeontologists who first recognized it (Hibbard and Wright, 1956), some palaeozoologists now consider the taxon a temporal subspecies – *Ovis canadensis catclawensis* based on its larger than modern average size (Harris and Mundel, 1974; Wang, 1984, 1988; Emslie, 1986), although not everyone agrees with this assessment (Gilbert and Martin, 1984; see especially Akersen et al., 2002). Detailed study of the morphometry of a large sample of skeletal remains suggests the temporal subspecies designation is reasonable (Lawler, 1992, 1996), and that is the designation I use here simply to designate the prehistoric large form.

The undated Moses Coulee Cave (45DO331) collection from southwestern Douglas County represents the largest collection of bighorn remains from any single site in eastern Washington, with more than 2500 specimens reported, the majority of which were accumulated by prehistoric humans who preyed on the sheep (Lyman, 1995). Temporally diagnostic projectile points suggest the cave was utilized by people during the entire span of the Holocene. The bighorn remains likely were accumulated throughout this time period. How do the sizes of those bighorn remains compare with modern bighorn and to *O. c. catclawensis*?

To determine if any of the Moses Coulee Cave bighorn remains were approximately the size of *O. c. catclawensis*, measurements of 15 dimensions of six kinds of well-preserved skeletal parts were taken. The 214 skeletal parts (distal humerus, proximal radius, proximal and distal metacarpal, distal tibia, proximal and distal metatarsal, astragalus) provided 408 measurements. Lawler (1992) presented size data for the same 15 dimensions from a sample of modern bighorn from Wyoming, and for those same dimensions of the *O. c. catclawensis* specimens from Natural Trap Cave, Wyoming. Hockett and Dillingham (2004) presented mean size data for ten of the dimensions as represented by a small sample of *O. c. catclawensis* remains from Mineral Hill Cave, Nevada. A ratio diagram (Simpson, 1941) was constructed using the mean size of modern bighorn bones as the standard (Figure 3). Mean size of *O. c.
At Natural Trap Cave (from Lawler, 1992) and at Mineral Hill Cave (Hockett and Dillingham, 2004) we replotted the individual measurements of Moses Coulee Cave specimens on the graph. Then, individual measurements of Moses Coulee Cave specimens were plotted on the ratio diagram. The ratio diagram (Figure 3) indicates several things. First, both samples of *O. c. catclawensis* specimens are, on average, larger than modern bighorn. Second, the Mineral Hill Cave *O. c. catclawensis* specimens are, on average, a bit smaller than the specimens from Natural Trap Cave. Third, most specimens from Moses Coulee Cave are approximately the same size as bones of modern bighorn from Wyoming. Fourth, most of the Moses Coulee Cave specimens are smaller than the bones from Natural Trap Cave, and many are smaller than those from Mineral Hill Cave. There are, however, two specimens that deserve closer inspection. One distal metacarpal is close to the average size of the Natural Trap Cave specimens, and one astragalus exceeds the size of an average Natural Trap Cave specimen. The distal breadth (DB) of the metacarpal specimen is significantly larger than the average modern bighorn (Student’s *t* = 3.066, *P* < 0.005, one-tailed test), and not significantly smaller than the average Natural Trap Cave specimen (Student’s *t* = 0.313, *P* > 0.5). However, the distal depth of this specimen is not significantly different than the average modern bighorn (Student’s *t* = 0.32, *P* > 0.5) and is significantly smaller than the average Natural Trap Cave specimen (Student’s *t* = 2.677, *P* < 0.01). Thus the metacarpal specimen cannot be confidently assigned to *O. c. catclawensis*, though it might represent that form given the overlap in size of that form with modern bighorn (Lawler, 1992, 1996).

The astragalus seems to represent *O. c. catclawensis*. It not only exceeds the mean size of specimens of this form recovered from Natural Trap Cave (Figure 3), but it falls well within the size range of those specimens and far outside the range of modern bighorn. I measured two dimensions (greatest lateral length, distal breadth; see von den Driesch, 1976) of 64 bighorn astragali (30 lefts, 34 rights) from Moses Coulee Cave. I also measured the same two dimensions on 61 astragali of modern bighorn sheep from

**Figure 3** Ratio diagram of bighorn sheep remains from Moses Coulee Cave (dots), *Ovis canadensis catclawensis* from Mineral Hill Cave (filled squares) and Natural Trap Cave (open squares) and modern bighorn from Wyoming (0.0 line). Points to the right of the 0.0 line are larger than an average modern bighorn, points to the left are smaller than an average modern bighorn. Some Moses Coulee Cave points do not show as a result of overlap. PB, proximal breadth (latero-medial); PD, proximal depth (antero-posterior); DB, distal breadth; DD, distal depth.
Wyoming; measurements of these dimensions on 78 astragali from Natural Trap Cave in north-central Wyoming were taken from Lawler (1992). All three sets of measurements are plotted in Figure 4, which indicates the majority of the astragali from Moses Coulee Cave are modern in size. The placement of the large Moses Coulee Cave astragalus in Figure 3 is based on one dimension. Figure 4 shows that this specimen is considerably larger than any modern bighorn and falls near the middle of the size range of Natural Trap Cave’s O. c. catclawensis sample in two dimensions, strengthening the taxonomic inference. This single specimen indicates that at least one individual from Moses Coulee Cave is of a size similar to Ovis canadensis catclawensis. The terminal Pleistocene through Holocene history of the chronocline of western North American bighorn sheep is poorly known, but it would not be unexpected, given that history for wapiti (Lyman, 2004b, 2006) and bison (Lyman, 2004a), to find some larger than modern bighorn in Holocene deposits. I therefore assign the large astragalus to O. c. catclawensis.

Specimens of O. c. catclawensis have been documented in Idaho (Akersten et al., 2002), Wyoming (Wang, 1984, 1988; Lawler, 1996), Colorado (Emslie, 1986; Wang and Neas, 1987), Nevada (Hockett and Dillingham, 2004), New Mexico (Harris and Mundel, 1974), and Arizona (Hibbard and Wright, 1956). The O. c. catclawensis specimen from Moses Coulee Cave is the first such specimen reported for Washington State.

**Conclusions**

Bighorn sheep were present in eastern Washington State during pre-Columbian times. Indeed, assuming inadequate samples from the early Holocene, available palaeozoological evidence suggests bighorn were present there during the last 10 500 (radiocarbon) years or so. The relative abundance of bighorn remains fluctuates over the last 4500 years in a manner related to climatic change; there are more remains when climate was drier and fewer remains when wetter. Bighorn remains tend to increase overall relative to remains of other artiodactyls over the last 6000 years. Bighorn were more abundant in eastern Washington than other artiodactyls in areas where rugged preditor-escape terrain was present. Available evidence is poor, but it seems likely that bighorn were rare in the nineteenth and early twentieth centuries as a result of firearm hunting, diseases introduced by domestic livestock and perhaps an exceptionally harsh winter or two. Finally, some prehistoric bighorn were, like those found elsewhere, larger than modern bighorn. Learning why they, like many other ungulates that survived the terminal Pleistocene, became smaller during the Holocene should be a research priority because the reasons may have implications for conservation biology.

**Acknowledgements**

Thanks to Danny Walker (University of Wyoming) for the loan of bighorn astragali, Bryan Hockett for the Mineral Hill Cave report, Jim Mead (Northern Arizona University) for a critical piece of information and Mark Lawler (Onondaga Community College) for a copy of his thesis and a reprint. Comments on an early draft by D.K. Grayson facilitated the revision process, and two anonymous reviewers identified several ways to improve the discussion.
References


Dalquest, W.W. and Hoffmeister, D.F. 1948: Mountain sheep from the state of Washington in the collection of the University of Kansas. Transactions of the Kansas Academy of Science 51, 224–34.


