Sierra Nevada Bighorn Sheep Herds: 2003 Status

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This report synthesizes population monitoring information for bighorn sheep herds in the Sierra Nevada developed over the past 2 winters and intervening summer. This is a synthesis of information collected as part of the Sierra Nevada Bighorn Sheep Recovery Program lead by the California Department of Fish and Game. We were greatly assisted in the collection of data by Greg Foote, Dave German, Dennis Jensen, Heather Johnson, and Cody Schroeder. Additionally, Erica Shockley and Marc Kenyon worked in the Mono Basin during the summer of 2003 under funding from the Yosemite Fund. This report will review prior information where needed to interpret data developed during this time period.

For numerous years a report has been produced at the end of each calendar year on results of population monitoring efforts for Sierra Nevada bighorn sheep. Because populations vary relative to the season (summer vs winter) when the best results are obtained, those reports have been compiled in the middle of the monitoring year, which begins in early summer following the births of new lambs, and ends in the spring. The result has been reports that, depending on population, cover two different monitoring years. This report takes the report from the end of 2003 and adds the data from the 2003-04 winter in an attempt to establish a more logical reporting schedule for these important data. As a result, it covers data from two winters and the intervening summer.

Efforts are made every year to develop some data on every herd in the Sierra Nevada. Over the years these efforts have used knowledge of habitat use patterns of each herd to attempt to count as many sheep as possible when they are most concentrated. Such counts all represent minimum numbers present by population, but those minima can vary greatly as to what percentage of the population was accounted for. Recent rapid increases in herd sizes, while very desirable, have made population monitoring more difficult in that each herd has a higher number of sheep that need to be found for a complete count. A result is that some counts are considered to be well below actual population levels. This judgement is based on the use of recorded numbers and reproduction in previous years tempered by potential mortalities. A concerted field effort was made the summer of 2003 to improve the data for two herds for which counts were considered inadequate in recent years: Mount Langley and Sawmill Canyon.

New information of particular note during this survey period was: (1) observation in January 2003 and March 2004 of the newly-discovered herd in Bubbs Creek on the west side of the Sierra Nevada; (2) the discovery in May 2003 that there were female sheep using the Lundy Canyon herd unit – a range expansion from the Mount Warren herd unit to the south; (3) the re-

occupation of the Sand Mountain winter range immediately south of Sawmill Canyon by sheep from Black Canyon in 2003; and (4) a long range movement south by a radio collared ram from the Mount Warren area to the range of extinct Convict Creek herd and his eventual return north to the Mono Basin.

The winter of 2002-03 began particularly early with a significant snow storm on November 9. It then snowed periodically in the mountains through most of December. However, winter storms then largely ended. In addition to scant further precipitation, January saw a lengthy period of warm weather, which hastened forage growth and thus the increase in diet quality on winter ranges. While this increased the attraction of winter ranges for sheep, it also gave sheep more options as snow melted on south-facing slopes to high elevations and some forage growth was initiated at higher elevations. In the absence of a good snow cover in late winter, the nutritional draw of winter ranges was not enough to consistently concentrate sheep at lower elevations where winter population monitoring takes place.

The winter of 2003-04 also began in the first half of November. In contrast to the previous winter, it did not largely end early in winter. While the winter of 2003-04 did have a large mid-winter break in storms, snowfall resumed in late February, including an important storm that covered high elevation areas that typically are blown free of snow. An important result was that in late winter and early spring, when sheep typically concentrate on low elevation winter ranges, there was considerable snow at elevations above those wintering areas – a condition that often leads to higher counts on winter ranges.

Below is a summary of pertinent information, organized by the herd units as defined in the Draft Recovery Plan. Where herd units include multiple demes of females, these are discussed separately. Monitoring efforts have been focused on determining numbers of females and measuring reproductive success.

Mount Langley Herd Unit

This herd has seen considerable growth since it hit an apparent low point in its reproductive base of 6 females in 1995. On the basis of prior data, as many as 16 adult and 5 yearling females were expected in 2002. Direct monitoring efforts in 2002 instead documented only 8 adult females, 2 yearling females, 5 lambs, and 2 yearling males, but there was ample evidence that others existed. This was verified by genotyping fecal samples from lambs, which yielded a total of 11 different genotypes. Because this was 6 more lambs than observed, those results indicated the existence of at least 6 additional adult females, for a minimum total of 14. Additional yearling females probably accompanied those additional adults. The expectation for 2003 based on data from prior years was as many as 21 adult females.

Only a brief appearance of part of this herd was recorded on winter ranges in 2003. That one group of sheep was first detected in Diaz Creek during a helicopter deer survey in the second half of March. It consisted of 5 adult females, 1 yearling female, 5 lambs, and two adult males, one of which was the male released at Mount Williamson 2 years prior, whose radio collar had already ceased to function.

In mid August of 2003 two observers were able, in one day, to count a total of 15 adult

females, 4 yearling females, 8 lambs, 2 yearling males, and 7 adult males in 3 separate groups. Those sheep comprised two female groups, one on the west side of the crest near the Major General and one in meadows at the top of the south fork of Tuttle Creek, and a group of males in Diaz Creek. Genotypes developed from 4 lamb fecal samples collected from the Major General group matched the 4 lambs seen in that group. Four additional samples from the area of the Tuttle Creek group yielded only 3 genotypes for the 4 lambs seen there. However, another 5 lamb samples from the region of the Tuttle Creek group yielded one additional genotype. A fresh (wet) lamb fecal sample collected from near the east end of Woolyback (south of Diaz Creek) 2 days after the three sheep groups were observed proved to be one of the lambs from the Major General group. Later in August a set of recent lamb fecal samples was collected in upper Diaz Creek. Six samples yielded 5 genotypes, none of which matched the previous genotypes. Clearly this was an additional group of sheep. The 5 additional lambs in it bring the minimum total number of lambs to 13 and the minimum number of adult females to 20. Undoubtedly there were some additional yearlings in that group as well and possibly more adult females.

In 2004, sheep in the Mount Langley herd unit used low elevation winter ranges more extensively than has been observed for numerous years. The first sheep seen in winter ranges were 2 adult males in the Diaz Creek winter range in late January, including a non-functional collar. By February 4 there were 10 sheep there, including the 2 males. One month later this group had grown to 16, including the 2 males seen earlier and an additional 2-year old male. An additional 8 sheep that included 2 adult males were in the Carroll Creek winter range at the same time. On March 19, the Diaz Creek group had grown to 21, but no longer contained the original two males, nor the 2-year old male. On that date 3 females were captured via net-gun and a helicopter. The total composition of the sheep accounted for in these winter ranges was: 13 adult females, 6 yearling females, 6 lambs, 2 yearling males, and 5 adult males for a total of 32. The 6 yearling females were 2 more than recorded the previous summer, which increases the minimum count of adult and yearling females to 26 for 2003.

Mount Williamson Herd Unit

This population has been notoriously difficult to monitor. The total number of sheep actually observed since 1996 is only 10. The past year was no exception; once again, no sheep were observed. Monitoring of this herd has depended on genotype data developed from droppings. In both 2001 and 2002, 7 different lamb genotypes were identified. Earlier genotype data indicated that more than 10 females existed in this herd.

Since 1996, data on the distribution of bighorn sheep sign on Mount Williamson has led to the hypothesis that the north ridge of Mount Williamson is the center of distribution for this herd. Climbing guide SP Parker corroborated this in 2002 by finding fresh droppings and beds of sheep on the top of that ridge during a winter ascent. On January 20, 2003 the north ridge of Mount Williamson and other potential areas that sheep might be using on the east side of that mountain were carefully surveyed by helicopter under optimal flying conditions. Noteworthy was the lack of any evidence of sheep. At the time, considerable snow still remained from earlier storms that would have readily revealed sheep via tracks. Also noted during that flight was the large amount of habitat along the crest of the range that had been cleared of snow by wind. Sheep clearly had numerous habitat options at the time.

Two investigations of this herd occurred during summer and fall in 2003. The first of these was a multi-day trip from South Bairs Creek to North Bairs Creek then over the north ridge of Mount Williamson to upper Williamson Creek and the Williamson Lakes. That trip ended with a survey of the Wright Lakes Basin. Notably less sheep sign was seen on Mount Williamson than in recent years, and the only evidence of lambs were droppings from what appeared to be two lambs in the lower Williamson Lakes Basin. No sign of sheep use was found in the Wright Lakes Basin.

The second trip was up Williamson Creek in the second half of October. Recent sheep beds were found low (7,400') in this drainage. Recent sheep sign also was found higher up (8,800'-10,500') on the north ridge of Mount Williamson.

Lamb fecal samples from the first trip produced 2 different genotypes. Lamb samples collected on the second trip produced only one genotype that matched one of those from the first set of samples. Thus, only two different lambs were documented for this herd in 2003.

During the winter of 2004 the Shepherd Creek winter range received extensive use by some sheep apparently beginning early in the winter, judging from sign seen there when first checked on February 10. Two sheep (1 female, 1 2-year old male) were seen of one ground survey but others in the same group might have been out of sight. Sheep sign indicated the existence of at least 1 lamb. Subsequent ground surveys failed to locate sheep again; but on 19 March 5 were seen from a helicopter.

Mount Baxter Herd Unit.

Bubbs Creek Herd

The existence of female sheep on the west slope of the Sierra Nevada in the Bubbs Creek area was brought to our attention in 2002. Field investigations that year verified that females and lambs were using that area, but failed to find any sheep. A ground survey in the spring of 2003 from Cedar Grove and two subsequent summer surveys at high elevations again failed to find any sheep. However, one of those summer surveys found very fresh evidence of females and lambs on Mount Gardiner, included fecal pellets that were still wet. DNA extracted from 9 lamb samples produced 7 different genotypes, indicating at least 7 adult females also. Frog researchers observed a group of female and young sheep west of the Glen Pass trail during the summer of 2003.

On 20 January 2003, this area was surveyed by helicopter under ideal flying conditions. That survey worked its way west along the snow-free ridge line of Mount Gardiner then ran a high contour west along the south-facing winter range in Bubbs Creek from the base of Charlotte Dome. Sheep were encountered at 7,900' just east of the confluence with the South Fork of the Kings River. Although the helicopter made numerous passes by these sheep, the nature of the terrain, elevation, and vegetation made it difficult even to count total numbers. The sheep broke into two groups and a few photos were successfully taken of the larger group. Those photos, coupled with what was recorded about the smaller group indicated that there were probably a total of 16 sheep. Two were young adult males (3-4 years old) and the rest were females, lambs and yearlings.

On 21 March 2004 this Bubbs Creek south-facing slope again was surveyed by helicopter. That range showed an abundance of green grass. Only 6 sheep were located: 1 ram at the base of Charlotte Dome and 4 females and 1 lamb further west. Early winter may be a better time for helicopter surveys of this herd.

Given the apparent independence of this group, it would be appropriate to call it a separate herd unit similar to the Sawmill Canyon herd unit. The first ever evidence of female sheep west of the Rae Lakes drainage was found in 1999. That was three years after a small group of females living in the Kearsarge Peak/Mount Gould area suddenly vanished unexpectedly. Given that information, the most likely explanation for the Bubbs Creek herd was a colonization by the Kearsarge Peak group around 1996. The two areas are directly connected by a high rocky ridge of excellent sheep habitat.

Black Mountain Deme

When the Sand Mountain winter range received high sheep use prior to 1987, those sheep were well documented to spread south along the crest in summer to Black Mountain and beyond. After those sheep began avoiding those low elevation winter range beginning in 1987, a small group of females discussed above was known to remain in the Kearsarge Peak area through winter and was treated as a separate deme. Since then it has been uncertain if the sheep that use Black Mount and Mount Mary Austin in summer have been the same sheep. Consequently, they have been treated as a separate demographic unit until pertinent data become available indicating otherwise.

Different genotypes obtained from fecal samples collected on Black Mountain during 2000 and 2001 suggested that there could be 9 different adult females using that area in 2002. In the summer of 2001, fresh fecal samples were collected just north of Black Mountain at the top of Oak Creek along the base of Diamond Peak from a female group that was then tracked north to the Baxter Lakes basin and located there. Six different adult genotypes obtained from that group failed to match any of those sampled on Black Mountain during 2000-01. The sheep using Black Mountain therefore have continued to be treated as a separate demographic unit.

During the summer of 2002, two female groups were seen on Black Mountain that, in combination, included 9 adult females. Other characteristics of the sheep in those groups suggested that they might have been independent groups. Accompanying those 9 females were 1 yearling female, 6 lambs, and 2 yearling males. Consequently, there appeared to be the potential for 10 adult females to be using Black Mountain in 2003.

Time constraints greatly limited the allocation of effort to the Black Mountain area in the summer of 2003. The only sheep seen consisted of 6 females and 5 lambs on Diamond Peak early in summer. An identifying characteristic of one female matched a female seen on Black Mountain the previous year.

During the 2003-04 winter, two females from the Mount Baxter deme were caught near the mouth of Black Canyon (see below), and genotyped. The genotype of one of them matched a Black Mountain genotype from 2000-01. That finding casts doubt on the validity of treating the sheep using Black Mountain and Mount Mary Austin as demographically separate from the

sheep using Baxter Pass and the region around Mount Baxter. That doubt is further fueled by failure to find any sheep on potential winter ranges on the east side of Mount Mary Austin. Those areas have been checked periodically since 1999 during periods of peak winter range use, including 2004.

Mount Baxter Deme

In July of 2002, 11 adult females, 4 yearling females, 5 lambs, and 3 yearling males were seen in the Baxter Pass region on a single day. Data from automated video cameras on Baxter Pass that summer did not document more than 5 lambs. Expectations for 2003 were consequently 15 or more adult females as the reproductive base.

Since the Mount Baxter herd began avoiding the Sand Mountain winter range in the late 1980s, most winter observations of sheep in this herd unit have been in and near Black Canyon, which topographically is safer habitat for sheep. However, a couple of females continued to visit the rockier winter range habitat on the northern edge of Sand Mountain immediately south of Sawmill Creek through the 1990s, but have not been seen there since 1999. That 4-year hiatus in the use of the Sand Mountain winter range ended in mid January of 2003, when a group of 4 females, 5 lambs, and a 2-year old male worked their way north of Black Canyon and crossed Sand Mountain to the same rocky area immediately south of Sawmill Creek. They remained there for 7 days until a female was netted from a helicopter and collared. Following that capture episode, those sheep returned to Black Canyon. However, some sheep again visited the north side of Sand Mountain at the end of that winter season.

Only 20 different sheep from this herd could be accounted for during the 2002-03 winter: 5 adult females, 3 yearling females, 5 lambs, 2 yearling males, 1 2-yr. old male, and 4 older males. It is possible that more than 5 different adult females were seen, but they were in groups seen sequentially and could not be distinguished individually. The five lambs were classified as 3 males, 1 female, and one too small to sex. Thus, this herd was not expected to recruit many yearling females in 2003.

Similar to Black Mountain, minimal time was allocated to the Mount Baxter area during the summer of 2003. One group of sheep was seen on the east side of Baxter Pass, consisting of 7 adult females (including the one collared on Sand Mountain the previous winter), 4 lambs, and 1 yearling male. Automated video cameras on Baxter Pass ridge recorded sheep for only one month before running out of film. Sheep were recorded on 10 days during that month and at 2 distinctly separate times on at least 2 of those days. Five different lambs could be documented at once in the camera footage, but the collared female, who had a lamb when seen in July, was never filmed. Twice a group of 2 females and 2 lambs that appeared to be the same pair of lambs were filmed independent of the larger group of females and lambs. They may have represented additional sheep, but this is not certain. Two different yearling males and 1 yearling female were filmed. Overall, the number of different females documented in this herd in 2003 was well below the expected number. This probably reflected less-than-optimal winter monitoring conditions and summer effort.

In contrast, the 2003-04 winter produced better opportunities for counting sheep, which began in early January. The highest count occurred on 27 February, when 28 different sheep

were classified as 9 adult females, 3 yearling females, 6 lambs, 3 yearling males, and 7 older males. While these counts constituted considerably more sheep than have been documented to use this winter range for more than a decade, numerous sheep in this population apparently were not included, considering the count of 15 adult and yearling females in the summer of 2002, which itself may not have included some sheep using the Black Mountain area.

Sawmill Canyon Herd Unit

Field data for this herd unit have been insufficient in recent years. Different genotypes identified from fecal samples collected between 1999 and 2001 along the mountain crest from Mount Cedric Wright to Mount Wynne have indicated that the number of females in this herd should well exceed 10. In contrast, the most females observed during recent summers have been 6 in 1997 and 1999. The numbers of females seen in the Sawmill Canyon winter range have not exceeded that number -- 6 in 1997, 2 in 1998, 2 adults and 1 yearling in 2001, and 4 adults and 1 yearling in 2002. The winter of 2002-03 was similar, despite a lengthy use of that winter range from early January to late March, during which only 3 different females were recorded there. One of those was caught in January and received a telemetry collar. She was very old, with incisors worn below the gum line, thus was likely about 20 years of age. She died in that winter range early the following winter.

Seven different genotypes were identified for 2001 lambs in the Sawmill Canyon herd, which was a notable increase relative to numbers of lambs known from the prior couple of years. No summer investigations of this herd occurred in 2002 due to an early snowstorm that prematurely terminated a trip there. Consequently, there was no information on numbers of lambs produced in 2002. Data collected in the summer of 2003 helped to rectify that data gap. Two groups of sheep were observed in one day north of Mount Perkins that totaled 16 sheep, of which 7 were yearlings (4 female, 3 male); thus, at least 7 lambs also existed in 2002. Accompanying those yearlings were 5 females and 2 lambs. Missing from these groups was the collared female, who was south of the Woods Lake Basin at the time. A subsequent trip to determine if she was accompanied by additional sheep failed to observe her. Consequently, again only 6 adult females were documented in this herd; but the 4 yearling females brought the total number of females to 10.

In early January of 2004, 14 sheep appeared in the Sawmill Canyon winter range. Details recorded for the sheep seen in September allowed the determination that 2 lambs and one yearling female in the January group were not among the sheep seen in September. The mothers of the 2 additional lambs similarly can be added to the summer minimum count, bringing the minimum number of adult and yearling females for 2003 to 13, the minimum number of lambs in 2003 to 5, and the minimum number of lambs in 2002 to 8.

During the 2003-04 winter only 5 adult and yearling females used the Sawmill Canyon winter range. Clearly, there are considerably more sheep in this herd than are using that winter range. In 2001, potential winter ranges that these sheep might use in the canyons of Division, Armstrong, Goodale, and Taboose Creeks were surveyed by helicopter with no sign of sheep observed. Similar helicopter surveys occurred twice in 2003, once on 21 January and again on 21 March. Again, no sheep or evidence of them was found.

The female caught at Sawmill Canyon in January 2004 did not use that winter range following her capture. She was finally located by helicopter with an uncollared female in the small winter range back in Division Creek in 21 March from a helicopter. Goodale Creek was again checked that day by helicopter and again yielded no evidence of sheep use.

Similar to the Mount Baxter herd, it appears that a significant proportion of the Sawmill Canyon herd continues to avoid low elevation winter ranges. Presumably, these sheep remain at higher elevations throughout winter and spring, but exactly where they are wintering remains unknown.

Wheeler Ridge Herd Unit

The Wheeler Ridge herd has shown steady population growth since hitting a low point in 1995. It currently is probably the largest herd in the Sierra Nevada. Extensive use of low elevation winter ranges by this herd since 1998 have aided monitoring efforts. However, counts in some recent years have been below what was expected based on prior data, and it has been suspected that this has resulted from some sheep remaining at higher elevations when the remaining sheep are best counted. The winter of 2002 was a prime example. During that winter only 24 adult and yearling females, 24 adult and yearling males, and 15 lambs could be accounted for, totaling 63,. Considerably more sheep were expected based on data from the previous year, including an additional 7 adult females. Further, the expected adult sex ratio would be weighted to females; thus, the observed equal sex ratio in 2002 also suggested that numerous females had been missed.

Winter 2003

Conditions during the winter of 2003 were not particularly different from 2002 relative to counting sheep. As usual, the most complete counts occurred in the first half of March. On March 9 and 10, 5 different sheep groups were found on the front country winter range, totaling 20 adult females, 3 yearling females, 11 lambs, and some males. On March 11, 5 yearling females were seen in Pine Creek, bringing the total for that class to 8, a number also counted for that sex/age class on February 26. Three days before the March 9-10 front country count, 4 lambs were seen in upper Pine Creek. While it is possible that 3 of those moved very quickly to the front country winter range and were counted there, this is doubtful given known movement patterns between those two areas. Consequently, those 4 lambs have been added to the 11 lambs seen in the front country, yielding a total of 15. For 13 of those lambs seen at sufficiently close range, sexes appeared to be 5 males and 7 females.

In addition to the adult females counted in the front country, 3 were seen consistently at that time in Pine Creek, including one with a radio collar (9.870). However, it was known that an additional two collared females (9.740 and 9.830) had remained above upper Pine Creek in Morgan Creek all winter. They appeared together with an uncollared female on March 16 and joined the other 3 adult females in upper Pine Creek. All 6 can reasonably be added to the 20 adult females counted in the front country 6 days earlier. Additionally, 5 different yearling males and 19 older males, including 3 that were 2 years old, could be accounted for that winter. This produces a total of 73 sheep (26 adult females, 8 yearling females, 15 lambs, 5 yearling males, and 19 older males), which is 10 more sheep than were counted the previous year. The 26

adult females are 2 more than would be expected from the count in 2002, which verifies that at least 2 females were missed that year. In 2003 the total yearlings counted was 13, which is 2 fewer than the number of lambs counted in 2002. The number of adult males counted dropped by 5 from the number of yearling and adult males counted the previous year. Four of those five can be accounted for as 2 that were translocated to Lee Vining Canyon in March of 2002 and 2 that were killed by a mountain lion during the winter of 2003.

On March 21, 2003 a helicopter again was used to look for sheep wintering at higher elevations on Wheeler Ridge. That survey covered all drainages in Pine Creek to Levergate Canyon in the low elevation (front country) winter range along the eastern escarpment. It was possible to survey well up to where continuous snow occurred at 10,000', but wind precluded looking at higher elevations in most canyons. The only sheep found were a couple high in the drainage above the last switchback to the Mill in upper Pine Creek – sheep that had already been accounted for. As usual, their presence was signaled by tracks in snow. The only other evidence of sheep were tracks at low elevation crossing a snow patch at the mouth of Huarte Creek, where sheep commonly are spotted from the road below.

Winter 2004

Minimum Population

For adult and yearling females, the highest minimum was obtained during a 1 March group count, when 24 adults and 6 yearlings were tallied. Nine of 12 marked females were seen on that survey. Of the 3 marked females not seen, 2 were in upper Pine Creek and are known not to have had any other unmarked females with them. The third marked female remained high at the north end of the front country winter range and was not seen until April when she joined other sheep in upper Wells Canyon. Consequently, it is not known how many other sheep might have been with her. Consequently, the minimum female count was 33, which is 1 fewer than known the previous year, despite 6 of the 33 being yearlings. Another concerted effort to find all collared females in early April netted 31 total females. A different marked female could not be located during that effort, leaving the minimum females for that count at 32.

The 1 March group survey yielded a total of 29 males, of which 3 were yearlings. That count lacked 1 marked male, which would increase the minimum total to 30. The subsequent count logged 5 yearling males, which would raise the minimum total for males to 32.

Mark-Resight Estimations

While the 2003 helicopter survey at Wheeler Ridge again suggested that few, if any, sheep were living back in canyons where they cannot be accessed during periods of good counts, the knowledge in 2004 that one collared female was not available to be counted raises the question of what proportion of the population is being missed in winter counts. The large number of marked sheep (esp. females) at Wheeler Ridge in 2004 allowed us to pursue this question to some extent using mark-resight estimation methods.

During the winter sampling period there were 12 marked females and 4 marked males at Wheeler Ridge. Sampling for these estimates required that observers not have specific

knowledge of locations of telemetered sheep, although not all marked sheep were telemetered.. The sampling for these estimates was initiated in two attempts by one individual to sample without the aid of telemetry, one in January and one in February. Those samplings were followed by a group effort on 1 March involving 5 different teams, and another group effort on 7 and 8 March involving 2 teams. Those early March counts produced the largest sample sizes because sheep were at their lowest elevations in that period. Three subsequent samplings were made by one individual between 27 March and 1 May. While the first 4 samples were drawn from Pine Creek and the lower elevation front-country winter range, the last 3 took place only in Pine Creek after most females had migrated back to that area.

For these analyses, lambs from 2003 were excluded and all yearling and older sheep were classified by sex and whether they were marked. Table 1 lists the data developed.

Table 1. 2004 mark-resight sampling results for the Wheeler Ridge herd.

Date	Total Females	Marked Females	Total Males	Marked Males
1/22	11	2	2	0
2/23	20	6	4	1
3/1	30	9	29	3
3/7,8	30	9	13	2
3/27,28	15	6	13	0
4/11	12	3	2	0
5/1	12	5	3	0

Only the March samplings produced enough males to be worth using for estimations of that sex. Males in the other 4 samplings largely were 1 or 2-year old sheep that accompanied females. The use of those samples would bias against marked males, because no young males were marked. We also recorded the identities of marked sheep seen and the resultant cumulative sighting frequencies for females (Table 2), which are one basis of a couple of estimators used.

Table 2. Cumulative sighting frequencies for marked females by sheep identity codes.

S1	S2	S3	S4	S5	S9	S17	S23	S25	S26	S27	S28
3	4	3	4	6	0	6	3	3	3	3	2

Mark-Resight Estimation Methods

Four different mark-resight estimators were utilized, of which 3 (joint hypergeometric, Minta-Mangel, and Bowden) can be calculated using the computer program NOREMARK, available from Gary White's website at Colorado State University (Neal et al. 1993). Two basic sampling approaches are possible: (1) sampling without replacement, which leads to the hypergeometric probability distribution; and (2) sampling with replacement, which leads to the binomial probability distribution. At each sampling episode, our sampling was without replacement. Sampling with replacement would ideally occur one sheep at a time. Because

sheep mostly occur in groups, this is not possible. However, a series of samples such as we obtained can be treated as an approximation of sampling with replacement.

The intuitive maximum likelihood estimator for mark-resight data is

$$N = Mn/m, \quad (1)$$

where N is the estimated population size, M is the number of marked animals in the population, m is the number of marked animals in the sample, and n is the sample size. This estimator has long been known to be biased because m and n cannot vary independently, leading to overestimates (Pielou 1974). Two standard unbiased estimators have been proposed. The Chapman (1951) estimator for sampling without replacement is

$$N = ((M+1)(n+1)/(m+1))-1, \quad (2)$$

and the Bailey (1952) estimator for sampling with replacement is

$$N = M(n+1)/(m+1). \quad (3)$$

Neal et al. (1993) developed the joint hypergeometric estimator (JHE) to calculate estimates and confidence intervals (CIs) for a series of samplings without replacement via an iterative approach. Jensen (1989) proposed a method to calculate CIs for the Bailey estimator that involved a normal approximation involving the reciprocal of the estimate (1/N). We used Jensen's (1989) method to calculate 95% CIs for Bailey estimates. We also developed true binomial confidence intervals. The Bailey equation can be rewritten as

$$N = M/((m+1)/(n+1)), \quad (4)$$

where the denominator (m+1)/(n+1) represents the estimated proportion of the population that is collared. That proportion represents a binomial sampling problem. Using a program that calculates binomial probabilities it is possible to find exact 95% CIs for (m+1)/(n+1); but this also must be done iteratively (Wenstøp 1988). We did this and inserted those interval values into equation (4) to produce 95% CIs for the estimate of N.

The Minta-Mangel and Bowden estimators contrast with the estimators based on hypergeometric and binomial probability distributions in that they use the distribution of resighting frequencies of individual animals (Table 2) to generate estimates and CIs. The limited number of adequate sampling episodes and marked males precluded the use of these estimators for that sex.

For all estimators, the lower 95% CI values were adjusted where appropriate to the minimum numbers of sheep known to exist for estimates based on samplings after that information was available.

Mark-Resight Results and Discussion

Estimates varied from 38 to 40 for females and 37-41 for males (Table 3). For females, the Minta-Mangel estimator produced the narrowest CI. The true binomial CIs for Bailey estimates were consistently narrower than the Jensen normal approximations. This difference was more extreme for males, because of the small proportion marked. The further that the marked proportion deviates from 0.5, the further the normal approximation of confidence limits is likely to deviate from the true binomial confidence limits. For males, the Bailey estimator with the true binomial approach produced the narrowest CI. CIs for males were notably greater than for females because of the lower sample size and low proportion marked (Table 3).

We also examined results for females as a function of sample size. The decline in CIs with increasing sample size is curvilinear (Fig. 1). Once sample sizes reached about 60, the JHE yielded consistently narrower CI widths than the binomial approach (Fig. 1). This seems appropriate given that the sampling without replacement used at each episode best fit the JHE. CIs for the Bowden estimator closely paralleled the binomial values, but were slightly larger. The Minta-Mangel estimator produced the narrowest CI widths coupled with the highest estimate, but White (1993) noted that Minta-Mangel CIs do not give adequate coverage in simulations.

Table 3. Estimates and 95% confidence intervals by sex and method.

Sex	Estimator	Estimate	95% CI
female	joint hypergeometric	39	35-46
female	Minta-Mangel	40	35-45
female	Bowden	39	31-50
female	Bailey/Jensen	38	33-51
female	Bailey/true binomial	38	33-48
male	joint hypergeometric	41	32-92
male	Bailey/Jensen	37	32-123
male	Bailey/true binomial	37	32-78

Population estimates for females exhibited a declining pattern with increasing cumulative sample size, rather than convergence (Fig. 2). It is not clear that the decline had stabilized entirely by the final sampling. This trend in estimates is due to an increasing proportion of marked females as the sampling progressed. For the first 4 samples, 28.6% of the females were marked, which rose to 37.8% for the final 3 samples. This trend could be due to sampling bias(es) early and/or late in the sampling, chance events, or both. The 12 marked females represent approximately one-third of the minimum and estimated number of females. Thus, for each marked female there should be approximately 2 unmarked ones. The two largest samples

from early March accounted for nearly half the total sample. In each of those samples two marked females in Pine Creek were not seen. Based on the regular monitoring of those females in that time period via telemetry, it is known that there were no unmarked females with them or in that area that were not seen. This suggests that those influential samples may have underestimated the proportion of females marked and contributed to an early overestimate of the population size. If so, the population estimates from the cumulative sample may have been an overestimate. However, it is also possible that the female sub-populations sampled in Pine Creek in the final 3 samples had a higher proportion of collars than the overall population and produced an opposite bias.

While Figure 2 suggests that there was a sampling bias problem, the results of this exercise nevertheless indicate that there were likely more females than the minimum of 33 that the sampling this winter could account for. In 2003, 34 different females could be accounted for. With 6 yearling females added to the population in 2004, the expected population size would be about what the mark-resight estimates yielded. If so, the minimum count in 2004 missed about 13% of the females.

It is difficult to completely meet all assumptions of mark-resight estimation for bighorn sheep in locations like Wheeler Ridge. Every individual should be equally available to be seen during the samplings. This was clearly not the case. The marked female that remained high throughout winter was unavailable for any of the samplings because of her location. Similarly, in the later samples, the females that remained longer in the front country winter ranges were relatively unavailable to be sampled because they were at higher elevations that would be difficult to access. If sheep that are unavailable to be sampled occur in the same marked to unmarked ratio as in the overall population, violation of the assumption of equal availability will not affect the estimate. Alternatively, estimates will be biased to the extent that unavailable sheep deviate from that ratio. It would be difficult to assess such biases. Samples developed when sheep are at high elevations in summer and early fall might have a lower tendency for bias. However, the lack of marks on these sheep that will be clearly identifiable at greater distances largely precludes the development of such estimates. Despite uncertainties about potential biases in mark-resight estimates, this method is useful for evaluating the approximate proportion of the population missed in minimum counts.

A total of 16 lambs was accounted for in the Wheeler Crest herd during this past winter. When combined with the minimum of 65 adults, the minimum total population size is 81. Our mark-resight estimates suggest that the total population of sheep on Wheeler Crest was higher than 81 and may have even exceeded 90.

Long Term Patterns

The lowest mark-resight estimates of 38 females for 2004 suggest that 5 females (13%) may have been missed in the minimum count. Data from the winter of 2003 verified that at least 2 females were missed the previous year, indicating a minimum count in 2002 no better than 92% of the total females. Thus, it appears that the efficiency of recent minimum counts is around 90%. While data for the first 4 years of recovery of this population appear to have

accounted for every female (Fig. 3), this was in part due to reconstructed population sizes possible because of occasional excellent census conditions and low numbers overall. During the first 3 of those years, prior to the beginning of re-occupation of the front country winter ranges, minimum count efficiencies for females (relative to reconstructed populations) varied from 75% to 86% and averaged 80%. For a much larger Mount Baxter herd population, when it made high use of the Sand Mountain winter range, Wehausen (1987) estimated that efficiencies of minimum counts varied mostly between 70 and 100% depending on winter forage and snow conditions, with an average of about 86%. Mount Baxter and Wheeler Ridge herd data are consistent relative to the general range of efficiencies of minimum counts.

We investigated how large the discrepancy was between the numbers of adult females projected to exist in the Wheeler Ridge herd and the numbers accounted for since 1996, using reconstructed (corrected) population figures where available. The number of yearling females counted each winter was added to the number of adult females projected for that winter (defined as beginning in January) to produce the projection for the next winter. The resulting trajectory is what would occur if there were no adult mortality of females (Figure 3).

As noted in monitoring reports from prior years, projected and actual numbers did not differ for 4 years from 1996 to 1999. Thereafter there is an increasing difference (Figure 3). By 2002 and 2003 the cumulative difference had grown to 8 females and in 2004 it jumped to 15. From 2000 to 2003 this difference amounted to an average loss of 2 per year, which could be due to mortality alone (average annual mortality rate of 9.6%). One of those would be the old floppy-collared female translocated to Wheeler Ridge in 1986 as a yearling and seen alive until 2001. In 2003, a telemetered female was documented to die in a rock slide in late spring. Other such deaths are inevitable in the particularly steep terrain used by sheep on Wheeler Ridge.

Similarly, the combination of telemetered sheep and telemetered mountain lions allowed the documentation of the loss of 4 adult males to one mountain lion during 2003; and an additional 3 males and a lamb are known to have been preyed on by a different mountain lion in 2003 and 2004. Other such losses may have gone undetected in previous years. Additionally, 4 adult males have been removed from this population since 2001 in translocation efforts. This cumulative loss of males would be expected to skew the sex ratio in favor of females. Further, for 73 different yearling sheep accounted for in winters since 1995, there have been 5 more females than males. Yet, the sex ratio appears to remain at nearly 1:1. This suggests that there has been considerable undocumented mortality of females. However, the notable jump in the discrepancy between projected and counted adult females in 2004 is likely due substantially to uncounted sheep, as indicated by the mark-resight results. In short, while some of the differences between the projected number of females and the number counted (Figure 3) may be missed sheep, much of that difference is probably due to mortalities.

The population trajectory for females is relatively linear overall, rather than showing an initial exponential increase that might be expected. Only during 1999-2003 does it show a slight hint of an exponential curve (Figure 3). For 1998-2003, the finite annual increase rate for this population has varied from 14.2% to 20% and averaged 17.3%. Only in 2003 and 2004 has the total number of females (including yearlings) clearly exceeded 30.

These figures have important relevance to the use of this herd as a source of translocation stock. Of similar relevance is the pattern of lamb recruitment, measured as winter ratios of lambs per 100 adult females. That measure had a declining pattern as the population first began increasing, then increased strongly for 3 years coincident with the winter habitat expansion to the lower elevation front country winter ranges (Figure 3). That expansion of habitat use occurred over a few years, and by 2000 all known females used that front country winter range to some extent, leaving a brief period when no females could be found in Pine Creek. Since then, there has been a trend in the opposite direction. In 2003, about one-third of adult and yearling females were in Pine Creek in early March, which was previously the time of maximum use of front country winter ranges when sheep were absent from Pine Creek. A significant portion of those females clearly never left Pine Creek that winter, of which a few carry functional radio collars.

Correlated with the recent reversal in low elevation winter range use has been a consistent decline in winter lamb recruitment ratios (Figure 3). What is driving the decline in this ratio is not entirely clear. Telemetered females have shown consistently high rates of lamb production, and include 3 of the females that are avoiding the front country winter range. Some sheep remaining in Pine Creek also have benefitted to small extent from supplemental feeding with alfalfa as part of attempts to catch them. The recent decline in lamb recruitment rates may reflect a larger scale density-dependent factor involving summer habitat. The overall recruitment pattern (Figure 3) suggests different density-dependence relationships depending on whether sheep use front country winter ranges. Regardless of the cause(s) of this pattern, it too will have important ramifications relative to harvesting strategies of the Wheeler Ridge herd for translocations. If the current declining lamb recruitment trend continues, the carrying capacity for this herd will be considerably lower than the 100 females used in the development of recovery goals for Sierra Nevada bighorn sheep. Similarly, these results suggest that it will be appropriate to lower estimates of carrying capacities for other herd units.

Mount Gibbs Herd Unit

The small size and predictable summer habitat use patterns of this herd have allowed it to be monitored readily every year. In 2002 this herd contained 3 adult females, 1 lamb, and 1 yearling male. This summer the composition was identical. This year we received a number of reports of 5 adult males in this herd unit, including one on Mount Lewis. A male from Mount Warren that received a radio collar in May 2002 dispersed south in November of 2002 to Bloody Mountain, just south of Mammoth Lakes. He remained in that area until fall of 2003, then suddenly moved back north. On his return he took up temporary residence in the Mount Gibbs area during the breeding season, and may have contributed to the genetic diversity of this small herd.

Mount Warren Herd Unit

Mount Warren Deme

Despite its small size, this group of females has been very difficult to track since 1998 in that sheep there cannot be found consistently, in contrast to years prior to 1999. In 2001, 3 females and 2 lambs were observed. In 2002, Les Chow and Erica Shockley of USGS BRD and Yosemite National Park observed 7 sheep north of Mount Warren which were classified as 3 females, 2 yearlings, and 2 lambs. In early October 2002, a group of sheep appeared on Tioga Crest at Dore Pass which was thought to be the group from Mount Warren. However, its composition (4 adult females, 1 yearling female, and 3 female lambs) differed a bit from what had been observed at Mount Warren earlier in the summer. It has now been established that the Dore Pass group included sheep seen the next spring across Lundy Canyon (see below). An unfortunate consequence of earlier misinterpretation of that Dore Pass group as from Mount Warren was that no further attempts were made in 2002 to collect droppings from sheep using Mount Warren.

In 2003, numerous surveys were made of the Mount Warren area during summer and fall by various personnel. No sightings of females and associates were made, nor was any sign of such sheep found. An adult male group was observed on multiple occasions in the Lamb-Ewe Basin area (west of Lee Vining Peak), consisting of as many as 7 individuals, including the remaining telemetered one.

Two adult males translocated to this area in March of 2003 showed tendencies to remain together but separate from the existing Mount Warren males. In early December of 2003, one of those two translocated males ran into a moving vehicle on Highway 395 on the south side of Conway Summit while attempting to disperse to the east. He suffered some damage that somewhat impaired the use of his hind legs, but initially showed normal feeding patterns. However, he died a month later. Early in the winter of 2003-04 a dog severely damaged an adult male in Lee Vining Canyon and that sheep had to be euthanized.

In early April, adult males that winter above Deer Creek again appeared in the Lee Vining Canyon winter range and reached a high of 7 later that month. In early May, 3 of those were captured via net gun, but one had to be euthanized due to injuries incurred at capture.

No females have been recorded in the Lee Vining Canyon winter range since 1998, but early in 2004 a female and lamb were seen on the east side of Warren Fork. They might have been from Tioga Crest.

Tioga Crest Deme

A small group of females on Tioga Crest has been monitored since 1995. In 2002 they consisted on 2 adult females, 2 yearling females, and a 2-year old male. This year that group

contained 4 adult females and 3 lambs. In March one of the older females was netted from a helicopter on Dore Pass and received telemetry collars. Important information learned from that collar was that these sheep use the slopes west above Warren Fork more then previously known. That female bore her lamb there in spring and was part of a group that spent time there later in the summer as well.

That collared female died at the south end of Tioga Crest early in the winter of 2003-04, apparently from a fall when snow was deep. Despite her loss, 4 females and 3 lambs were seen on Dore Pass at the end of March.

Lundy Canyon Herd Unit

Lundy Canyon has been a focus for some years as a likely place for a natural population expansion to occur. In past years male sheep have been recorded there occasionally, but not females. During the 2002 fall breeding season males were again documented on the north side of Lundy. Because that observation was during the breeding season, it suggested the possibility that females were present. In early May of 2003, 3 adult female sheep and 2 yearlings (2002 lambs) were observed on the north side of Lundy Canyon. Considerable subsequent effort led to a count of 11 different sheep during the summer of 2003: 5 adult females, 2 yearling females, and 4 lambs. Similarities with the unexplained group of sheep observed on Dore Pass in October 2002 led to tests for genotype matches between those two groups using fecal samples. Four genotypes from the Dore Pass sheep matched individual later sampled across Lundy Canyon. In early fall of 2003, a group of sheep exactly matching the composition of the Lundy Canyon sheep again was observed in the Dore Pass area. Apparently that group of sheep continues to move between those two areas.

Between 1998 and 1999, most females and associated sheep disappeared from Mount Warren. Unlike previous overwinter losses, that population change was unexpected because it followed a mild winter. In the summer of 1999 the first author walked the northern ridge top of Lundy Canyon from Excelsior Peak to Lundy Lake seeking evidence that sheep might have moved to the north side of Lundy Canyon that year or in earlier years. Any sheep there were expected to gravitate to the ridge top where beds and other evidence of sheep would be encountered. No such evidence was found. In 2003, the first author again walked the same route and found ample evidence of sheep. The sheep sign there and lower in the canyon suggests that these sheep have been using the north side of Lundy Canyon for at least a few years.

The apparent mobility of sheep using Lundy Canyon stimulated tests for genotype matches with samples collected from the Mount Warren area in 1998 and subsequent years. One of the adult females sampled on Dore Pass and Lundy Canyon in 2002-03 matched a 1998 sheep from Mount Warren. Additionally, 2 more genotypes of adult females in Lundy Canyon matched genotypes from fecal samples collected near Mount Warren -- a female lamb in 1999, and an adult in 2001. Given that only a single adult female could be documented in the Mount Warren area in 1999, it is probable that expansion to Lundy Canyon occurred between 1998 and 1999, and that these sheep have been moving throughout this region since then. This would explain the unpredictability of females in the Mount Warren area after 1998.

Considerable effort was focused on the north side of Lundy Canyon during the 2003-04 winter and subsequent spring. The only sheep that could be found were 2 adult males that remained there throughout that period. It appears that Lundy Canyon can be as unpredictable as Mount Warren for finding females. The finding of an extra female on Dore Pass in late March and a female and lamb on the east side of Warren Fork in early winter may reflect the movement of Lundy Canyon sheep in that direction.

A small amount of survey work in 2003 looked at potential habitat further north from Dunderberg Peak to Matterhorn Peak. A few beds in the talus on Dunderberg Peak suggested that some sheep already had moved out the ridge from Excelsior Peak that connects those two peaks. This was verified during the winter of 2003-04, when a telemetered male spent the winter on the north side of Dunderberg Peak. While some possible sheep sign was found further north, this possibility needs further investigation.

Synthesis

Total Population Size

Working from a conservative estimate of 250 total sheep in 2001, the total bighorn sheep population in the Sierra Nevada was projected to be greater than 300 in 2002 (Wehausen 2002). In arriving at that figure, it was noted that (1) known lamb numbers for the 3 southern herd units alone totaled 30, (2) there were an additional 11 sheep in Bubbs Creek not known in 2001, (3) genotyping data suggested that there were at least 5 more females in the Sawmill Canyon herd than known in 2001, and (4) additional lambs in the remaining herd units would add considerably more sheep.

That projection can now be re-evaluated using additional data obtained since 2002. First, the 11 sheep in Bubbs Creek can be increased by 5. Second, the total number of lambs in 2002 was at least 60 – twice the 30 known at the time. Third, the 5 adult and yearling ewes in the 2002 Dore Pass group can be added as previously unknown sheep. Combined, those gains would add about 80 to 250, yielding 330. To arrive at a new population estimate, mortality losses need to be subtracted from that sum. Those losses are largely unknown. Evidence from the Wheeler Ridge herd suggests that survivorship may be 90% or lower in some years. Nevertheless, a minimum of 300 remains a conservative estimate for 2002.

To continue to make estimates in that way risks the compounding of errors, since each successive estimate is based on the previous. It is necessary to anchor figures for each herd to a solid count every few years to prevent such errors from resulting in a significant deviation from the correct number. Because monitoring efforts focus on females, there are few data on males for many herds. This reduces the reliability of total population estimates. At least 57 lambs are known to have existed in the summer of 2003. However, there have been some known mortalities in 2003 and undoubtedly many unknown losses. While there were certainly further population gains overall from 2002 to 2003, a conservative projection would put the total

population in 2003 between 300 and 350, perhaps closer to 350.

Table 4. Known reproductive bases (adult and yearling females) for herds or demes, 2002-03.

Herd or Deme	**Reproductive Base**	**Year of Data**
Mount Langley	26	2003
Mount Williamson	12?	2002
Bubbs Creek	8?	2003
Black Mountain	?	2002
Mount Baxter	15	2002
Sawmill Canyon	13	2003
Wheeler Ridge	38	2003
Mount Gibbs	3	2003
Mount Warren	?	2002
Tioga Crest	3	2003
Lundy Canyon	7	2003
TOTAL	125	

A more meaningful population figure is the size of the reproductive base – adult and yearling females. The draft recovery plan uses that category as the basis for recovery goals. Table 4 lists mostly reliable numbers of adult and yearling females from the past two years by demographic units that total 125 females. Dates associated with data represent the second half of each year after the previous year's lambs have become yearlings. Because of current uncertainty concerning the independence of sheep using Black Mountain in summer, no figure was allocated to that groups. That risks under-representing the total. Similarly, because some of the values are a year out of date for populations that are increasing overall, the total should be viewed as a minimum, conservative figure. The total of 125 is approximately one-third of the recovery goal number in the draft recovery plan. This does not consider the geographic distribution that the recovery plan mandates. From another perspective, 125 females represents more than a tripling of the 38 females known to exist in 1998 when the decision was made that federal endangered status was needed for these sheep.

Future Data Collection

There are a number of holes in the monitoring data for Sierra Nevada bighorn sheep herds. One that has plagued us continually is the Mount Williamson herd, for which almost everything currently known comes from fecal genotyping. There is a need to allocate more overall effort to this herd to try to understand more about patterns of habitat use. A day trip up Williamson Creek in October 2003 was very educational. It may be beneficial to allocate more

time to both sides of the north ridge of this mountain in Williamson and North Bairs Creeks in a variety of seasons.

Most of the Sawmill Canyon herd sheep do not use the Sawmill Canyon winter range. It would be desirable to determine if any of those sheep are descending at all to lower elevations in late winter or spring. Helicopter surveys have failed to find them in likely winter ranges up through March. However, in the past some herds have shown elevation descents later in spring. This was once evident in Lee Vining Canyon, where winter range use by many females increased considerably in April. For higher elevation ranges like Lee Vining Canyon, this later use correlates with later initiation of forage growth. The Mount Langley herd also has seen sheep appear on winter ranges in mid April in some years. Goodale Creek remains a primary candidate as a spring range for the Sawmill Canyon herd, given its use as a winter range for some years in the early 1980s. It and nearby canyons need more concerted efforts to find sheep in April and May. A helicopter might greatly facilitate such an effort.

As the largest herd in the Sierra Nevada, and the current prospect for a source of translocation stock, the Wheeler Ridge herd has received extra attention relative to development of demographic data. Sampling of collared females indicates that lamb production has been consistently high. However, the winter ratio of lambs:100 adult females has been dropping steeply (Figure 3). This begs the question of whether collared females are a representative sample of the entire herd. A sampling of the overall population of females in summer might shed some light on whether lamb production is dropping or, alternatively, many lambs are disappearing between summer and winter. As a group effort, a summer sampling of the entire herd might be accomplished in a single day.

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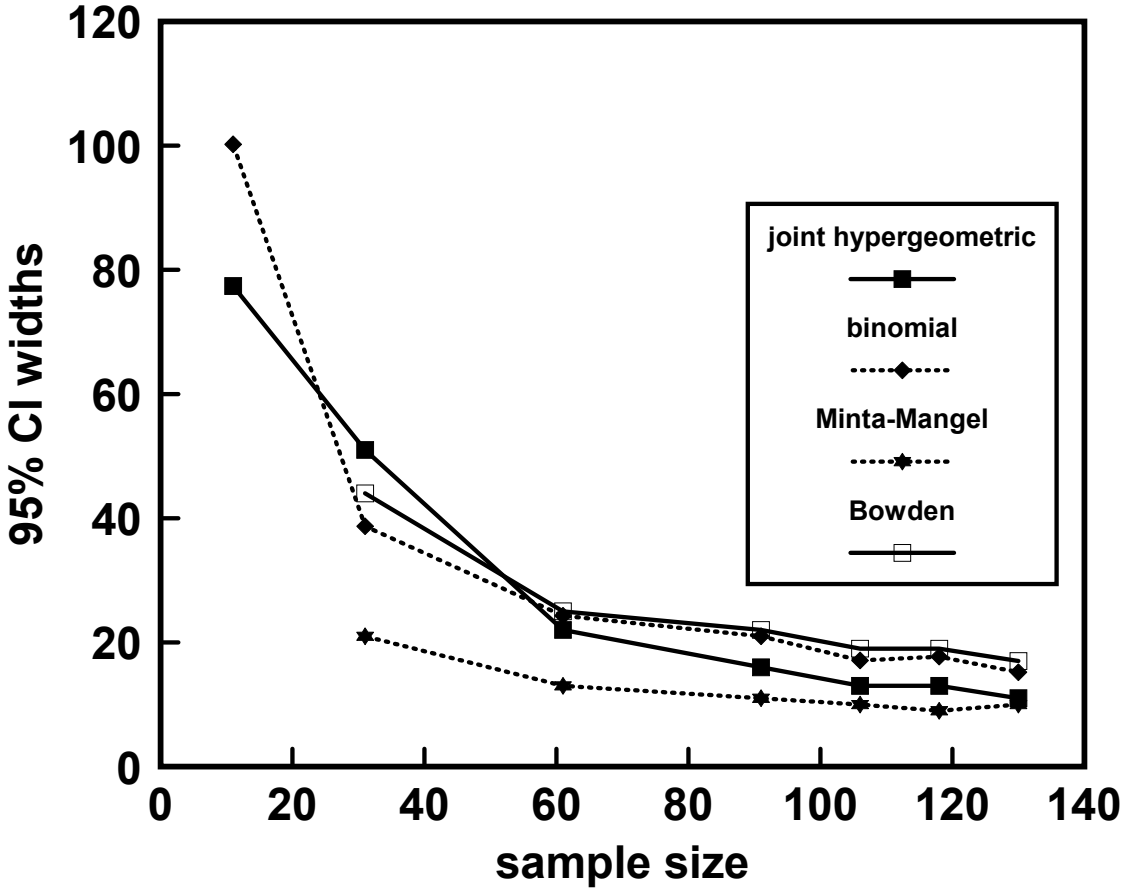

Figure 1. Confidence interval widths for different estimators.

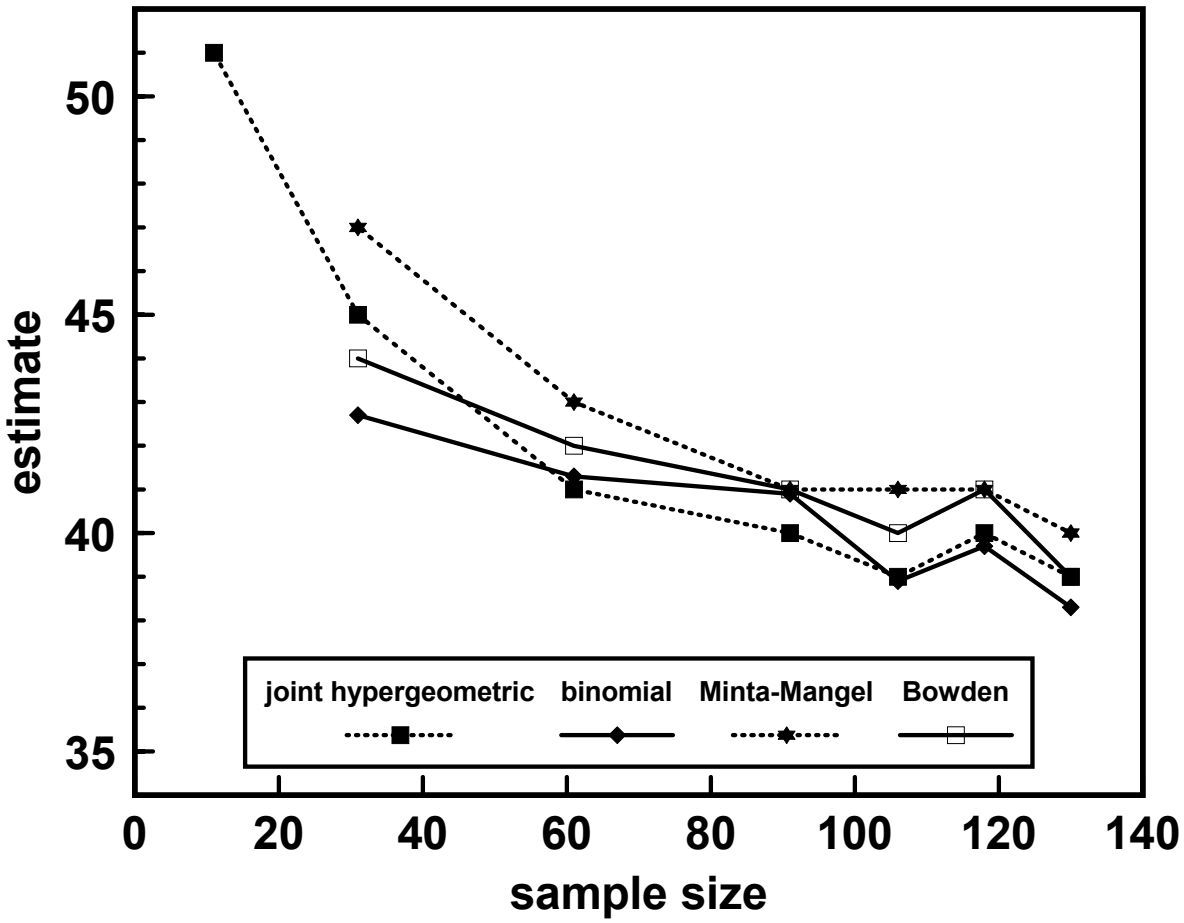

Figure 2. Mark-resight estimates of females relative to sample size.

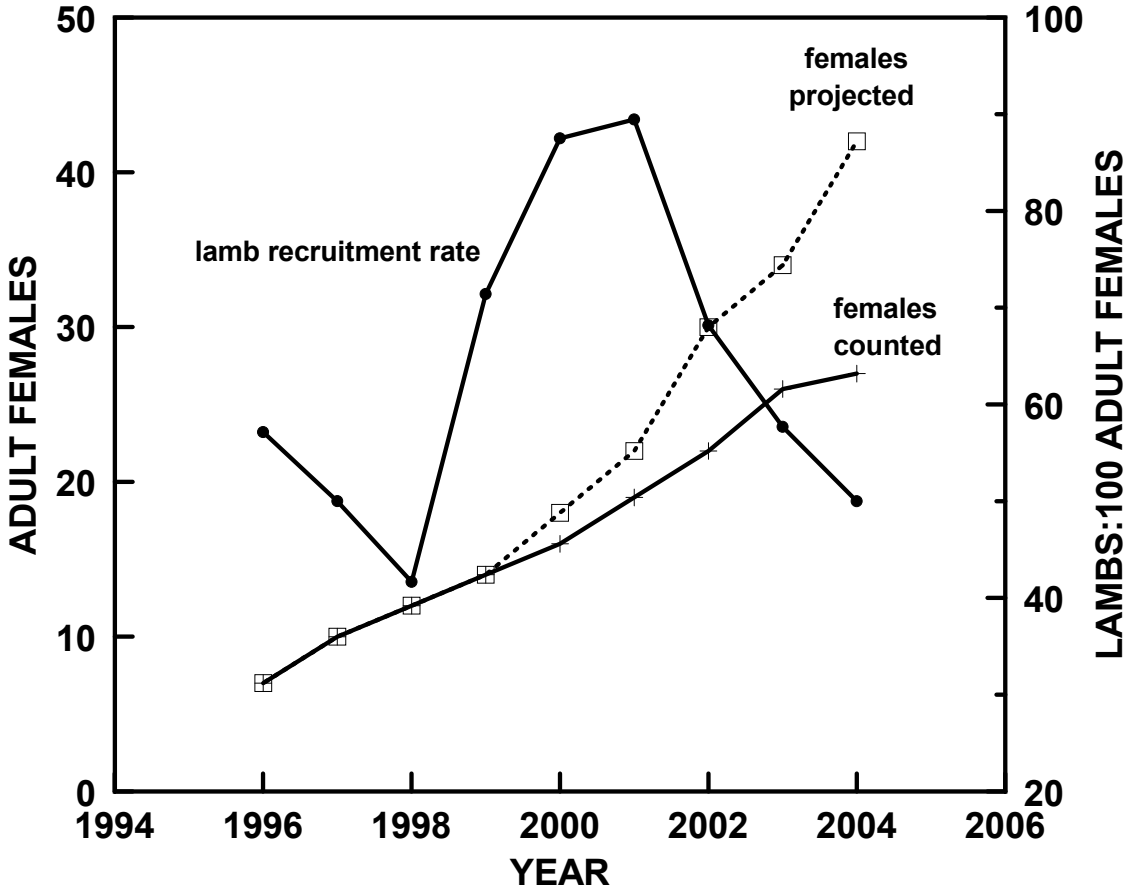

Figure 3. Temporal patterns of lamb recruitment rate, measured adult female population size, and projected adult female size for Wheeler Ridge herd. See text for details of population projection.