PREGNANCY RATE AND THE TIMING OF LAMB LOSSES IN CALIFORNIA BIGHORN SHEEP IN THE ASHNOLA, B. C.

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ABSTRACT

A free-ranging population of California bighorn sheep (*Ovis canadensis californiana*), with a history of low lamb production, was studied to determine that point in the reproductive cycle when offspring losses were occurring. A pregnancy rate of 100% was determined among adult females using Doppler ultrasound. Adult female liveweights, body condition scores, disease incidence, and serum trace element levels of captured females indicated these animals were not under nutritional stress during late gestation. Sixty percent mortality of lambs from tagged females occurred in the first three weeks postpartum. Assuming a 100% pregnancy rate, 72% mortality of lambs from untagged females occurred in the same period. Determination of prenancy rate allowed identification of the critical period in lamb survival responsible for low lamb production.

INTRODUCTION

A critical piece of information, required to fully understand the population dynamics of bighorn sheep, is the proportion of females which successfully conceive each year. This information is lacking for most populations. Counts of offspring to estimate female production are usually made after the neonatal period, a time when significant mortality can occur.

Classification counts of the Flatiron Mountain population indicate that lamb productivity has generally decreased since the 1950's and early 1960's, and has averaged only 26 lambs per 100 females since 1970 (Figure 1). Many management strategies (cattle removal, coyote removal, spring and fall burning, winter feeding, mineral supplementation, water supplementation, and antihelmintic treatment) have been, and are being, applied to this population in an effort to increase lamb production. While there was a brief increase in lamb production to 0.47 lambs:female after the first year of winter feeding, lamb counts have since declined.

The main objectives of this study were:

1) To investigate the reproductive, nutritional, and disease status of females prior to lambing, and;

2) To identify the period in the reproductive cycle where most offspring losses were occurring.

THE STUDY AREA

Flatiron Mountain is located east of Ewart Creek in the Ashnola River watershed of south-central British Columbia (Figure 2). Trapping and subsequent observation of tagged and untagged females took place primarily on the south side of the mountain (South Slope) where a continuous 400 hectare grass steppe community occurs. Elevations in the study area vary from 1000-2100 meters a.s.l. Detailed descriptions of the topography, soils, and botanical composition of the grass steppe communities of the Ashnola watershed are available elsewhere (Blood 1961; Demarchi 1965; Harper 1969; Scheffler 1972; Harcombe and Kowall 1982).

METHODS

A total of 12 bighorn females were captured during February and March, 1983, in a trap located at 1400 m elevation on the west end of South Slope (Figure 2). The population has been fed winter supplements in the form of a pelleted ration since 1978, and this was used as bait for the trapping program. Minimal amounts of bait were used to avoid confounding the nutritional status of the population. A corral-type trap was constructed 3 to 4 m high and 25 m in diameter from 1 cm mesh netting covered with burlap to form a visual barrier. A gate 3 m high and 5 m wide was released, either manually, or electrically, when bighorn were inside the corral. Once captured, the sheep were quietly driven into two plywood handling crates. The last five sheep captured were given a low dose (< 1 mg. kg^{-1}) of Rompun to achieve mild sedation.

Pregnancy status was diagnosed, based on the presence or absence of fetal and maternal tissues of pregnancy, by ultrasonic scanning using a Doppler Ultrasound Pregnancy Detector (Medata Systems Ltd., The Parade, Pagham, West Sussex, England, PO21 4WT). Specific details of this technique, and the accuracy of diagnosis for bighorn sheep (100%), are available elsewhere (Harper and Cohen, in press).

Liveweight was determined with a dial spring scale, accurate to 0.5 kg, with the animals held in a small plywood box. Body measurements to 1.0 mm, taken with a flexible steel tape, included: hind foot length, total body length, and chest girth. Body Condition Scoring (Russel et al. 1969) was used to provide a standardized subjective assessment of the fatness of live animals. A score ranging from 0 to 5, was assigned to each animal based on certain physical characteristics which vary according to the level of fat deposition around the lumbar vertebrae.

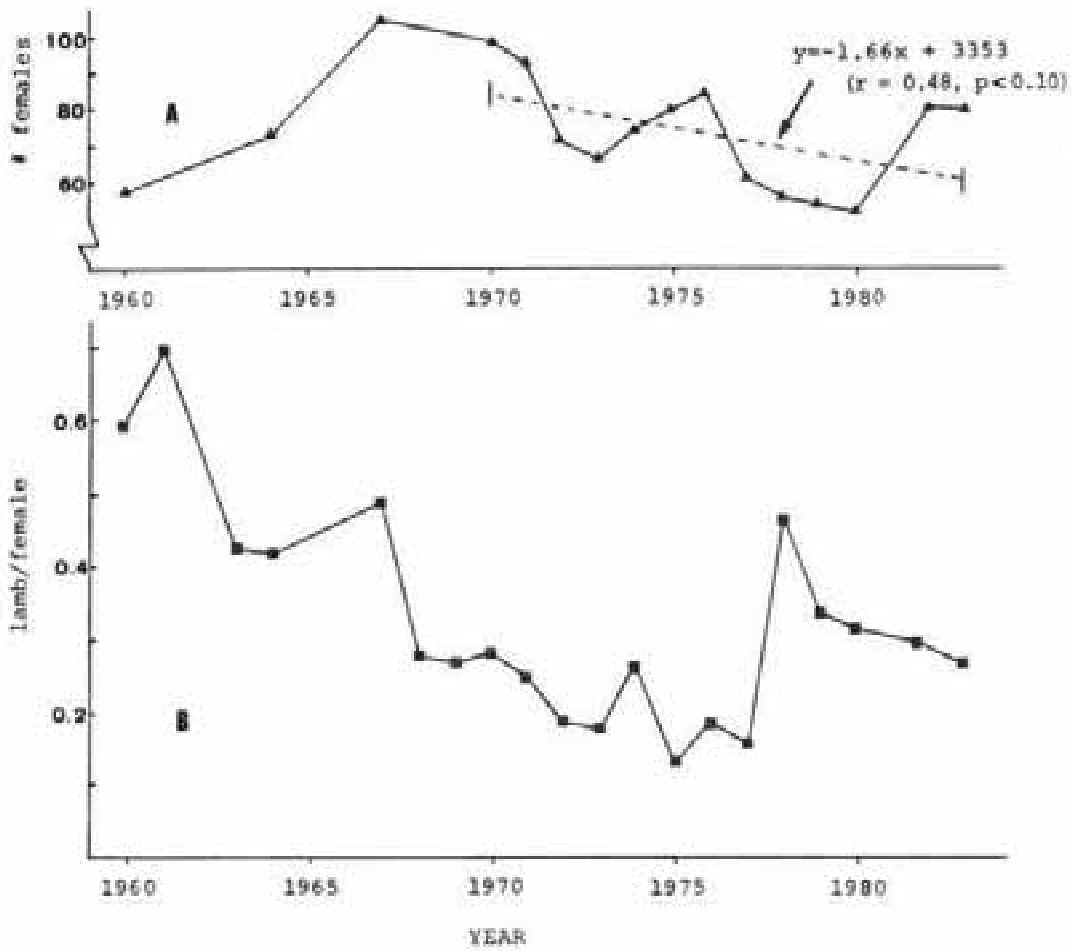

Figure 1. (A) Yearly maximum counts of females (2 years and older) on Flatiron Mountain from 1960 to 1983. (B) Ratio of lambs per adult female from 1960 to 1983 based on yearly maximum counts

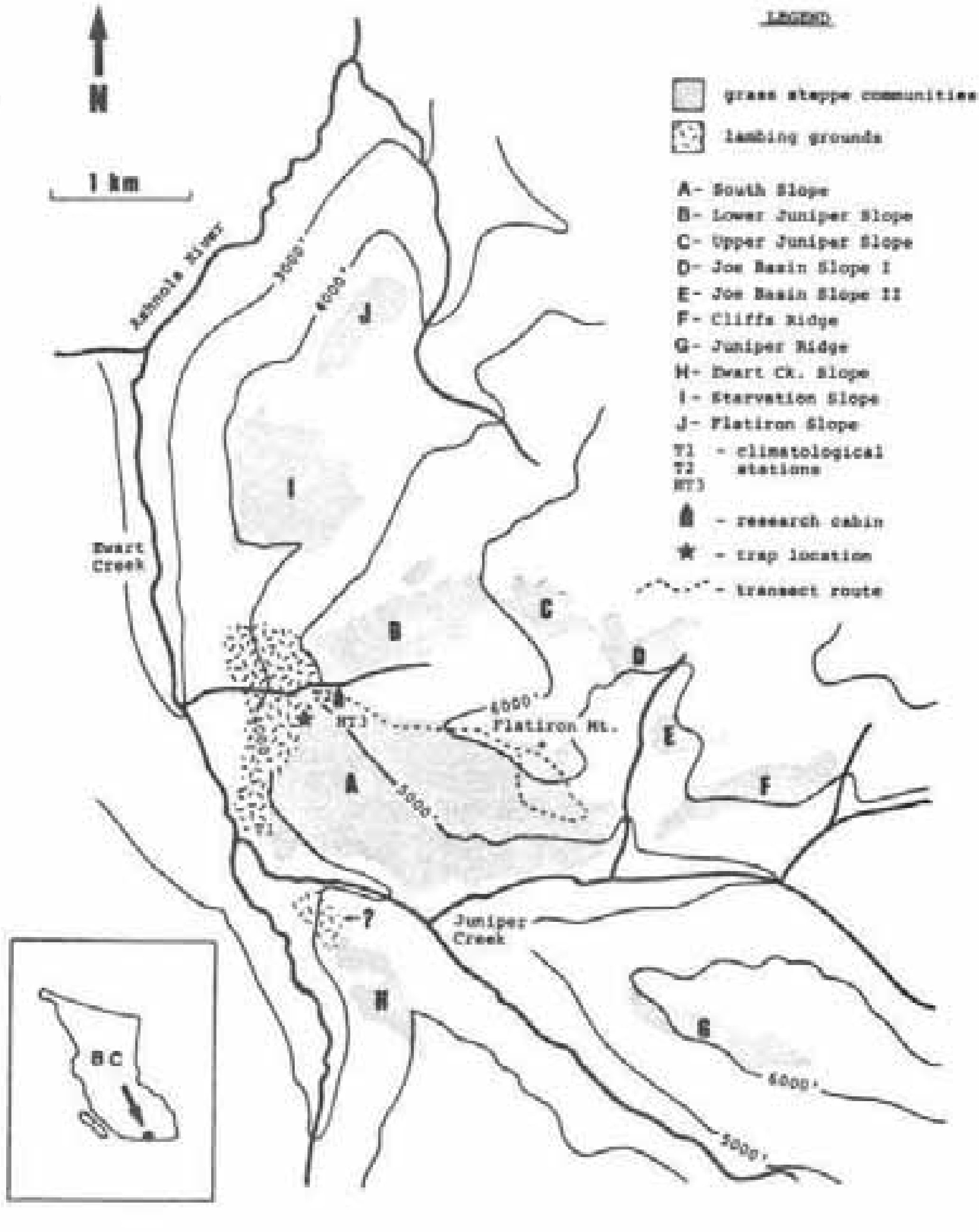

Figure 2. The study area on Flatiron Mountain in the Ashnola River watershed.

To determine trace mineral status, six blood samples were obtained by jugular venipuncture. Once the blood had coagulated, serum was separated by centrifugation, or when not possible, by letting the blood stand overnight. The serum samples were then kept on ice until they could be frozen (within 5 days), and submitted to the Veterinary Pathology Laboratory at Abbotsford, B. C. for trace element analysis and disease antibody titres. Disease incidence was also determined from nasal swabs taken from the external nares. Nasal swabs were immediately placed in sterile fixative and kept cool until submitted to the Provincial Veterinary Pathology Laboratory at Abbotsford, B. C. Culturettes (manufactured by Canlab), a sterile culture collection system containing 0.5 ml of modified Stuart's bacterial transport medium, were used to collect bacterial samples. For viral samples the Virocult collection system was used (Medical Wire and Equipment Co. Ltd.).

Before being released, the adult females were fitted with a permanent, nylon, identification collar (n=10). Five animals, including a lamb, were also given individual plastic eartags (Duflex, manufactured by Fearing).

A standardized transect, developed by B. C. Ministry of Environment personnel and employed during a previous study of the population (Ramsay 1980), was the most frequently used route for classification counts of the population (Figure 2). Only those classification counts in which all of the South Slope and Juniper Slope were thoroughly scanned are included in estimates of the total size and age-sex composition of the population.

Age-sex classes and marked individuals were identified using 7 x 50 binoculars and a spotting scope with 20X or 40X eyepieces. Bighorn were classified as lambs (less than 1 year old), male and female yearlings (1 to 2 years old), adult females and adult males (greater than 2 years old). The adult males were additionally classified into one of four age classes based on horn size (Geist 1971).

RESULTS

PHYSIOLOGICAL AND NUTRITIONAL STATUS IN LATE GESTATION

All 10 adult females captured on Flatiron Mountain between January 29 and March 24, 1983, were diagnosed as pregnant. The one capture mortality was also pregnant with a single fetus. Thus for the sample of bighorn 4.5 years and older the pregnancy rate was 100% (Table 1). Based on a gestation period for O. c. californiana of 174 days (Shackleton et al. 1984), and estimated dates of parturition of each female, fetal age at the time of diagnosis varied from 73 to 130 days (Table 1).

Mean weights and lengths of Ashnola adult females (+/- sd) were as follows: liveweight 61.6 +/- 4.1 kg (range 56.7 to 68.0 kg), total length 1608 +/- 69 mm (range 1470 to 1700 mm), and hindfoot length 393 +/- 16 mm (range 363 to 420) (Table 1). The mean chestgirth of adult females was 1011 +/- 41 mm (n=11). Body condition scores varied from 1.5 to 3.0 with a mean adult score of 2.3 (Table 1). The female lamb had the lowest body condition score at 1.5.

Table 1. Pregnancy diagnosis, weights, and measurements of bighorn females captured on Flatiron Mountain in 1983.

I.D.	AGE years	DATE OF DIAGNOSIS	FETAL AGE days	BASIS OF DIAGNOSIS[a] (Doppler ultrasound) FHR	FM	PC	UA	WEIGHT kg	BODY COND. SCORE	TOTAL LENGTH mm	HINDFOOT LENGTH mm
01	0.5	n/a						25.5	1.50	1280	-
02	4.5	07/03	128[b]	132	+	+		56.7	1.75	1650	380
03	6.5	21/02	102[c]	168	+		+	58.0	2.00	1560	364
04	6.5	06/03	122[c]		+		+	59.4	3.00	-	385
05	6.5	21/02	95-105[d]		(autopsy)			64.9	3.00	1570	405
06	7.5	07/03	119[c]	126	+	+	+	57.6	2.00	1470	410
07	7.5+	06/02	87[c]		+			67.1	2.50	1670	420
08	7.5+	29/01	86[b]		+			68.0	3.00	-	400
09	8.5+	06/02	73[b]		+	+		59.0	2.00	1630	375
10	8.5+	24/03	130[c]	108	+	+	+	64.4	1.75	1620	400
11	9.5+	07/03	105[c]		+			61.2	1.75	1600	395
12	9.5+	26/02	112[b]	162	+	+		-	2.50	1700	390

a - FHR=fetal heart rate (bpm); FM=fetal movement; PC=placental circulation; UA=uterine artery. b - Fetal age estimated from observations of newborn lambs.

c - Fetal age estimated from dates when females isolated themselves.

d - Fetal age estimated from the mean birthdate of the population.

The mean serum levels of selenium, copper, zinc, and iodine for adult bighorn and one lamb on Flatiron Mountain are presented in Table 2. The average level of 0.090 ppm selenium in the five mature females was twice the level of 0.046 ppm for the 10 month old female lamb, and the same magnitude of difference was also found in copper and zinc levels. Serum copper averaged 0.69 ppm in adult females, but was only 0.35 ppm in the lamb. Zinc averaged 0.52 ppm in the adult sera, but was only 0.25 ppm in the lamb. There was no great difference in the concentration of iodine, calcium, and magnesium between the two age classes (Table 2). Phosphorus, however, was almost twice as concentrated in the lamb serum compared to the mean level of adult females (Table 2).

On the advice of the pathologist, serum antibody tests were conducted for the presence of two highly pathogenic organisms that can cause late term abortions. Rapid Plate Tests on six serum samples for *Brucella* spp. were all negative. Serological tests for the presence of *Leptospira* spp. antibodies were also negative.

Analysis of the nasal swabs indicated the presence of four species of bacteria and one species of virus. A 30 to 50% incidence of the following three non-pathogenic bacteria was found: *Flavobacter* spp., non-hemolytic *Corynebacterium* spp., and alpha-*Streptococcus*. Two of six nasal swabs isolated hemolytic *Staphylococcus aureus*, a potentially pathogenic bacterium. All 12 nasal swabs were negative for the presence of *Pasteurella* spp. and hemolytic *Cornyebacterium pyogenes*. Viral nasal swabs were all negative for bovine viral diarrhea (BVD), infectious bovine rhinotracheitis (IBR), and adenovirus. However, six of twelve nasal swabs from these bighorn contained parainfluenza type-3 (PI-3) virus, based on successful culturing on ovine cell medium, and identification by electron microscopy (Dr. R. Lewis, pers. comm.).

PRODUCTION AND SURVIVAL OF OFFSPRING DURING THE LAMBING PERIOD OF 1983.

Periodic censuses of Flatiron Mountain from April 23 to June 11, 1983, showed that the number of females observed on the winter-spring range of Flatiron Mountain declined from 70 in late April to 50 animals by May 3 when females were leaving the herd presumably to give birth. The number of females observed remained at approximately 50 until May 10, after which it increased to 58 by May 21. The number of females observed did not return to pre-lambing period levels until May 24, and then remained at approximately 70 females until at least June 11. This exodus of animals from South Slope for a period of one month coincided with a steady increase in the observable number of lambs (Figure 3).

The pattern of lamb observations through the lambing period indicated that parturition occurred over a period of approximately 1 month between April 22 and May 22 (Figure 3). In 1983 when 13% of the females were tagged, three periods when the number of lambs decreased were identified. These were April 28 to 30, May 12 to 18, and May 26 to June 6 (Figure 3). In each case the decrease was verified due to the loss of lambs from known individuals, which coincided with the lower total number of lambs observed. The number of lambs observed on Flatiron Mountain peaked at 16 on May 22, but decreased to 15 with the loss of female #9's lamb. Maximum lamb counts remained at 15 for the entire month of June. The number of lambs then increased in early July with

Table 2. Blood chemistry of female bighorn from Flatiron Mountain.

Serum Constituent	Units	Concentration in Blood Serum: Adult females $\overline{X}$	SD	n	Lamb female n=1
Trace elements-					
Selenium	ppm	.090	.034	5	.046
Copper	ppm	.69	.08	4	.35
Zinc	ppm	.52	.19	4	.25
Iodine (total)	mcg%	5.3	1.3	4	5.0
Macro elements-					
Calcium	mg%	8.95	.41	4	9.7
Magnesium	mg%	1.95	.57	4	1.28
Phosphorus	mg%	3.25	.73	4	5.9

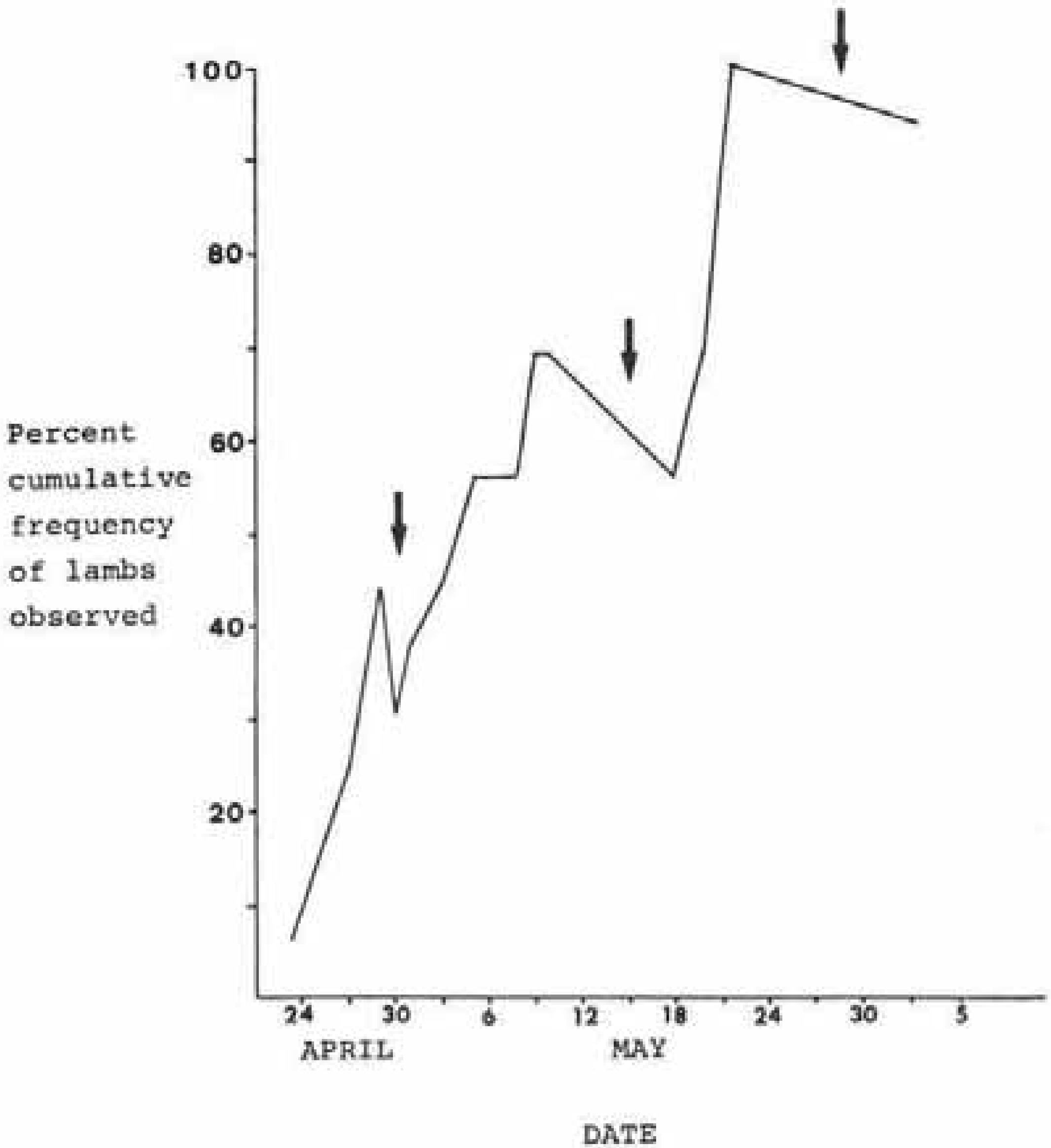

Figure 3. Cumulative frequency of newborn lambs observed on South Slope in 1983.

the return of seven females (including #6 and #11), and 5 lambs to Flatiron Mountain. The final lamb:female ratio for 1983 was thus 20/82 or 0.24.

Of the total estimated population of 82 adult females, 10 tagged females and one naturally marked female could be individually identified and observed through the lambing period. The pattern of isolation showed five of them (Category I) gave birth on the cliff escape terrain at the west end of South Slope (Figure 2), and five of them (Category II) gave birth at an undetermined location (Figure 4). Although female #10 had been diagnosed pregnant, she was consistently observed on South Slope, but never with a lamb of her own. Since it could not be determined if and when she isolated herself, she was placed in neither category.

Of the five females in Category I observed on the South Slope lambing grounds, only two (#2 and #12) had lambs which survived until early August (Figure 4). The other three females in Category I were observed with lambs, but they lost them when the lambs were between 5 and 21 days old (Figure 4). The females in Category II left South Slope for periods ranging from approximately 16 to 60 days. There was considerable variation in the date they left and in the time they spent away from the main winter-spring range. As with the females which remained on and near South Slope, only 2 of the 5 females in Category II returned with lambs. Based on the date when they isolated themselves and the date when they returned to South Slope without a lamb, the unsuccessful females in Category II lost their lambs when they were less than 20 days old. The females in Category II which lost their lambs, returned to South Slope between May 10 and May 20. Those which did not lose their lambs returned more than one month later in early July (Figure 4).

DISCUSSION

PHYSIOLOGICAL AND NUTRITIONAL STATUS IN LATE GESTATION

Assuming the sample of females is representative of the population as a whole, the 100% pregnancy rate obtained in mid to late gestation from the sample of 11 females from Flatiron Mountain indicates the cause of low lamb production is not low conception. Unless a specific disease causing late term abortion were present in the population, it is probable that most, if not all, of these pregnant females would have carried their fetuses to term.

Similarly high pregnancy rates have been determined for bighorn from the Vaseux Lake bighorn population in the South Okanagan. Autopsies of road-killed and shot females from Vaseux Lake revealed 17 fetuses from 16 females (Spalding 1966; and Ministry of Environment file notes). A sample of females captured live from Vaseux in 1977 also revealed a 100% pregnancy rate, with two cases of twinning (Eccles and Shackleton 1979). Slightly lower pregnancy rates were found in Dall's sheep from the MacKenzie Mountains in the Northwest Territories where 78% of the 94 mature females autopsied were pregnant with single fetuses (Simmons et al. 1984). Whereas it appears most wild Ovis populations have high conception rates, Heimer (1978) documented a 50% pregnancy rate, and alternate year production in a Alaskan population of Dall's sheep.

The mean liveweight of 62 kg for adult females from Flatiron Mountain is higher than would be expected if these animals were nutritionally stressed.

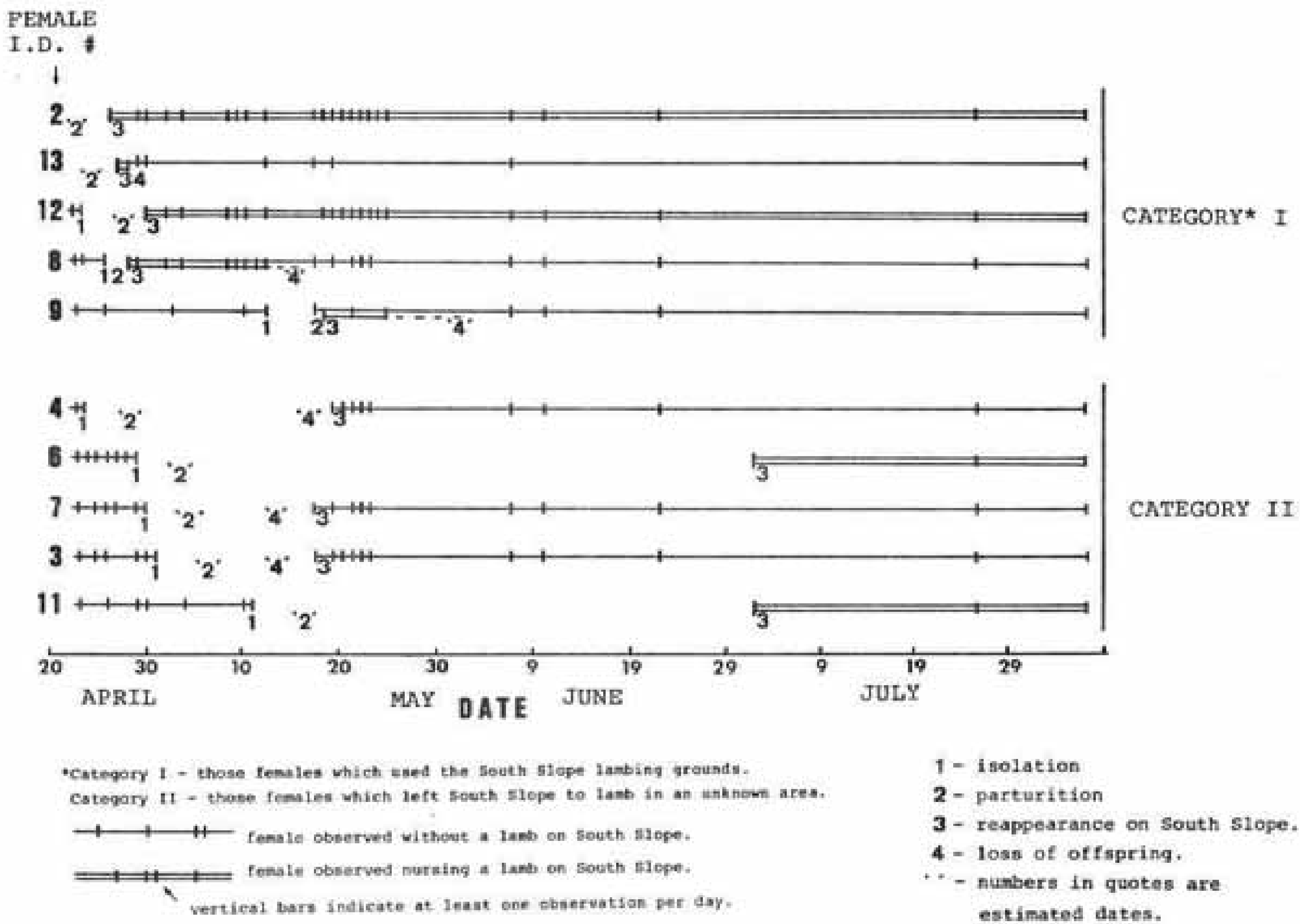

Figure 4. Pattern of birth and survival of lambs from identified female bighorn on Flatiron Mountain.

Liveweights of adult females in a captive research population at the Okanagan Game Farm averaged much lower at 47 kg. Despite these low body weights, lamb survival was higher in the captive population in 1982 and 1983 (64 and 82% respectively) than in the free-ranging Flatiron Mountain population (28 and 24% respectively). This suggests the nutritional level of the Flatiron Mountain population is well above any limit which would greatly affect lamb survival.

The mean body condition score of 2.3 indicates most females had adequate fat stores in mid to late winter. The lightest female measured was a lamb and it also had the lowest backfat index score. Body condition scores of bighorn from the Game Farm research population were lower than that of females from Flatiron Mountain. In domestic sheep, body condition scores were able to predict (r^2 = 0.88) the chemical fat in the fleece-free empty body (Russell et al. 1969). Using the regression relationship from domestic sheep, the mean score of 2.3 in Flatiron females suggests the chemical fat in their empty body should be around 20%. This indirect estimate is higher than the maximum 15% chemical fat measured directly in Dall's sheep females in early winter (Heimer 1980).

Although energy status of the Flatiron females appeared to be adequate during gestation, blood serum levels of copper, zinc, and selenium, may be marginally deficient based on the adequate levels which have been established for domestic sheep (Puls 1981). However, iodine, calcium, magnesium, and phosphorous are fairly normal based on domestic sheep requirements (R. Puls, pers. comm.).

Calcium levels in bighorn sheep sera range from means of 9.2 to 11.0 mg/dl (Franzmann and Thorne 1970; Peterson and Bottrell 1978; Hickey 1976). Flatiron Mountain females have calcium levels slightly lower than this range. Conversely, magnesium levels are higher than those reported by Franzmann and Thorne (1970). Inorganic phosphorus levels in Flatiron female sera are lower than those reported in Idaho and Colorado (Hickey 1976). Wyoming bighorn also had slightly higher levels of serum inorganic phosphorus than Flatiron females (Franzmann and Thorne 1970). Of significance is the low blood mineral levels found in the lamb. This is consistent with the low body condition score of this animal. However, this lamb did not die despite its apparent nutritional stress, and the survival of lambs from one month to one year of age is high (82% in 1982, and 85% in 1983).

The most interesting result of the nasal swab analysis was the isolation of PI-3 virus from 6 of the 12 bighorn females samples since Parks et al. (1972) suggested PI-3 was implicated in an acute disease situation leading to death in some captive bighorns. However, similar high incidences of PI-3 in bighorn has been documented in Colorado and Wyoming, where 62% of 29 sheep had positive antibody titres (Parks and England 1974). The high incidence of PI-3 in this population is probably not responsible for the low lamb productivity. Three of the four lambs which survived from the sample of marked females came from dams which were infected with PI-3 in mid to late gestation, and no clinical sign of disease were observed in the population.

PRODUCTION AND SURVIVAL OF OFFSPRING

Lamb Production in Previous Years

Classification counts to estimate the number of adult females and the lamb:female ratio from 1960 to present are summarized in Figure 1. The pattern of horn growth in this population did not allow accurate classification of 2 year old females, therefore, 2-year olds were included in the lamb:female ratios. Total numbers of lambs observed range from a high of 49 in 1967 (Scheffler 1973) to a low of 10 in 1975 and 1977 (Ramsay 1980). Lamb production exceeded 65% in 1960 and 1961 (Blood 1961), and remained relatively high through the 1960's ranging from 0.42 to 0.46 (Demarchi 1965; Scheffler 1973). During the period 1960 to 1967 the population was apparently increasing based on the maximum number of females observed (Figure 1). The population reached a maximum of at least 107 adult females (2 yr+) in 1967 (Scheffler 1973). Lamb production 1970 to 1983 was lower, however, and varied from 0.13 to 0.47 lambs:female (Ramsay 1980), averaging only 0.26. An apparent decline in the maximum number of adult females observed in the 1970's corresponded to low lamb:female ratios (Figure 1). From 1978 to 1980 lamb:female ratios were over 0.30 but the number of adult females continued to decline. Lamb:female ratios for 1982 and 1983 were 0.28 and 0.24 respectively, very near the average of 0.25 for the period 1970 to 1980.

Censuses conducted as part of this study indicate an increase in the number of females in the population from 1980 to 1982 (Figure 1). This apparent increase could be an artifact of survey technique and range occupation by bighorn, or could be due to increased adult survival. Lamb production during this period, however, was probably not high enough to account for the increase in female numbers.

Production and Survival of Lambs in 1983

Using an estimated 69 pregnant females (Harper 1984), the lamb production from sexually mature untagged females was 16 of 58 or 28%. This is somewhat lower than lamb production from tagged pregnant females which was 4 of 10 or 40%. Observations of marked females in Category I (see Figure 4) indicate that the losses occurred when the lambs were between 5 and 21 days old. Tagged females in Category II lost their lambs when they were less than 21 days old also. Coupled with the 100% pregnancy rate, this indicates that lamb mortality during the first three weeks of life was 60% for tagged females, and 72% for untagged females.

Once the bighorn lambs reach approximately one month of age then their survival rate increases dramatically. From maximum counts of the 1982 cohort in mid-June, the survival rate to May of 1983 was 82% (Figure 5). This is slightly higher than the survival rates determined from 1963-1964 of 71% (Demarchi 1965), and from 1960-1961 of 73% (Blood 1961).

It is apparent that the problem of low lamb production to this population occurs sometime after parturition, but before the lambs reach 3-4 weeks old. Diagnoses of pregnancy made it possible to focus in on that period in the reproductive cycle, when the majority of losses to recruitment were occurring. Factors which can affect the survival of lambs such as lactation, inclement weather, predation, and poor mothering, are currently being investigated.

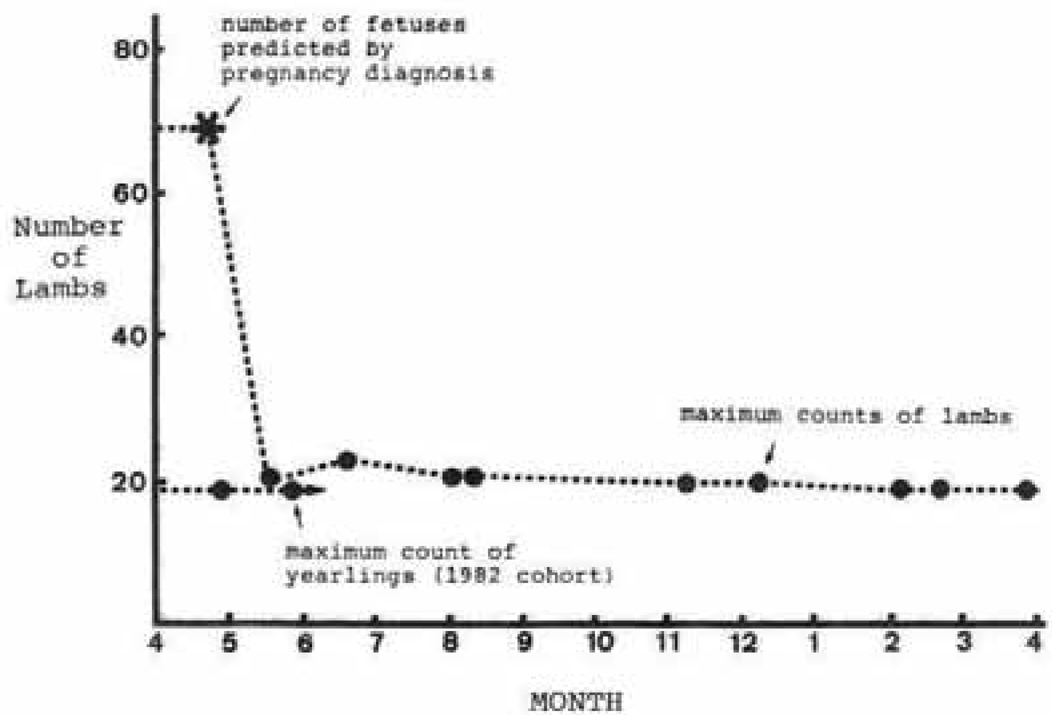

Figure 5. Survival of bighorn lambs on South Slope from June, 1982 to May 1983 based on pregnancy diagnosis in 1983, and maximum counts of lambs and yearlings.

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