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Reproduction and Hematology of the Cache Elk Herd

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REPRODUCTION AND HEMATOLOGY OF THE CACHE ELK HERD

by

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Thomas Burton Follis

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ABSTRACT

Reproduction and Hematology of the Cache Elk Herd

by

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The initial three years of a 10-year reproductive study of elk involved three major phases. A fourth was added because of convenience. Objective 1 was to ascertain pregnancy rates in yearling and mature elk by rectal palpation, associate these rates with subsequent fall cow/calf ratios, and to test concurrently an ultrasonic fetal heart detector. Rectally observed anatomical changes in gravid uteri of cattle were directly applicable to elk. Ultrasonic detections of pregnancies in elk and deer were unsuccessful.

Pregnancy rates in the 1969-70 winter of 100 and 0 percent, respectively, for 19 adult and five yearling elk were associated with subsequent pre- and post-season cow/calf ratios of 100/55 and 100/68. Pregnancy rates the next winter of 82 and 17 percent, respectively, for 60 adults and 23 yearlings resulted in pre- and post-season cow/calf ratios of 100/52 and 100/39. Pregnancy rates in the 1971-72 winter were 82 and eight percent, respectively, for 39 adults and 13 yearlings; compilation of data for the first three years of the study precluded inclusion of associated fall and winter cow/calf ratios.

Objective 2 was to determine the breeding efficiency of yearling male elk. Pregnancy rates were 86 and 93 percent, respectively, in

14 yearling-bred cows and 15 adult-bred cows in 1971. Rectal palpations revealed eight of 12 conceived in October from yearling breeding and 10 of 14 in September from adult breeding.

A peak in yearling breeding was estimated to have occurred between October 11 and October 25, as compared to two peaks in adult breeding estimated near September 5 and September 20. The earliest and latest conceptions were estimated near October 5 and November 21, and September 5 and November 3, respectively, in yearling and adult bred cows. Most wild and captive yearlings polished or began peeling their antlers about October 1, compared to August 15 for captive adults.

Data suggested recrudescent testicular tissues had initiated a rise in blood androgen, which coincided with a peak in breeding activity in September and October.

Inducement of twin births in Objective 3 was attempted via synchronized superovulations during the September rut in 1970. Progestogen implants were used from 14 to 20 days to synchronize elk in two pre-rut trials and one mid-rut trial.

Follicle-stimulating hormone (FSH) suspended in carboxy-methylcellulose (CMC), injected (intramuscular) coincident with implant removal, was judged superior to pregnant mares serum (PMS) alone or FSH in peanut oil. Injections of FSH in anestrous elk produced a mean of 2.4 follicles and corpora lutea (CL) (2.0 follicles and 1.33 CL), the first week, and PMS produced a mean of 9.67 follicles and CL (8.67 follicles and 1.5 CL); response was low in a pre-rut trial with two levels of FSH in peanut oil.

No conceptions apparently occurred in two groups of six cows injected with 15 and 20 milligrams FSH. Nine of 12 adults (including

three of four controls) and none of four remaining yearlings were estimated to have conceived between September 30 and October 15 (five to 20 days after the treatment period). Two additional yearlings were superovulated with FSH without synchronization, but did not conceive.

Data presented from blood analyses in Objective 4 included mean values for free-ranging mature elk (probability value indicates a significant difference between free-ranging and captive mature elk). The values were: total leucocytes (WBC), 6160/cubic millimeter (cu mm); WBC differential (percent)--neutrophils (44), lymphocytes (48, $P < .05$), monocytes (1), eosinophils (7), and basophils (0.1, $P < .01$); erythrocytes, 11 million/cu mm; hemoglobin, 21 grams/100 milliliters (g%), ($P < .01$); packed cell volume, 53 percent; blood urea nitrogen, 36 Sigma units ($P < .01$); serum glutamic-oxalacetic transaminase, 91 Units; lactic dehydrogenase, 863 Units; alkaline phosphatase, 2.22 Sigma units ($P < .01$); total protein, 7.0 g% ($P < .01$); albumin, 3.8 g% ($P < .05$); globulin fractions (g%)--$alpha_1$ (.44), $alpha_2$ (.6) beta (.95), and gamma (1.98); glucose, 183 milligrams/100 milliliters (mg%), ($P < .05$); creatinine, 2.9 mg%; uric acid, 0.39 mg%; cholesterol, 80.5 mg%; total bilirubin, 0.65 mg%; inorganic phosphorous, 3.4 mg%; and calcium ion, 9.2 mg%. Serology for Brucella abortus and Leptospira pomona was negative.

Blood values from five big game species and three species of domestic animals are presented for comparison. Significant differences in sampled elk were noted ($P < .01$ or $< .05$) in various tests between sexes, reproductive status, free-ranging and captive at different ages, and serial four-hour samples. A significant difference ($P < .10$)

was noted in progestogen assays for non-pregnant and pregnant elk. Captive elk were positive and free-ranging were negative for Dictyocaulus infestations. Yearling and adult male reproductive tracts were microscopically differentiated. Nutritional conditions of experimental elk were considered excellent when fed a special pelleted formula free-choice with grass hay.

(147 pages)

INTRODUCTION

Management of a wild population is, to a great extent, determined by the reproductive performance of that population. Information on reproductive processes, their potential and possible manipulative control, provides a sound basis upon which to establish management programs. These controls, used to increase, maintain, or decrease a herd's productivity, would permit a more accurate prediction of allowable harvest.

The hunting of elk (Cervus canadensis nelsoni) by Utah sportsmen has become increasingly popular. About 2,500 permits were issued on a state-wide drawing basis each year between 1958 and 1966. In 1967 the Utah Division of Wildlife Resources declared an open bull hunt with hunting permits available to residents once every three years. Permit purchases increased from 4,196 in 1967 to 9,639 in 1970, placing a tremendous pressure on the herd sires.

Intensified elk management programs require detailed reproductive studies to provide a knowledgeable basis for herd manipulations. Available information on a variety of species demonstrates that reproductive processes vary from one population to another, as climate and other variables change. The Cache Elk Herd and the Hardware Ranch Game Management Unit provide an excellent opportunity to study many reproductive phenomena, which will contribute to the pool of available information on this species.

This study covered the initial three years of a 10-year reproductive study on the Cache Elk Herd.

Nutritional deficiencies and effects of external stresses on behavior initiated modification of the original design. Pens and restraining facilities were relocated during the summer of 1971, to minimize external stresses on the experimental animals and to allow for more normal sexual behavior. A well-balanced, highly nutritious ration was developed to enhance reproductive success, and techniques were developed to obtain data from the proposed experiments. These techniques included surgical procedures, laboratory analyses, and testing and modification of ultrasonic (Doppler) equipment for pregnancy determinations.

Objectives

1. To measure reproductive rates for yearling and older cows in the Cache Elk Herd, using manual palpation and the "Doppler" machine.
2. To define reproductive processes in male and female elk from the Cache Elk Herd.
3. To investigate methods of inducing viable multiple births in elk and to study their subsequent survival.
4. To collect data on aspects of elk physiology, parasitology, diseases, and nutrition in the Cache Elk Herd.

Justification

Increased reproductive rates, resulting in increased harvest potentials, depend upon an adequate understanding of the reproductive processes involved, how they are influenced by environment (including management) and how they can be manipulated. Winter pregnancy diagnoses of an elk herd would provide the wildlife manager with an

accurate pre-season gauge of the present year's reproduction. Correlation of pregnancy rates with subsequent fall cow/calf counts would provide additional information on calf survival.

A possible adult bull over-kill, i.e., reduction of the adult breeding males to very low numbers during an open bull season, places a conceivable dependency for near total herd reproduction on the yearling males. This chance dependency gave the highest priority to a critical analysis of the breeding capacity of yearling male elk.

Exogenous hormone control of ovarian follicle formation and ovulation would herald the possibility of producing multiple births in elk. If successful for field application, it would add one more measure for control of elk populations to provide the big game hunter with maximum harvests.

OBJECTIVE 1

PREGNANCY RATE DETERMINATIONS IN THE CACHE ELK HERD

Literature Review

Pregnancy diagnosis

A search for a simple, rapid, and accurate method for pregnancy diagnosis has been in progress for many years. Even the ancient Greeks were concerned with early pregnancy diagnosis (Simons, 1961). Most physiologic tests have been with hormones from the serum and urine of pregnant women and with hormones contained in the serum and urine of mares. The hormones were assayed with the use of laboratory animals for physiologic changes in the reproductive organs.

Blood chemical studies were developed as another approach to pregnancy diagnosis. Determinations of serum diamino-oxidase has been positively correlated with pregnancy in humans. However, Havassy (1961) was unsuccessful when he attempted extraction of pregnancy hormones from blood, injection of serum and chorionic gonadotropins into male frogs, and vaginal smear culture in mice for wild ruminant pregnancy determinations. Serum protein and lipoprotein patterns were studied in cattle and sheep with negative results (Campbell, 1962). When Button and Olds (1968) evaluated six chemical tests for pregnancies in cattle, they found only 53.4 percent accuracy when 51.2 percent of the cows were pregnant. These tests involved cervical mucus, urine, milk or cream, which had been reported to be of value in the past. Cupps et al. (1966) obtained an overall 90.3 percent

efficiency using an urine estrogen test in sows. They were 96 percent correct on positive cases, but only 70 percent correct on non-gravid sows.

An apparatus to measure the consistency of cervical mucus was developed and reported by Blackburn and Castle (1962). Their success rate was directly related to an index causing their positive pregnancy diagnosis to vary from a low of 75 percent to a high of 83-91 percent.

Verme, Fay, and Mostosky (1962) found X-ray was of considerable value after the 100th day of gestation in deer. This technique provided an accurate fetal count. Jablan-Ponti and Brna (1966) classified Cervus elaphus fetuses by X-ray into 7-10, 11-17, and 18-24 week, and seven months to birth classes.

One of the simplest and most accurate tests was reported by de Bois, Muurling, and Weusing (1965). Examinations of vaginal biopsies by cell layer differential gave 100 percent accuracy for predicting pregnancies in sows. However, Walker (1967) was only 90 percent accurate in examining 599 animals with their method. This technique was highly successful in pregnant sows, but only partially accurate in those non-pregnant. Hemmingsen (1969) noted that this method has not been completely accepted.

Rectal palpation

Bovine and equine rectal palpation has been used routinely by veterinarians and others for pregnancy diagnosis, artificial insemination, infertility examinations, and uterine or vaginal treatments. Daily follicular palpation is an established practice with equine to determine the optimal hour for breeding. Rectal examination is generally accepted to be the most reliable method of detecting pregnancies in bovine, particularly in the early and midgestational

periods (Arthur, 1964). The expertise with which a diagnosis can be made depends on several factors. According to Arthur (1964) the most important are:

(a) The stage in gestation at which examination is made.

(b) The degree of voluntary or involuntary resistance by the animal to rectal examination.

(c) The degree of animal parity (non-parous or parous).

He claimed that, to reliably diagnose pregnancy by a method so prone to error as rectal palpation, it is essential that the person conducting the examination be well acquainted with the anatomy and physiology of the uterus and ovaries, not only during the various stages of gestation, but also during the different phases of the estrus cycle.

The cornua enlarge in a pregnant animal, their size being estimated by moving the fingers and palm slowly over the cornual curve. Bahtov and Rumyancev (1935) were accurate in the examination of 8,000 cows after the first month of pregnancy. One must become proficient in palpating female genitalia to determine fetal age (Gould, Hignett, and Steele-Bodger, 1942; Moore, 1950; Zemjanis, 1962; and Arthur, 1964). An experienced practitioner should feel confident in diagnosing pregnancies in heifers and adult bovine on the 35th and 45th day, respectively. The accuracy of fetal age prediction is a direct function of the expertise developed in palpating the cornua, embryonic membranes, cotyledons, and corresponding uterine enlargements.

Table 1 shows the close correlation between fetal sizes for elk and cattle. It also includes other information of value for palpating pregnancies. Figure 1 indicates similar fetal growth curves for elk and cattle during gestation.

Table 1. Comparisons of fetal measurements in elk and heifer cattle during the gestation period and associated uterine measurements of cattle.

Days from estrus	CR-FR (mm) Elk[a]	CR-FR (mm) Cattle[bd]	Uterine horn diameter of cattle (cm)[c] Gravid	Uterine horn diameter of cattle (cm)[c] Non-gravid	Total uterine fluids of cattle (ml)[b]
25	6.2				
28		8.0			
30	8.2	10.0	2.79	2.43	57.4
37	14.4				
40		20.0			75.-
42		25.0	3.20	2.52	150.
43	24.0				
59	65				190 (58 days)
60		60-65	4.81	2.86	310
70		110			475
80		140			760
90	167.5	150	8.47	3.64	870
100		210			1955
110		240			2550
118		270			3080
120		280-300	12.48	5.86	3440
123	305				4150
130		310			5150
168		440			6405
182	540	520			
220		725			6000
260		870			12000
274	925	900			14745
284		900			20072

CR Crown-Rump - early stages of embryonic development, from the anterior-most to the posterior-most points of the body.

FR Forehead-Rump - later stages of development (fetal, after 60 days), from the anterior-most point of the crown to the ischial tuberosity.

a Morrison, Trainer, and Wright (1959).

b Benesch and Wright (1952) and Arthur (1964).

c Perkins, Olds, and Seath (1954).

d Most fetal measurements in cattle were taken from first-calf heifers with cm converted to mm.

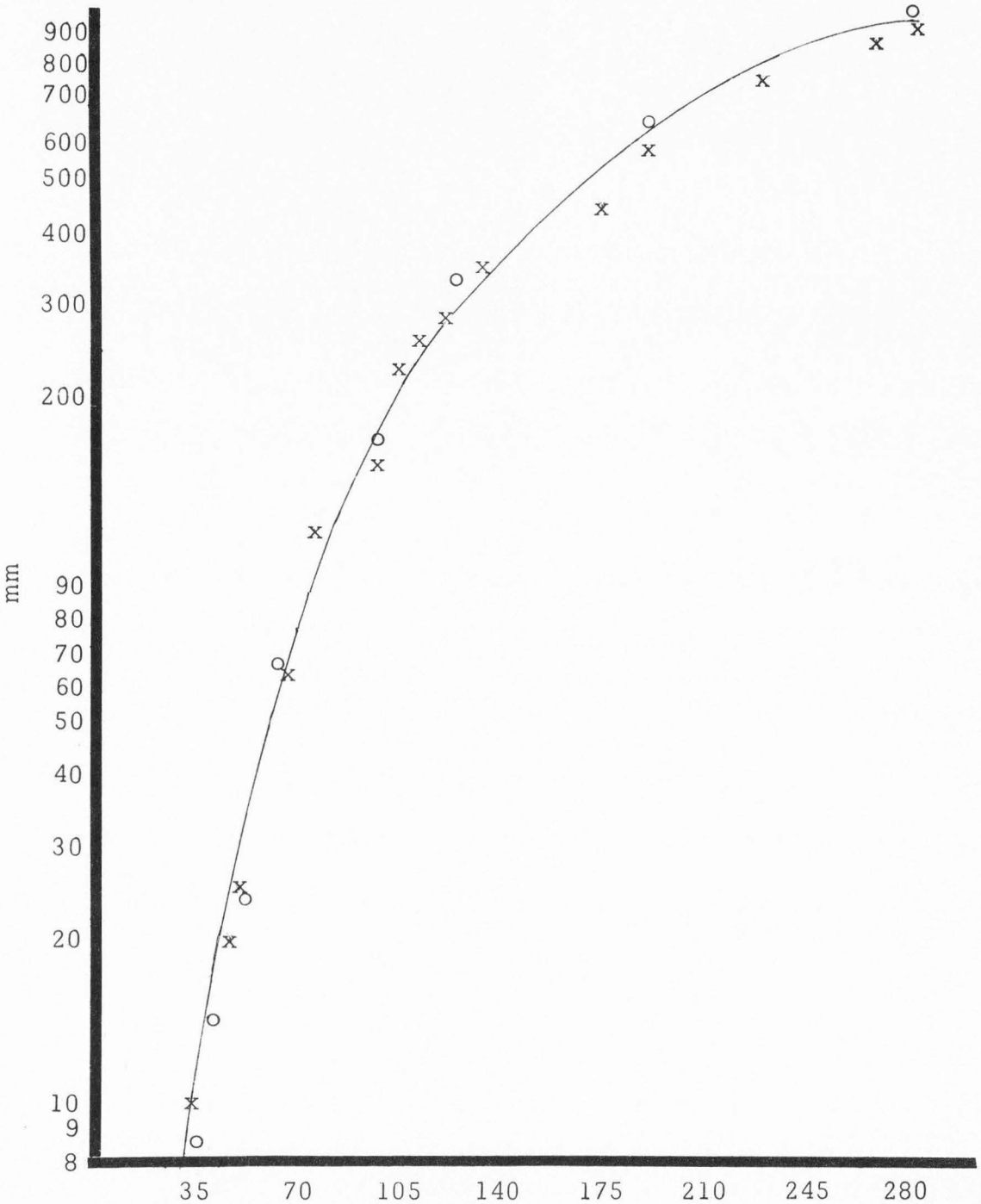

Figure 1. A semi-log curve indicating similar fetal lengths during the gestation periods of adult elk and heifer cattle (Morrison, Trainer, and Wright, 1959; Benesch and Wright, 1952; and Arthur, 1964).

o - fetal lengths from adult elk

x - fetal lengths from yearling cattle

Ultrasonic detection

Callagan, Rowland and Goldman (1964) were the first to announce the use of ultrasonic measurements of fetal blood flow to diagnose pregnancy. Johnson et al. (1965) described a flow-meter, which also was based on fetal pulse or placental detection.

Johnson et al. (1965) and Bernstine and Callagan (1966) gave due credit to Christian Doppler for noting midway in the 19th Century that the frequency of waves depends on the relative motion of the wave source and the observer. Doppler, while a professor of physics at the University of Vienna, applied the theory to explain a star's color as it and the earth approached or withdrew in space.

Doppler's theory was used to study the fetal heart and its movement. Ultrasonic waves were provided by vibrations of quartz crystals in a transducer. As the waves struck the flowing fetal blood, they were reflected back to the receiver at a different frequency than when entering the body. The outputs were recorded in various ways, i.e., auditory, by tape or speaker, or visual on an oscilloscope or paper. Critical analysis of the outputs enabled Bishop (1966) to differentiate between maternal vessels, fetal heart, placenta, cord, and fetal vessels. He very rarely detected fetal pulse at 11 weeks after the last menstrual period; at 17 to 20 weeks of fetal life, pregnancy was diagnosed with 85 percent accuracy; and 97 percent from 21-24 weeks. Bishop noted evidence of fetal life may be determined earlier with this equipment than conventional methods, including fetoscope or notation of fetal movement by the mother.

Lindahl (1966) was apparently the first to use an ultrasonic apparatus, which he called an amplitude depth detector (A-Scope), for diagnosing pregnancy in animals. It measured the depth of the reflecting

object, which caused a signal change. If the deflective object was over 12 cm away from the head of the transducer, the animal was diagnosed pregnant. The distance the waves traveled round-trip was quoted at 36 cm in ewes, while a total distance in the non-pregnant animal was 12 cm (Anon., 1966). Campbell, Herve, and Bell (1969) recognized pregnancies with an ultrasonic compound scanner from an echo 12 cm within the ewe's abdomen. They were 96.8 percent correct in positive cases, but only 64.4 percent accurate in non-pregnant ewes. Wilson and Newton (1969) used an ultrasonic detector on farm calls. Based on interpretation of audible sounds, they found a "high degree" of accuracy in ewes after 80 days.

Fraser and Robertson (1967) described the construction and use of an ultrasonic fetal pulse detector, which gave at best 75 percent positive results. In a subsequent paper (1968), they noted improvement in the detector and technique, which produced positive diagnosis of pregnancies in sheep at nine weeks and sows at 7.5 weeks. Fraser (1968) noted the detection of maternal circulation in the gravid uterus, independent of foetal pulse. This is not possible with external examination. An intrarectal probe with a transducer inclined to face ventrally produced good results. The gravid uterine pulse was recognized in 12 mated sows throughout the second half of gestation. Examinations of non-mated sows were correctly diagnosed non-pregnant. Two benefits of the intrapelvic transducer were: (1) improved amplification of sound, and (2) a more standardized examination procedure.

Lindahl (1969a) compared his applitude-depth-ultrasound technique and the Doppler technique. He found the Doppler more accurate and efficient in ewes at 65 days of gestation. Neither technique could detect multiple fetuses.

Lindahl (1969b) was able to accurately detect pregnancy in goats from one to 104 days before parturition, but predictions of multiple births were not successful. Ultrasonic instruments with 5 megahertz (MHZ) transducers seemed to be superior in early pregnancy detection and 2.25 MHZ more accurate in late pregnancies.

Stouffler et al. (1969) was 100 percent accurate in diagnosing pregnancy in 136 ewes. They also were 50 percent accurate in predicting multiple births.

Confusion existed in interpreting vascular sounds from the sow and her fetuses when Christiansen and Hansen (1969a) used a Sonicaid fetal blood flow detector. They later (1969b) revealed that negative results may follow positive results when an animal is re-examined and a stethoscope adapter is distinctly better than a loud-speaker. For the experienced examiner, a period of five minutes was sufficient for diagnoses, and the fetal sounds could often be detected within 30 seconds.

Using the "Doptone" (a Doppler instrument), Shone and Fricker (1969) were 98.4 percent accurate on 309 Merino ewes, mostly from 81 to 120 days after service. The fetal pulse sound from the umbilical artery was most frequently heard. They found that examinations became more difficult in advanced pregnancies. Keane (1969) examined 41 100-120-day post-estrus ewes in two hours with 95 percent accuracy.

Bitch examinations were made by Helper (1970) and Lamm (1970). They were able to detect pregnancies at 32 to 33 days. Helper had 100 percent accuracy, while Lamm was less successful--misdiagnosing 10 of 31 non-pregnant bitches.

Lindahl (1970) modified a Doppler probe containing a 5 MHZ transducer for intrarectal use in 599 ewes. The animals were placed on their back before probe insertion. Only fetal heart beat, movement, or pulse were used as positive criteria of pregnancy. The ewes were examined during a three-day period, 14 to 62 days following removal of the rams. The negative ewes were re-examined in 20 days and those remaining negative 45 days later. This prolonged, but efficient, process provided detection of 97.2 percent of the pregnant ewes. The earliest and latest detection of pregnancy was 126 and 17 days before parturition, respectively.

Pregnancy rates in elk

Hancock (1955) found October killed yearling females did not provide recognizable evidence of embryonic membranes, but examinations in January revealed a 75 percent yearling pregnancy rate. He hypothesized that yearling ovulation and pregnancy were somewhat dependent on the previous winter and its severity. The nutrient intake and condition of the calf seemed to be most important for subsequent fecundity and fertility. Greer (1966) found most adults have detectable evidence of pregnancy by late October. Buechner and Swanson (1955) observed significant changes in yearling pregnancy rates during a reduction program. Data taken from hunter-killed elk revealed an increase from 21 to 42 to 58 percent in 1952, 1953, and 1954, respectively. These studies were made after a heavy three to four year elk harvest. The authors compared these percent of yearling pregnancies with other herds, such as the Wichita Mountain herd in Oklahoma, 10; Nebo herd in Utah, 10; Yakima herd in Washington, 17; Rocky Mountain National Park, 17; and Yellowstone National Park, 7.

Greer (1968) found yearling pregnancy rates from 1961 to 1968 ranged from 0 to 36 percent, but averaged 15 percent. Studies indicated percentages of yearlings pregnant following a severe winter were less than 5, 7 to 15 following intermediate winters, and 30 to 35 after mild winters.

Cheatum and Gaab (1952) proved that the presence of one or more corpora lutea was positive evidence of pregnancy in elk. With the use of this method, they reported seven percent (1 of 17) yearlings pregnant and adult pregnancies as follows:

Age (years)	Pregnancy rate (percent)
2.5	93
3.5	91
4.5 to 9.5	100
10 - 14	94
15 and over	62

Murphy (1963) used the Cheatum and Gaab technique and found one yearling of four pregnant and 14 corpora lutea present in 10 adults. Kittams (1953), noting only two of 44 yearlings pregnant (4.6 percent), stated that, in practical elk management, breeding under two years of age was of minor importance. Elk cows studied by Harper et al. (1967) were at least in their third year during their first active rutting season.

Knight (1964) considered yearling breeding the exception. He found one of six pregnant (16.6 percent). This compared to an adult average of 70 percent pregnancies over three years. An ovarian examination by Knight of the five non-pregnant yearling elk indicated an absence of developed graafian follicles.

Cole (1969) found most female elk sampled between 1962 and 1966 had become sexually mature at 2.5 years, with an average of 15 percent of the yearlings productive.

Yearling elk pregnancies have been thought so uncommon that Coffin and Remington (1953) and Batchelor (1963) published evidence of yearling pregnancies. Rognrud (1953) noted one yearling pregnancy.

Evidence of fluctuations of yearling pregnancies from 0 to 80 percent are presented in Table 2. Adult pregnancy rates of 43 to 100 percent have been recorded.

Harper (1967) recorded pregnancy rates of various age classes of Roosevelt elk:

Age (years)	Pregnancy rate (percent)
1.5	14
2.5	50
3.5	57
4.5	75
5.5	71
6.5 - 8	100

Cowan (1950) found poor correlation between January pregnancy rates and percentage of cows with calves in July.

Year	January pregnancy rate (percent)	Cows with calves in July (percent)
1942-43	63	50
1943-44	76	61
1944-45	93	56

Table 2. Reported yearling and adult elk pregnancy rates.

Year	Yearlings pregnant (percent)	Number examined (yearlings)	Adults pregnant (percent)	Author
1941			75-90	West, 1941
1945			43	Schwartz and Mitchell, 1945
1950			78 of 632	Green, 1950
1951			91	Rognrud, 1953
1952	7	17	see text	Cheatum and Gaab, 1952
1952	0		97	Hancock, 1955
1953	5	44	87	Kittams, 1953
1953			77	Rognrud, 1953
1953-54	75		100	Hancock, 1955
1960	22	18	93	Gates, 1960
1961-67	27	88		Flook, 1970
1961-62	0	3	80	Greer, 1965a
1962	81	16	87	Raught, 1962
1962-63	0	12	94	Greer, 1965a
1963	80 (European red deer)			Daniel, 1963
1963	25	4	100 of 10	Murphy, 1963
1963-64	27	33	94	Greer, 1965a
1964	25 (European red deer)		94	de Crombrugghe, 1964
1964	16.6	6	70	Knight, 1964
1964-65	8	36	94	Greer, 1965a
1965	0		74	Gates, 1965
1965	64		79	Gates, 1965
1965	30	13	91	Greer, 1965b
1966	37.5	8	80	Gates, 1966
1966	0	7	83	Gates, 1966
1967	31		96	Greer, 1967
1970	0	5	100	Follis, 1972
1971	17	23	82	Follis, 1972
1972	8	13	82	Follis, 1972

Based on these figures, Cowan noted calf losses may be as high as 47 percent and not less than 20 percent, with Brucellosis eliminated as a factor.

Nutrition and reproduction

Gross (1969) noted that fecundity rates appear to be a sensitive monitor of the balance between population food demands and habitat food supply. He claims they may be used as discreet and reliable measures for manipulating a population to desired densities. He found the density that annually produced the maximum net number of young to be below the density which the habitat could maintain (i.e., carrying capacity). Murphy (1963) indicated the minimum carrying capacity to be near 23 acres per animal unit in Missouri. Cowan (1950) noted the following differences between two National Parks in Canada:

	Banff	Watertown (Understocked)
Cow/calf ratio	100/55	100/76
Yearlings pregnant	25 percent	38 percent

Greer (1966) found overpopulation affected pregnancy rates. He reported that 88 percent of the two-year old and older cows were pregnant in an overpopulated herd, compared to 94 percent following a reduction program.

In the indigenous forests of New Zealand where food is very abundant, Daniel (1963) found red deer hinds produced calves at 24 months. In some herds, yearling pregnancies reached 80 percent. He reported red deer fawns were found to have follicular activity at five to six months of age. In contrast, red deer fawns from poorer range did not show follicular activity until 12 months and estrus at 16 months of

age. He noted poorer range possibly caused hinds to not breed until their third year as in Britain. Lowe (1969) noted a significant reduction in fecundity of two-year old red deer following cessation of muirburn (burning of a moor). When some groups of two-year olds were again exposed to areas burnt as fire-breaks their fecundity responded to 70 percent in contrast to 30.5 percent for those remaining on undisturbed lands. Riney (1956) noted red deer hind/fawn ratios in New Zealand ranged from 100/28 to 100/70 over five widely contrasting environments.

Casida (1959) stated that restricted feed intake during the growing period delays the occurrence of puberty in both sexes in cattle and swine and, if continued, reduces the number of eggs in swine and sheep or sperm produced immediately post-puberally in cattle, swine, and sheep. He noted no effect on the potential fertility of the gametes produced.

Consideration should be given to adjusting utilization standards, population levels, and stocking rates to levels compatible with forage supplies during drought periods, if basic forage supplies are to be maintained or replaced (Mackie, 1970).

Research on reproduction in eland (Taurotragus oryx) by Skinner and Van Zyl (1969) indicated nutritional deficiencies were responsible for later calving peaks, later breeding age, lower birth weights, longer inter-calving intervals, and lower calving percentages. Sadlier (1969b) noted that a major factor in the environment of mammals, with regard to their reproductive activity, was the quality and quantity of nutrients available. He claimed that reduced availability of food during the juvenile period of wild cervids delayed puberty; poor nutrition in seasonal or polyestrous species can delay puberty by inhibiting growth

independently of any annual timing; and availability of food can control the cessation of breeding activity. Fairall (1968) commented that light regime is the major influence on breeding patterns, but nutrition affects the calving pattern within the season, i.e., calves are dropped early in good years and late and more dispersed in poor years. Morrison (pers. comm.) placed nutrition above all as an influence in the controlling or modifying of timing, intensity, duration and behavioral characteristics of estrus in elk.

Knight (1964) theorized that the problem of low productivity of the Sun River Elk Herd lay in the population structure, rather than in a nutritional deficiency. His work indicated a differential in herd productivity. This agrees with the increases in yearling pregnancy rates following a heavy harvest in SE Washington (Buechner and Swanson, 1955).

Methods and Materials

Rectal palpation

Rectal palpation was selected as the most efficient method for pregnancy diagnosis in elk. A reduced rectal opening prevents the use of this technique in deer, bighorn sheep, antelope or other similar sized animals.

Experience in rectal palpation of cattle was transposed to elk. All females trapped or held captive at Hardware Ranch were routinely palpated to determine their reproductive condition. Free-ranging elk, aged as mature or yearling (Hancock and Low, 1956), were examined for pregnancy, while captive animals were also studied for ovarian structural changes, when applicable.

A plastic arm-length glove was used to protect the hand and arm. After the animals were properly restrained in a "Powder River" squeeze chute, the gloved hand was lubricated and inserted into the rectum. Internal organs were contacted and identified. Uterine and ovarian locations and structure were very similar to cattle, which increased the efficiency of elk palpation.

Eighteen captive elk were caught and palpated rectally at one to two week intervals during the winter of 1969-70. A detailed recording was made of graafian follicles and corpora lutea present and alterations in uterine size and condition.

Nineteen adult and five yearling free-ranging elk were trapped and examined rectally during the 1969-70 winter, 60 adults and 23 yearlings in 1970-71, and 39 adults and 13 yearlings in 1971-72. The genitalia were palpated and the animal's reproductive status recorded.

Observations included a pregnancy diagnosis, ovarian structure and size, when possible, hypertrophied condition of the middle uterine arteries, and an estimate of the fetal age, when predictable. If cotyledons were estimated one inch or larger, a positive diagnosis of pregnancy was made with fetal age predicted at three months or more.

Pre- and post-season cow/calf ratios were collected by the Utah Division of Wildlife Resources personnel.

Ultrasonic detection

A two megahertz (MGH) Doptone[1] was used in the study. The unit consisted of one small transisterized detector with two transducer containing probes. A large, cone-shaped probe was designed for the fetal

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[1]Smith-Kline, Inc., Palo Alto, California.

searching phase of a human's abdomen. A second, small flat probe was for continuous fetal monitoring before and during birth.

The probe was placed against a wool-free area in sheep about three inches anterior and lateral from the udder. The area was dressed with a commercial emulsion or soapy water prior to contact with the probe. This facilitated radiation of the waves from the transducer into the body and subsequent reception of the reflected waves. A hair-free area in the elk is posterior to the udder, but absence of a suitable hair-free area precluded successful external contact on 14 deer.

The external and internal approaches were used. Fraser (1968a) and Lindahl (1970) modified probes for intrarectal insertion. The former was searching for maternal uterine circulation, while the latter used only fetal circulation as proof of pregnancy.

Intrarectal insertion with the larger probe was made possible with a 12-inch plastic sleeve, which permitted reaching the abdominal area in elk and deer. Conduction of ultrasonic waves was enhanced by a lubricant and moisture in the large bowel. The smaller probe was placed in a plastic support for intrarectal insertion. This probe was used during the 1971-72 winter on 10 elk in conjunction with rectal palpation.

Pregnancy examinations of domestic sheep with the Doptone were conducted to gain proficiency with the instrument. A group of 18 pregnant sheep were examined at 100 days post-estrus, 82 at 85-90 days post-estrus, and 37 at 110-135 days subsequent to removal of rams.

Twenty-four elk were examined ultrasonically during winter trapping operations at Hardware Ranch. The Doptone was used in

conjunction with rectal palpations in elk to test its efficiency with an animal much larger than bighorn sheep, deer or antelope. Eight bighorn sheep were examined with the Doptone while held captive for pasteurellosis treatment near Brigham City, Utah. Fourteen deer were examined when trapped in a marking program at Hardware Ranch. Antelope were scheduled to be examined, but the animals did not become available.

Results and Conclusions

Rectal palpation

Adult and yearling pregnancy diagnoses are presented in Table 3. A mild 1969-70 winter had depressed trapping success below that of 1970-71. There was no significant difference between the first two years' pregnancy rates, and none was observed when comparing data from first and third years' pregnancy rates.

Rectal palpations were found to be most efficient in diagnosing pregnancy in elk. Experience in pregnancy diagnoses in cattle can be directly transposed to elk.

The 1969-70 recordings of 100 and 0 percent pregnancies, respectively, in 19 adult and five yearlings were associated with a cow/calf ratio of 100/55 the following fall; the second year's finding of 82 and 17 percent adult and yearling pregnancies, respectively, in 60 and 23 adults and yearlings were associated with a cow/calf ratio of 100/52. The 1971-72 pregnancy rates of 82 and 8 percent, respectively, in 39 and 13 adults and yearlings forecasts a cow/calf ratio of about 100/50 in the fall of 1972.

Table 3. Comparative winter pregnancy rates and subsequent fall cow/calf ratios.

Year	Adults			Yearlings			Associated Cow/Calf Ratios	
	Number palpated	Percent pregnant	Estimated percent of herd on meadow	Number palpated	Percent pregnant	Estimated percent of herd on meadow	Pre-season	Post-season
1969-70	19	100	12.7	5	0	10	100/55	100/68
1970-71	60	82	30.0	23	17	33	100/52	100/39
1971-72	39	82	24.7	13	8	16	--[a]	--[a]

[a]A cow/calf ratio from the 1971-72 reproductive period was not recorded, until after the completion of this study.

Adult pregnancy rates of 100 and 82 percent, respectively, should produce 59 and 47 calves per 100 cows. A 0 and 17 percent yearling pregnancy rate would add 0 to 3 calves per 100 cows, respectively, producing total calf productions of 59 and 50 per 100 cows in 1970 and 1971, respectively (see Appendix). The two years' cow/calf ratios were 100/55 and 100/52, respectively, which were near the predicted values. McCormack (1951) and Hancock (1955) gave 55, 55, and 51 calves per 100 cows, respectively, in the Cache Elk Herd, for 1949, 1950, and 1951.

To interpret results from two years into a valid basis for predicting harvestable numbers during the subsequent hunting season would seem premature. It is feasible, however, that following the program's completion, a significant correlation may be found between pregnancy rates and cow/calf ratios. Pre- and post-puberal losses must remain constant, however.

Presence of ovarian structures were not observed consistently during pregnancy examinations. Ovarian palpation proved to be difficult in elk, because the trapping season predetermined the stage of gestation and the uterus and its fetal contents were extended beyond the pelvic brim. This pulled the ovaries into the abdominal cavity a distance of 2-6 inches or more. A portion of the uterus was pushed into the pelvic area when the elk struggled against being restrained in the chute, but this was usually adequate reason to render an early diagnosis and quickly release the animal. Continual probing for the ovaries in an extended position could have damaged the large bowel.

The non-gravid uterus, a small bicornual body resting on the pelvic floor, was easily distinguished from the large gravid uterus during

January to March trapping seasons. The ovaries, small and inactive in the non-pregnant elk, would have been difficult to identify by the inexperienced. They possibly could be confused with fecal pellets in yearlings.

The ovaries should be palpated in 35-85 day pregnancies to identify and observe the presence of a corpus luteum of pregnancy. Morrison (1960b) recorded an average diameter of 14.3 mm for corpora lutea of pregnancy. Development of post-conception accessory corpora lutea in 66 percent of pregnant elk (Halazon and Buechner, 1956) precluded the determination of fetal numbers from the number of corpora lutea present.

Trapping seasons predetermined the gestation period in which pregnancy diagnoses were completed. Cole (1969) aged elk fetuses collected from 1963-66 at Grand Teton National Park. He found conceptions had occurred between September 2 and November 29, with approximately 16, 62, and 22 percent, respectively, occurring between September 2-20, September 21 to October 10, and October 11 to November 13. This indicates that about 80 percent of the pregnancies diagnosed in January would be of 90-day duration. In February, one would find almost all of the gravid uteri suspended in the abdominal cavity beyond the pelvis. As noted earlier, differentiating between non-gravid and gravid uteri at this time would not be extremely difficult for someone with moderate training and experience in rectal palpations.

Ultrasonic detection

Eight of 22 bighorn ewes were examined in February, 1970. The rut had occurred between November 15 and December 15, placing the time of testing about 60 days after estrus. The Doptone indicated all ewes

tested were negative. The following summer only two lambs were observed in the entire flock, substantiating the low pregnancy rate found.

Eighteen 100-day pregnant domestic ewes were correctly diagnosed ultrasonically (in some cases within a few seconds); 82 ewes were examined 85-90 days post-estrus with an over-all accuracy of 96.4 percent; and 37 ewes, which had been exposed to rams over 110 days earlier, were difficult to detect resulting in an 80 percent accuracy rate. Many of the latter ewes carried palpable lambs, but uterine or fetal blood flow could not be detected.

Experience with domestic ewes was invaluable in subsequent auscultation of elk and deer. Difficulty in probe placement on the elk's abdomen may have precluded ultrasonic pregnancy diagnoses with this species. Simultaneous ultrasonic scanning with manual rectal palpation indicated negative results. Only three of 24 elk ultrasonically examined produced positive results.

Intrarectal use of the large probe resulted in ultrasonic sounds from the lumbar portion of the aorta and external and internal iliac arteries. Horizontal emission of signals from the probe's face, which should have been emitted ventrally toward the uterus, possibly decreased successful detection of maternal or fetal circulation.

No fetal heart sounds were detected from 14 deer examined ultrasonically. External and intrarectal approaches were used without success during the 1970-71 winter.

Intrarectal use of the smaller probe held within a plastic sleeve gave negative results in 10 pregnant elk during the 1971-72 winter. Deer were not examined in this manner.

Success in domestic sheep may have given a false sense of confidence for adaptation of the Doptone to wild ruminants. It was noted, for example, that the uterine arterial "thrill" or fremitis in the bovine (a powerful swishing of blood as the hypertrophied middle uterine artery is partially constricted) is not present in pregnant elk. Fremitis has been reported in the bovine at 80 days by Zemjanis (1962), 85 days by Arthur (1964) and 90 days by Moore (1950). Most elk examined routinely during the trapping operation presented at least 90-day pregnancies, but the absence of fremitis suggests a variation in uterine blood flow of elk. The possibility that the elk uterine artery does not become greatly hypertrophied and twisted or develop an intense gravid uterine blood flow noted in the bovine requires further study.

The intrarectal approach, if successful, would provide a standard technique for pregnancy diagnosis in small wild ruminants. The technique would indicate the distance to insert the probe in various species and the time of year for intrarectal examination would be predetermined according to fetal age. Further study is needed to develop a feasible method.

Discussion and Recommendations

Direct correlation between winter pregnancy rates and subsequent calf production, previously predicted by cow/calf ratios, would give wildlife managers a six to eight-month forecast on a herd's productivity. This would permit, with increased confidence, an early setting of harvestable numbers for the subsequent hunting season.

The 0 percent yearling pregnancy rate in 1969-70 does not support the 100 percent adult pregnancy rate, i.e., a low yearling rate with an exceptionally high adult rate would not be expected. Table 2 indicated

generally a high yearling rate with a high adult rate or a low yearling rate with a low adult rate.

The 17 percent pregnancy rate of 23 yearlings in 1970-71 is slightly under a predicted level based on the previous mild winter, but an eight percent pregnancy rate of 13 yearlings in 1971-72 was correctly predicted from the severe winter of 1970-71.

Further studies are needed to find valid causes for a possible adult pregnancy rate decrease in the Cache Elk Herd. The 1970-71 and 1971-72 adult pregnancy rates of about 82 percent may possibly be a reflection of (1) a dependence on yearling bull breeding and (2) a gradual herd increase resulting in increased habitat pressure, which has depressed the fertility rate.

The former will need added research for validation, but it is rather coincidental that the first year's results of a yearling bull breeding trial under captive conditions was 85.7 percent (12 of 14, see Objective 2). Boyd (1970) noted a decreased cow/calf ratio coincided with open bull hunts, which had placed extreme pressures on adult bulls and almost complete reliance on yearling breeding for reproduction. It resulted in a reduced cow/calf ratio of about 100/59 from a high of 100/70.

Fraser (1968b)claimed that large male numbers are necessary at subordinate levels for competitive pressures and as reserve forces to ensure adequate reproduction both qualitatively and quantitatively.

The second possible cause for lowered productivity has been well documented by many authors, including Cowan (1950), Daniel (1963), Greer (1966), Gross (1969), Lowe (1969) and Flook (1970).

Lack of yearling productivity in the Cache Elk Herd may be an indication of over-utilization of the habitat. Buechner and Swanson

(1955) noted a dramatic increase in yearling pregnancies when a herd was reduced in size. Hancock's (1955) data of 75 percent yearling pregnancies may have reflected an understocked condition on the Cache, coupled with a previous mild winter. With the improvement of herd management and habitat in recent years, fertility rates have generally increased in most elk herds (Flook, 1970).

Eighteen percent of the adult cows were not pregnant during the 1970-71 and 1971-72 winters. Thus, these cows were non-productive inhabitants on an already over-utilized winter range. Resultant increased competition for winter vegetation possibly created an unnecessary weight loss for the elk, which in effect may have matched body condition losses noted during a severe winter. It is possible, therefore, that measures should be initiated to reduce the female elk population. Continued pregnancy rate determinations in yearlings and adults would reveal reproductive responses. These responses would not be expected until the second winter subsequent to herd reduction. Optimal herd size and productivity should, in this manner, be attained.

The 1970 and 1971 elk hunting seasons were similar in that extreme hunting pressures existed. Two to three yearling bulls wintered on the Hardware Ranch meadow during the severe winter of 1970-71. The following winter a total of 21 bulls were recorded, three raghorns (2.5-year olds) and 18 yearlings. It is possible that a concomitant increase in the wariness of the elk will develop with increased hunting pressure.

The post-season bull/cow ratios rose from 5/100 in 1970-71 to 9/100 in 1971-72. An accurate 1972-73 pregnancy rate will be important, as it may indicate an increase from a greater female exposure to older

bulls. Other areas on the Cache should be sampled to determine if they have reproductive rates similar to those on the meadow at Hardware Ranch.

Ultrasonic detection

Lack of success in external ultrasonic detection of pregnancy in elk and deer may have been due to several problems: (1) restraint, (2) hair cover, (3) age of fetus, and (4) probe placement.

(1) Restraint in wild animal studies always adds an unknown entity or bias. Elk standing in a chute are not easily auscultated with the ultrasonic detector (or a simple stethoscope). The position of net trapped deer is critical to ideal probe placement. The deer's legs are invariably pulled up in a position which tends to make the inquinal area inaccessible. Immobilized animals do not present this difficulty.

(2) Hair may be important in preventing ultrasonic detection of pregnant deer. The does are completely covered with hair (in domestic and wild sheep a convenient bare area is located near the udder). Deer hairs are hollow, which interferes with penetration of signals into and reception from the animal. The hair may be plucked from the selected area in late winter; early winter requires shaving the hair.

(3) Breeding season dates may be critical. January to March is usually the most advantageous period for trapping wild ruminants. One must calculate fetal ages from these months back to the rut. The rut is from early September to early October in elk. Between January and March the fetuses should be 100-180 days old. It was difficult to auscultate fetal sounds in sheep past 110 days, even though the fetus could be palpated through the abdomen. A similar problem may occur in elk because of a heavy abdominal wall or increased uterine mass which

may prevent penetration of the ultrasonic signals to the fetus. The much later rut in deer (mid-November to mid-December), would shorten the period between conception and examination. Those examined in January may carry only 20 to 75-day fetuses. Using domestic sheep as reference, this period is too early to permit pregnancy diagnoses with over 90 percent accuracy. Those tested in February would be from 50-100 days pregnant. The older fetuses should be detectable, were it not for the problems listed. The stress of trapping and handling in the latter portion of severe winters may impair the animal's health.

The rut in wild sheep is usually in late-November to early-December. February trapping would produce only a few 60-day old fetuses.

(4) External placement of the probe is a searching or scanning procedure. Probe movement, during this search for fetal heart sounds, causes noises from the hair alone. The area scanned must be well lubricated with an emulsion, which may be difficult to apply. Signal penetration is impossible without good apposition or abdominal contact.

Use of the smaller probe provided ventrally directed ultrasonic waves. Maternal or fetal circulation should have elicited ultrasonic sounds, but none were heard.

Lindahl (1970) used a 5 MGH instrument, while the Doptone used in this study was of 2 MGH power. It is possible the difference in amplitude precluded successful examination of wild animals.

Studies should be completed with (1) probes specially modified for intrarectal insertion and (2) Doppler instruments with increased megahertz power. The Doptone was not specifically made for field examinations of wild animals. The instrument and probes must be rugged in construction to prevent an untimely interference in ultrasonic detection.

Summary

Free-ranging elk wintering at the Hardware Ranch were diagnosed for pregnancy by rectal palpation. Observations of anatomical changes in gravid and non-gravid uteri of cattle were found directly applicable to elk. Ultrasonic detections of pregnancy in elk and deer were unsuccessful. This was possibly due to (1) animal restraint, (2) hair cover, (3) fetal ages, (4) probe placement, and (5) detector design and power.

The 1969-70 winter pregnancy rates of 100 and 0 percent, respectively, in 19 adult and 5 yearling cows were associated the following fall with a pre-season cow/calf ratio of 100/55, which resulted in a post-season ratio of 100/68. The 1970-71 sampling revealed pregnancy rates of 82 and 17 percent, respectively, in 60 adults and 23 yearlings, which produced respective pre- and post-season cow/calf ratios of 100/52 and 100/39. The 1971-72 trappings resulted in pregnancy rates of 82 and 8 percent, respectively, in 39 adults and 13 yearlings. Completion of this three-year study prevented inclusion of subsequent 1972-73 fall and winter cow/calf ratios.

OBJECTIVE 2

BREEDING EFFICIENCY OF YEARLING MALE ELK

Literature Review

It is to be expected that the ratio of yearling to older bulls in "open bull" hunting areas will eventually be predominantly yearlings. Boyd (1970) related a gradual decline of bull/cow ratios in Colorado from 69/100 to 33/100, respectively, in 1960 and 1965. Most remaining bulls were yearlings.

Mace (1970) compared cow/calf ratios of 100/36 and 100/42, respectively, for 1958-60 and 1964-68. Yearlings were protected during the former period but not during the latter. A significant difference between the ratios was not evident. However, by including yearlings in the hunt, it appears a reduced hunting pressure on the older bulls would have resulted.

Yearling males may be deterred from breeding under natural conditions by the aggressive behavior of adult males, but successful yearling breedings, perhaps, would result in the absence of the latter. If this capacity to breed begins at a late date, the result would be delayed calving by the cows. Late calving coupled with a severe winter would reduce the calves' chances of survival, and an altered breeding cycle could result in relatively few calves being added to a herd (Morrison, 1960a).

Evidence indicates a physiologic correlation in elk of antler hardness and breeding condition. Frankenberger (1953) stated that during

antler growth the red deer stags (a close relative of elk) were, reproductively, in a resting state. Lincoln (1971b) found testosterone was barely detectable in testicular tissue while the antlers were rapidly growing in velvet. Towards the end of June and early July, testosterone secretion was increased, spermatogonia and eventually spermatids appeared in the seminiferous tubules. In August, the antlers were cleaned of velvet, and the neck girth started to expand. This coincided with a marked increase in testicular testosterone, spermatogenesis, increased weight of accessory glands, and a rise in vesicular fructose concentrations. Lincoln claimed that by mid-September, during the rutting season, testosterone levels were 100 times that of the quiescent stage.

Lincoln, Youngson, and Short (1970) found rutting behavior was hormone-dependent and not induced by behavioral changes in red deer hinds. In contrast to the abrupt onset and termination of the rut, they found a lingering libido, which lasted through March or April. During this time, estrual hinds elicited male copulatory behavior and aggressive threats toward rival stags.

They stated that copulatory behavior was independent of hormone level, but did not present data on sperm production. Conaway (1952) recorded spermatogenesis in October in yearlings and the appearance of regressing seminiferous tubules in November and December.

Lincoln (1971b) noted that by November rutting activity had almost ceased, testicular testosterone had declined, tubular shrinkage had begun, and there was a reduction in spermatogenesis. In completing an annual cycle, he noticed a progressive reduction in androgenic and spermatogenic activity, even though the epididymis remained packed with spermatozoa.

He reported that in April, the stag entered a stage of sexual quiescense and the antlers were cast. This annual cycle of reproductive activity in the stag was thought to be controlled by day length, and was associated with changes in the pituitary, adrenal, and thyroid glands.

Sadlier (1969a) and Morrison (pers. comm.) believed no single variable is in complete control of breeding, but light, temperature, nutrition, humidity, and elevation aid in controlling the elements of reproduction.

Amoroso (1969) claimed that light provided most reproductive regulatory cues. He assigned sheep, goat, and deer as short-day breeders and birds, asses, and horses as long-day breeders.

Lincoln et al. (1970) reported that following the winter solstice, testosterone secretion and spermatogenesis are suppressed by increasing daylight length, which leads to antler casting.

They believed increasing daylight was an inhibitory force. Its release occurred after the summer solstice, when daylight length began to decrease. They felt the amount of daylight more important than temperature in regulating reproductive activity.

These citings appear to substantiate the claim that males with antlers in velvet are physiologically sterile (Darling, 1937). Two-year old bull elk lose their velvet later in the year than do adult bulls (Murie, 1951), and possibly 10-15 percent of the yearling bulls retain their velvet into the winter. Causes are probably based on unknown endocrine changes. Harper (1966) found that 67 percent of yearling bulls sampled in October, 1966, carried a testicular sperm density that matched those of adult bulls. Lincoln (1971a) claimed that red deer stags were fertile at 1.5 years, but continued to become more active behaviorally, until almost full grown and at least seven years old.

Moffitt (1934) observed two pregnancies in a herd of four cows exposed to two yearling bulls. Mace (1956) stated that, although yearling bulls do not generally engage in breeding, they have been observed in coitus with elk cows and are undoubtedly fertile. Rensel (pers. comm.) observed successful breeding by a yearling bull in captivity, and Batchelor (1965) reported yearling breeding in the wild. Two pregnancies were recorded in an 11-cow harem exposed to yearling bulls (Blunt, pers. comm.). Moran (1970) noted the birth of a yearling sired calf.

Conaway (1952) found abundant sperm in 11 of 12 yearling bulls killed between September 17 and December 29. Frankenberger (1953) claimed puberty in the red deer was reached in the second year of life, but few sperm were produced.

Harper et al. (1967) and Knight (1970) did not observe breeding by yearling bull elk. Murie (1951, p. 124) wrote:

> Many woodsman and other observers are of the opinion that old bulls are kept so busy dashing about chasing rivals that much of the breeding is done by the young bulls, by stealth.

Harper (1971) reported that daily observations of elk in rut indicated most breeding is done by yearlings, 2.5-year olds, and 3.5-year olds.

Yearling bulls, added to a harem in a 477-acre enclosure, produced 20 and 45 percent calf crops in 1967-68 and 1968-69, respectively (Trainer and Lightfoot, 1970). A comparable adult bull study in captivity was not conducted, but the calf crops recorded the second year compared favorably with that in the wild.

Maximum pregnancy rates of 45 percent would be considered very low in most elk herds. However, if yearling males match the productivity

of adults in Oregon, perhaps similar results could be obtained in herds of greater productivity.

Methods and Materials

In February, 1971, two 15-cow harems were placed with intact males in separate 20-acre enclosures. Group 1 included five male calves trapped from the meadow at Hardware Ranch. Group 2 contained three 3.5-year old bulls. The groups were separated by an eight-foot high burlapped wire fence.

The nutrition included grass hay and pellets fed free-choice. The elk had access to available grass on the pasture, a portion of which was irrigated during the summer and fall.

Two yearling bulls were removed from group 1 on September 26, 1971, when initial hardening of the antlers was observed. Blood samples were taken for hormone analyses. One bull was placed in a corral for weekly blood sampling through the breeding season.

Cows exposed to adult bulls were palpated for pregnancy on December 18, 1971, with conception dates estimated by uterine size and structure as in Objective 1.

Cows exposed to yearling bulls were scheduled for pregnancy testing at a later date, but on December 18, 11 of the 15 test animals escaped. These cows were examined for pregnancy during routine trapping operations in January and February, 1972. Fetal ages were estimated as described in Objective 1. The remaining four captive cows were examined on January 28, 1972.

Blood samples were collected from bull calves, yearlings, ragHorns, and adult bulls during handling procedures each winter. Blood

androgen levels were determined to possibly provide an annual reflection of reproductive conditions.

Semen samples were collected by electro-ejaculation for observations of sperm motility and structure.

Observations of sexual behavior in groups 1 and 2 were conducted from September 6 to mid-October. Coital dates were compared with uterine conditions found by rectal palpation in December and January.

A comparative analysis of the social and sexual behavior in the two captive groups was assigned to Walter Prothero, graduate student. A detailed behavioral study of groups 1 and 2 will be presented in a Master of Science thesis scheduled for completion in 1972.

Results and Conclusions

Pregnancy rates

Exposure of group 1 to three yearling bulls and group 2 to three adult bulls resulted in 85.7 (12 of 14) and 93.3 (14 of 15) percent pregnancy rates, respectively. The earliest and latest conception dates were about October 5 and November 21, and September 5 and November 3, 1971, in groups 1 and 2, respectively. Eight of 12 pregnancies in group 1 were in October, while 10 of 14 in group 2 were in September.

There was no significant difference in breeding success of the two experimental groups. The pregnancy rate of 85.7 percent recorded by yearling bulls was much higher than previously reported. Moffitt (1934), Trainer and Lightfoot (1970), and Blunt (1970) reported yearling bull breedings, during similar fall breeding seasons, of 50, 45, and 18 percent, respectively. A 93.3 percent pregnancy rate produced by adult

bulls was nearly a median between that found in the Cache Elk Herd in the 1969-70 trapping operation and those of 1970-71 and 1971-72 (see Objective 1).

Conception dates

Table 4 gives the age and reproductive status of each animal when placed in the 20-acre enclosures during the 1970-71 winter, the estimated age of fetuses in groups 1 and 2 when palpated during the 1971-72 winter, conception dates based on uterine size and structure, and a projected calving date in 1972.

Conceptions in group 1 were about a month later than in group 2, but both groups included cows which conceived in November. Greer (1965b) noted 10 percent of aged fetuses were conceived in the latter part of November.

Figure 2 indicates some grouping of estrous cycles. Estimated fetal ages are probably accurate within four to five days. First conceptions occurred about September 5, 1971. In the adult bull harem an early estrus peak occurred near this time. Pregnancies recorded as 105 days should be interpreted as "a minimum." Difficulty in distinguishing between a 105-day pregnancy, and those slightly advanced, precluded a more accurate estimate. Death of one experimental cow permitted verification of a 105-day predicted pregnancy by fetal measurement (see Objective 1).

There appeared to be two peaks of breeding in cows bred by adult bulls. The first peak occurred during the first week of September, with the second occurring about September 20. Seven of 12 pregnancies in cows bred by yearling bulls were conceived between October 11-25, and one cow conceived as early as October 5, 1971.

Table 4. Calculated conception dates and projected calving dates from estimated fetal ages of females bred to yearling bulls and females bred to adult bulls.

Reproductive status at time of confinement[a] (Feb. 1971)	Age at breeding (yrs)[b] (1971)	Estimated age of fetuses[c] (± 5 days)[d] (1971-72 winter)	Calculated dates (or see Figure 2) (month/day) Conception (± 5 days)[d] (1971)	Calving (± 7 days)[e] (1972)
Females bred to yearling bulls				
Non-pregnant	2.5	90 (85-95)	10/15 (10/10-20)	6/27 (6/20-7/4)
Non-pregnant	2.5	85 (80-90)	10/25 (10/20-30)	7/07 (6/30-7/14)
Non-pregnant	2.5	105 (100-110)	10/05 (9/30-10/10)	6/17 (6/10-24)
Non-pregnant	2.5	Non-pregnant		
Non-pregnant	2.5	90 (85-95)	10/22 (10/17-27)	7/04 (6/27-7/11)
Pregnant	10.5	65 (60-70)	11/21 (11/16-26)	8/03 (7/27-8/10)
Non-pregnant	2.5	105 (100-110)	10/11 (10/6-16)	6/23 (6/16-30)
Non-pregnant	2.5	105 (100-110)	10/11 (10/6-16)	6/23 (6/16-30)
Non-pregnant	Mature	80 (75-85)	11/09 (11/4-14)	7/22 (7/15-29)
Non-pregnant	2.5	85 (80-90)	11/4 (10/30-11/9)	7/17 (7/10-24)
Non-pregnant	2.5	100 (95-105)	10/20 (10/15-25)	7/02 (6/25-7/9)
Pregnant	5.5	105 (100-110)	10/14 (10/9-19)	6/26 (6/19-7/3)
Non-pregnant	Mature	Non-pregnant		
Pregnant	Mature	105 (100-110)	11/09 (11/4-14)	7/22 (7/15-29)
Pregnant	5.5	(Escaped)		
15 adult cows (calf)	Yearling	Non-pregnant		
Females bred to adult bulls				
Non-pregnant	2.5	105 (100-110)	9/05 (8/31-9/10)	5/18 (5/11-25)
Non-pregnant	2.5	105 (100-110)	9/05 (8/31-9/10)	5/18 (5/11-25)

Table 4. Continued

Reproductive status at time of confinement[a] (Feb. 1971)	Age at breeding (yrs)[b] (1971)	Estimated age of fetuses[c] (± 5 days)[d] (1971-72 winter)	Calculated dates (or see Figure 2) (month/day) Conception (± 5 days)[d] (1971)	Calculated dates (or see Figure 2) (month/day) Calving (± 7 days)[e] (1972)
Non-pregnant	2.5	105 (100-110)	9/05 (8/31-9/10)	5/18 (5/11-25)
Pregnant	9.5	105 (100-110)	9/05 (8/31-9/10)	5/18 (5/11-25)
Non-pregnant	11.0	105 (100-110)	9/05 (8/31-9/10)	5/18 (5/11-25)
Non-pregnant	2.5	90 (85-95)	9/20 (9/15-25)	6/02 (5/26-6/9)
Non-pregnant	2.5	90 (85-95)	9/20 (9/15-25)	6/02 (5/26-6/9)
Non-pregnant	2.5	90 (85-95)	9/20 (9/15-25)	6/02 (5/26-6/9)
Non-pregnant	2.5	90 (85-95)	9/20 (9/15-25)	6/02 (5/26-6/9)
Non-pregnant	2.5	80 (75-85)	9/30 (9/25-10/5)	6/12 (6/5-19)
Pregnant	6.5	65 (60-70)	10/15 (10/10-20)	6/27 (6/20-7/4)
Pregnant	10.0	50 (45-55)	10/30 (10/25-11/4)	7/12 (7/5-19)
Pregnant	9.5	45 (40-50)	11/03 (10/29-11/8)	7/16 (7/9-23)
Pregnant	Mature	45 (40-50)	11/03 (10/29-11/8)	7/16 (7/9-23)
Pregnant	Mature	Non-pregnant		
15 adult cows				

[a]Based on rectal palpation when trapped for confinement.
[b]Based on tagging data or aging by incisor teeth (Hancock and Low, 1956).
[c]Age of fetuses estimated by rectal palpation between December 18, 1971 and February 22, 1972.
[d]Based on estimated fetal age (human error of ± 5 days).
[e]Based on an average 255-day gestation period (248-262 days).

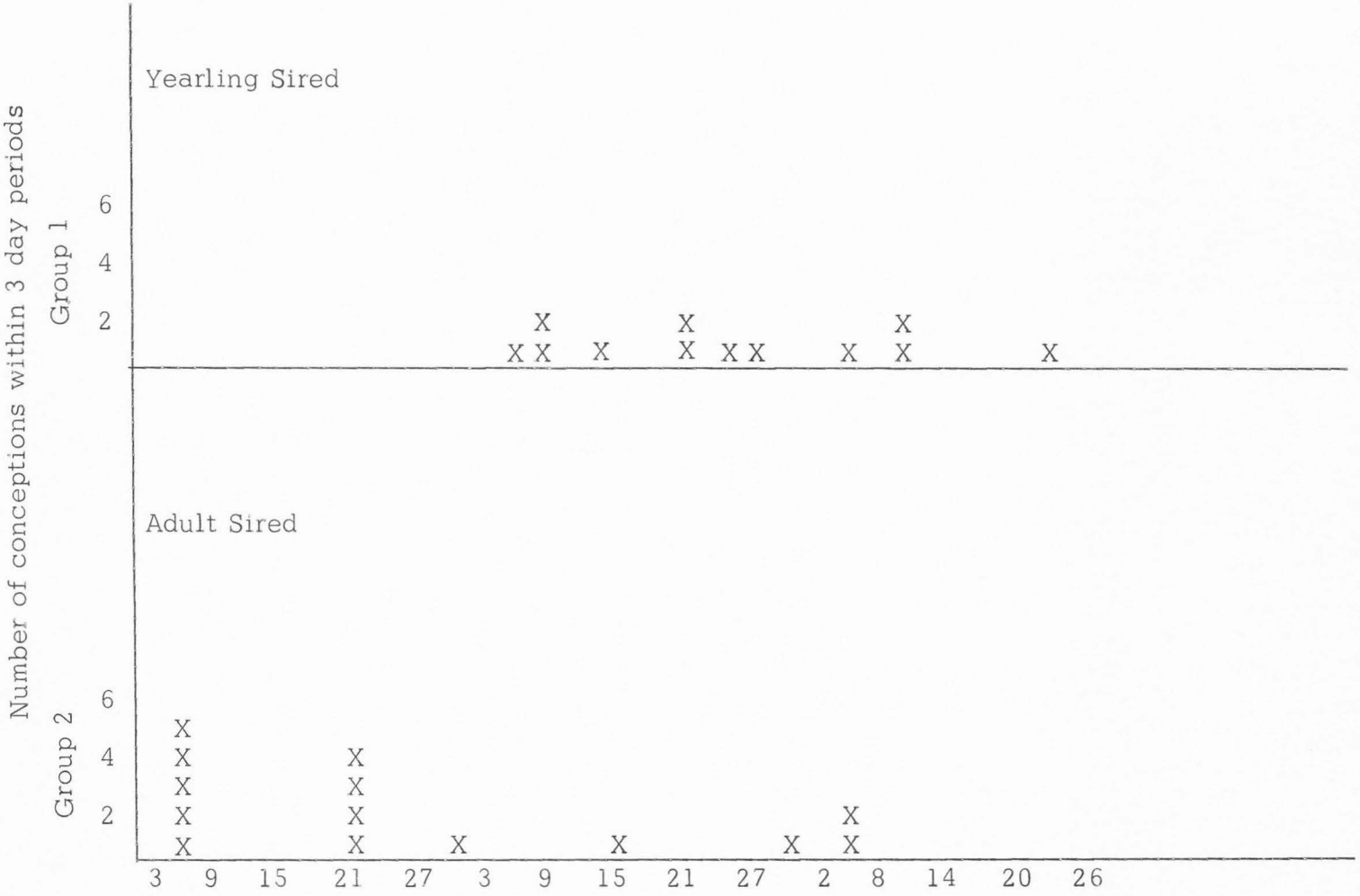


Figure 2. Estimated conception dates of cows in separate harems bred by yearling and adult bulls.

This indicates that the majority of calves sired by yearling bulls will be four to six weeks younger than those sired by adult bulls. Parturition in the former group should occur during late-June, July, and early-August. All, but three births in the adult bred group, should occur from mid-May to early-June.

As most calves from group 1 will be younger than group 2, their pre-winter weights will be less, which would reduce their feeding competitiveness during the winter months. Reduced availability of food during the juvenile period may delay puberty (Sadlier, 1969a). A lower percentage of yearling bulls capable of breeding early in the breeding season may occur, which would continue delaying the calving period. The onset of breeding in affected female calves may be delayed until they are 2.5 years of age.

The 1971 elk hunt in the Cache and Ogden River areas was held on October 3-17. Table 4 and Figure 2 indicate this coincided with the beginning of breeding by the captive yearling bulls. What effect, if any, this has on breeding in the wild is questionable. Estrous cows will seek out males (Morrison, 1960a). In the wild, yearlings seek shelter during the day, but probably seek other elk for companionship at night, at which time breeding could take place.

Blood androgens

Values in Table 5 and Figures 3 and 4 indicate comparable blood androgen levels each winter in male elk of all ages. Absence of sampling during the summer makes interpretation of Figures 3 and 4 difficult, but a high level is shown in September for yearlings and October for adults. This coincided with an increase in breeding activity.

An androgenic peak at this time is preceded and followed by a low level in the winter months in yearling and adult bulls.

Table 5. An analysis of blood androgen values[a] collected from male calves between January and March, and yearlings and adults between January and May (1970, 1971, and 1972).

Number tested	Mean	Standard error	Range
24 calves	2.00	0.165	0.28-4.28
31 yearlings	2.20	0.140	1.11-4.45
14 adults	2.35	0.173	1.56-3.79

[a]Androgen values are in ng/ml.

Loss of velvet

Utah Division of Wildlife Resources personnel recorded data on velvet loss of yearling examined during the 1971 fall hunt (October 3 to 17).

Area	No. examined	No. polished or peeling	No. in velvet
Cache	44	41	3
Ogden River	14	7	7
	48	48	10

An overall 82.8 percent with hard antlers correlated favorably with four of the five yearlings held in captivity with group 1 having polished antlers by October 1. The other yearling bull remained in velvet until late October. The captive adult bulls began rubbing their antlers during the week of August 15.

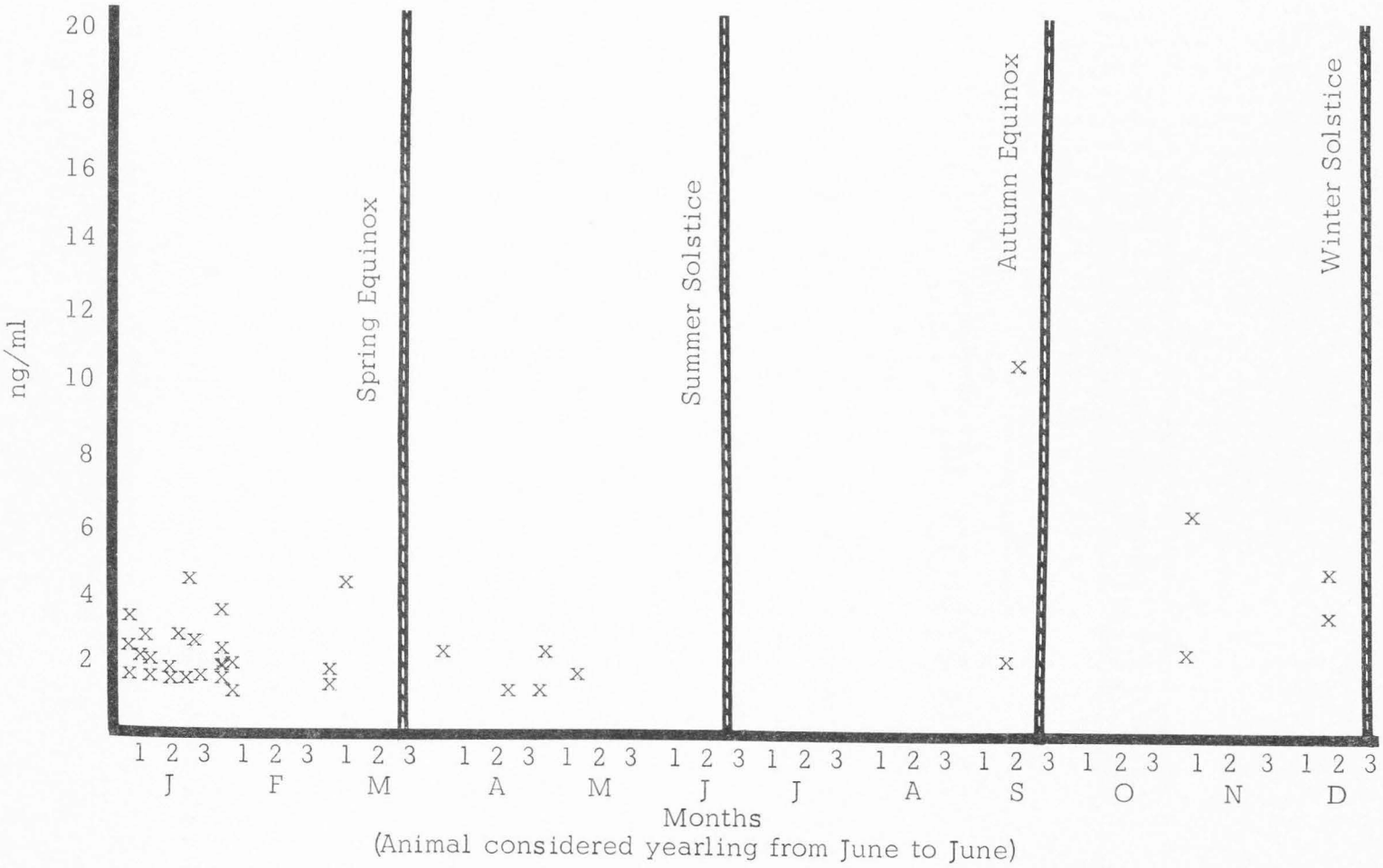
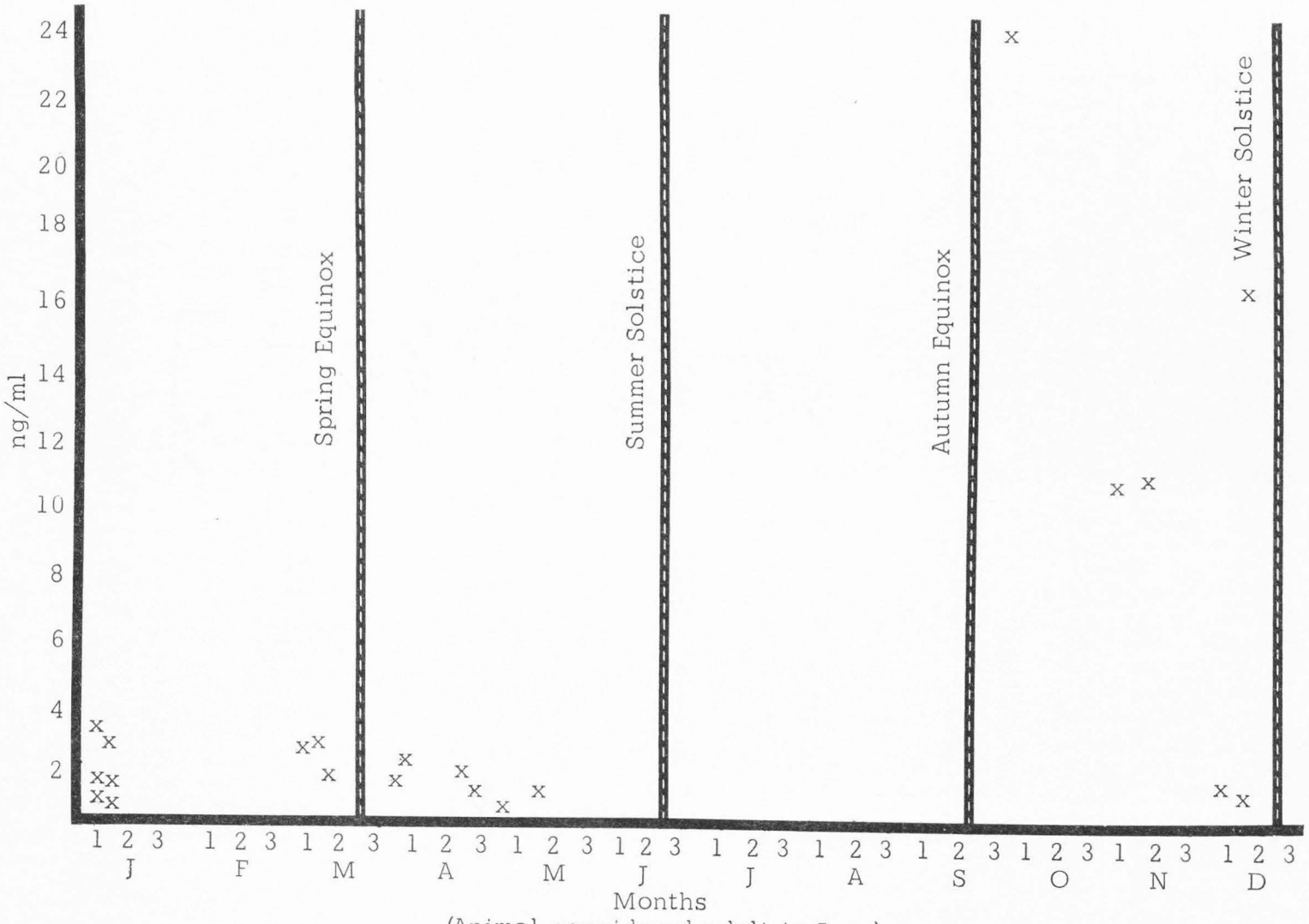


Figure 3. Blood androgen values recorded for yearling male elk (fall 1969 to winter 1972).



(Animal considered adult in June)

Figure 4. Blood androgen values recorded for adult male elk (fall 1969 to winter 1972).

Yearling bull androgen levels

Two yearling bulls with hard antlers were to be immobilized (with succinyl choline hydrochloride) and placed in a corral near the end of September for weekly blood sampling. It was hoped that serial blood tests would provide androgen levels closely related to the yearlings remaining with the harem. Unfortunately, one yearling ("H") was lost to injuries during capture procedures. Three yearlings were randomly selected to match the three adults in group 2 which allowed placement of yearling "O" in the corral.

Yearling "O" was first sampled on September 4, revealing a blood androgen level of 7.01 ng/ml. Table 6 shows a low androgen reading of 2.02 ng/ml for yearling "Z", while in soft velvet on September 15. This agrees with levels recorded between January and May (Table 5) prior to and coincident with early antler development. Levels of 10.91 and 11.29 ng/ml, respectively, were recorded on September 26 in yearlings "O" and "H" (Table 6), indicating a rise of blood androgen in yearling "O" from September 4.

Captive yearling blood androgen levels reached a peak on September 26, 1971. A peak here may be followed by a gradual decline to low levels in December. Some data are presented to support this assumption, but further blood samplings during this period are needed to gain a better insight into the reproductive physiology of yearling breeding seasons. Lincoln (1971b) reported a similar peak of testis testosterone in adult red deer.

Additional measurements of blood androgen for yearling "O" revealed a depressed level of 2.02 ng/ml on October 4 (Table 6). The animal had been highly irritable, pacing constantly in the corral, but

Table 6. Androgen levels for yearling bulls during the 1971 rut.

Date	Yearling identification	Blood androgen ng/ml	Antler condition
9/4/71	O	7.01	dried
9/15/71	Z	2.02	velvet
9/26/71	O	10.91	rubbed
9/26/71	H	11.29	"
10/4/71[a]	O	2.02	neglected
10/19/71	O	2.18	"
10/26/71	O	1.61	"
11/6/71	O	1.98	"
11/11/71	O	2.61	"
11/18/71	O	2.17	"
11/22/71	O	1.58	"

[a]Yearling "O" appeared greatly stressed, developed pododematitis around October 10, 1971, and was eventually sacrificed because of poor health. Low values for this animal probably reflect this condition.

feed intake had remained good. A severe case of pododermatitis (foot rot) developed two weeks later. Despite the initiation of appropriate therapy, the animal's condition deteriorated and it was sacrificed in early December. A very large subscapular abscess appeared to be the cause of the animal's rapid deterioration in body condition.

Breeding patterns

Figure 2 indicates all yearling breeding was accomplished during the sampling period of yearling "O." Copulation by one of the yearlings was observed on November 14, 1971, by Alan Muir, Superintendent of Hardware Ranch.

Behavior studies during this project indicated similar breeding patterns by yearling and 2.5-year old bulls, one of intermingling with the herd. Definite rutting or hypersexual activity was not observed until the bulls were at least 3.5 years of age.

Troyer (1960) and Batchelor (1965) did not observe harem formation on Afognak Island, Alaska. Bulls of all ages intermingled in the herds in an evenly distributed pattern. Copulations by yearlings were observed in this unusual breeding situation.

Breeding season observations were conducted from September 6 to mid-October. Rut behavior in group 2 began in late-August and reaching a peak in late-September. A dominant harem bull was present throughout the breeding season, which ended in mid-November.

In group 1, some heterosexual (male-female) activity was noted in late-September, while antlers were polished about October 1. The yearling bulls intermingled in the herd with a peak of activity appearing from late-October to mid-November. Altmann (1960) noted a terminal rutting behavior as the seasonal rut waned. Struhsaker (1967) found

that yearlings, initially driven away by harem-forming bulls, returned to rejoin the herd earlier than the 2.5-year olds. She claimed that the adult bulls tolerated the yearlings re-entry. The yearlings, however, would have enjoyed an unchallenged opportunity to breed cows during this terminal rut behavior.

Darling (1937) stated that it was extremely rare to witness coitus in red deer. Morrison (1960a) separated his experimental bull from the females at night. He observed that most all estrous signs began and ended at night. He recorded an average 17-hour estrus occurred at intervals of about 21 days.

Copulations were not observed during the first two breeding seasons (1969 and 1970) in which observations of captive elk were conducted. Coitus by one yearling and one adult bull was actually observed during the fall of 1971. Almost continuous daylight observations on sexual behavior, during the breeding season, were conducted by two investigators. Intromission by one adult bull was recorded by Walter Prothero, graduate student, at 3:30 p.m. on September 26 and the second breeding was observed by Alan Muir. Rectal examinations revealed that 26 of 29 captive cows in groups 1 and 2 were pregnant. Thus, only two of a minimum of 26 copulations were observed, which indicates most breeding occurred at night.

The burlapped fence appeared to effectively prevent behavioral influences between the two groups. Adult bugling apparently did not have an inhibitory effect on the yearling bulls, nor an attractive effect on females in group 1. Visual dominant behavior by adult bulls appeared to be effectively blocked by the burlap between the enclosures.

Semen collection

Semen samples were collected by electro-ejaculation from one 2.5-year old and one yearling bull in November, 1969, and one adult and three yearling bulls on March 3, 1970. The 2.5-year old bull produced live sperm in November, but the yearling produced a minimal amount of semen which became contaminated and contained dead sperm. The March samples were of good quality from the adult and two of three yearlings. Cytoplasmic droplets (small nodules on the tail) were commonly observed. Motility and structure were classified as good by Keith Hoffman and Mike Kohler from the Cache Valley Breeding Association, who assisted in the collection procedures. Attempts to collect second samples from the yearlings produced a minimal amount of semen.

Semen samples were collected from yearlings in January and February, 1971. The initial ejaculation provided abundant sperm of normal appearance. Attempts to collect sequential samples from the yearlings during the following weeks were unsuccessful. This suggested that yearlings (and possibly adults) would not have been capable of breeding estrous cows after more than one or two copulations during this period. The sperm portion of the ejaculate was probably from the animal's epididymal sperm reserve. Flook (1970) observed epididymis-stored sperm of normal density in January, while Lincoln (1971b) noted sperm in the epididymides of red deer in May and June.

Discussion and Recommendations

Delayed breeding

Table 4 indicates that seven of eight cows, pregnant in February, 1971, had not conceived until October 14 or later. Many of these cows

had not calved before late-June or July, 1970. Morrison (1969a) suggested elk do not show heat for three to four months following parturition. He observed a captive cow showing recurrent estrus to a vasectomized bull until December. This cow produced an autumn calf after being exposed to an intact or viable bull. She retained this delay in breeding for several years, producing few calves which survived the winter despite adequate food and shelter.

Rectal palpations during the 1969-70 winter revealed the appearance of follicular and luteal structures in captive non-pregnant elk. These animals intermingled with vasectomized bulls. Observations for coitus were made with heat mount detectors. Mountings were observed by Steve Kearl while feeding animals, but copulations were not seen. Four heat detectors were broken, two in November, 1969, and two in January, 1970.

Winter ovulations may not be accompanied by estrus, resulting in "silent heats." Late estrus with conceptions would, of course, prolong the calving period into late summer and early fall.

The yearling bulls were estimated to have begun breeding on October 5, 1971, which was five days following appearance of polished antlers. Two of the yearlings appeared to have dried velvet at an earlier date, but had not used the rubbing post. Conceptions in the yearling bull harem were about a month later than those of the adult bull harem.

Although none of the experimental cows in Objective 2 conceived as late as December, the delay in breeding apparent in group 1 may become perpetual for late-conceiving cows. This altered breeding cycle would be detrimental to herd health and reproduction.

Seven of the 12 pregnancies were conceived between October 11 and October 25, 1971. This breeding peak occurred one to three weeks after the yearlings began velvet removal. These conceptions would produce late-June to early-July calves. Four pregnancies were conceived in November, one near November 21. Parturition from these conceptions should be from late-July to early-August.

Calves born in late-June to early-July create a problem of small calves facing winter conditions. Any further delay would decrease chances for survival. Dependence on yearling breeding the following year, under such conditions, might be hazardous. This would be due to an increase in the percentage of immature calves. As this percentage increases, total dependence on yearling breeding may alter an elk herd's calving dates. Even if this was recognized and hunting was restricted for a year or more to permit an increase in adult bull numbers, the herd's return to normal calving dates may be slow.

An increase in immature male calves would probably lead to a decrease in pregnancy rates. The cows, which had not conceived during the previous fall, would probably begin an early estrous cycle the following rut and conceive. This implies that a return to a normal annual reproductive cycle (where the majority of adult cows probably become pregnant in September) may occur. However, pregnant cows from late conceptions may continue to be late breeders, despite the presence of adult bulls.

Initiation of estrus

Morrison et al. (1959) found approximately one-week difference between elk breeding peaks on the National Bison Range and at Gardner, Montana. Gates (1960 and 1961) reported rutting in New Mexico elk

herds from August 25 to September 28 the first year, and until October 28 the second year, with respective peaks on September 7-14 and 4-17. Raught (1962) found breeding from August 24 to October 11, and Gates (1966) reported dual peaks of conceptions, September 7-11 and 18-24. Gates reported peaks between September 18-24 for three years. Greer (1965b) reported five percent of the elk conceptions occurred in mid-September, a major portion from late-September to early-October, and 10 percent in the latter part of November. Murie (1951) stated that the active rut extended from September 1 to late-October, though the bulls ardor had diminished by October 10.

According to the literature, an estimated peak in estrus near September 5 seemed early (Figure 2), but these cows were in continuous contact with harem bulls. This event probably does not occur in the wild, where bulls appear to polish their antlers in isolation from cows.

Antler rubbing, which signaled the initiation of breeding capacity, was six weeks later in the yearlings than in the adults. This delay in shedding velvet by younger bulls also was noted by Murie (1951) and Cross (1965).

"Hyper-sexual activity" (rutting behavior) begins in the presence of females, which Lincoln et al. (1970) noted was usually four to six weeks after the antlers were cleaned. The intermingling of adult bulls in the experimental groups may have increased the onset of an early estrous peak.

Schinckel (1954) and Vera y Vega (1959) discussed differences between intermingling and introduction of rams into flocks. Vera y Vega noted in his 1951-58 work that intermingling caused year-round lambing. Both authors noted synchronization of estrus when rams were introduced

into flocks at specific times, and Shelton (1960) reported similar effects in goats. Schinckel reported that introduction had a primary effect of stimulating ovulation without estrus (silent heat) in the majority of ewes which had not begun cyclic breeding activity. This had an effect of causing a "lag of peak" effect, which tended to synchronize (within eight to ten days) most ewes into a breeding estrus. Preovulatory evidence seven days before estrus in mule deer (Odocoileus hemionus) will be reported shortly from Canadian research (Cowan, pers. comm.). This phenomenon has not been reported in elk.

Blood androgens

Blood androgen levels are shown in Figures 3 and 4, respectively, for yearling and adult bulls. These samples were taken when possible and do not represent planned intervals throughout the year. Low levels in the winter are followed by high levels in the late-summer and fall. Lincoln (1971b) related testis testosterone, combined testis weight, and diameter of the seminiferous tubules as measurements of changes in the reproductive conditions of male European red deer. Passage of the summer solstice, he claimed, heralded recrudescent reproductive changes in the red deer. He recorded seasonal changes in all three parameters. Lincoln's data indicated a low level of testis testosterone prior to the summer solstice and a peak in early-September, with a gradual reduction to near 0 in December. If the male elk reproductive cycle is similar to red deer, one would expect blood androgen activity to gradually rise in the summer. Flook (1970) recorded a peak in testis size in September, from which it decreased rapidly by November. His data indicated an increase in testis size each year during this period, from calf to six years of age.

Similar blood androgen mean, range, and standard error of the mean in Table 5, suggested that from January to May, the reproductive system in elk of all ages entered a state of relative inactivity. Lindner and Mann (1960) noted that bovine testicular androgenic activity was mainly androstenedione and testosterone. The ratio between these two male hormones varied considerably, especially within age. In young calves, they found this ratio reached approximate unity, but by nine months testosterone became the predominant testicular steroid with a ratio of 1/10. Elk calves, tested between January and March, were from eight to ten months of age. Continued testing in calves is needed to match April and May samples for yearling and adult males. Cole and Cupps (1969) reported androstenedione and other male steroids were present in small amount in the bovine. Separation of androstenedione and testosterone activity for elk blood samples collected periodically throughout the year are needed to gain a more sensitive measure of male steroidal activity. It is generally known that testosterone is the main steroid secreted by Leydig cells. Lindner (1961) noted a close correlation between testosterone synthesis and that found in the spermatic vein. It could be assumed, therefore, that blood androgenic activity would indicate testicular activity, if androstenedione and other steroids are present only in small amounts.

Lincoln et al. (1970) noted libido in red deer during this period, and stated that the stag was unable to maintain this activity for more than a few months after a sudden drop in testosterone, and depended on a recrudescent period each autumn to revive this lost libido. They claimed visual cues alone may be sufficient to elicit libido long after the rut, when testosterone levels have reached low levels, but not past early velvet.

Breeding patterns of yearling bulls

Altmann (1960) reasoned that, as elk mature, they become more organized in their behavioral patterns. The yearling bulls in Rocky Mountain herds appeared to be psychologically castrated after a dominant adult bull jointed the harem. Before this period, she claimed yearlings had often shown a number of characteristics, typical of adult rutting patterns, i.e., tending, mounting, bugling, reduced feeding, and increased locomotion.

A yearling bull, active in breeding and responsible for reproduction may, from his first rut experience, be more of a harem bull during his next breeding season as a 2.5-year old. The yearlings exhibited juvenile behavior patterns of harem formation. In attempts to urge a female towards the herd, they often would appear to pursue the cow, driving her away from the harem.

Semen collection

Electro-ejaculation is an artificial means of collecting semen, which could elicit unfavorable responses at variance with those of natural coitus. Cole and Cupps (1969) noted that electrically induced bovine ejaculates greatly exceed those collected with an artificial vagina. Further studies are needed to determine which reproductive glands are functioning, total amounts of seminal plasma produced by each gland, and percent of epididymal sperm in each ejaculate. Cole and Cupps reported Yamane's work that the sperm portion of stallion semen may be three percent. Bovine semen samples they noted may contain from three to about ten percent sperm volume of the total ejaculate.

The decrease in blood androgen levels in late-November and December, noted in this study, possibly signaled the reduction of Leydig cell secretion. This lack of adequate androgen causes testicles and accessory reproductive glands to reduce in size (Cole and Cupps, 1969), which would, in effect, reduce the seminal plasma for sperm transport. The adult bull produced a good semen sample with viable sperm during the second ejaculation. There are probably sufficient viable sperm in yearling epididymides (Flook, 1970) for a second ejaculate, but the possible lack of adequate sperm transport fluid might prevent actual fertilization.

Detailed studies should be conducted on elk herds in which males of selected age groups could be sacrificed. A study of the annual reproductive cycle is urgently needed to supplement the information obtained during this study. The information presented in Objective 2 has answered many questions posed by wildlife managers, but in turn, it has posed additional questions. The yearling bull study should be repeated in 1972. Comparable results would reinforce the belief that male elk, born during the normal calving season from mid-May to early-June, could produce pregnancies in adult elk cows. However, experiments should be conducted which would (1) measure the difference in breeding onset and efficiency between late-born calves and those born from mid-May to early June, and (2) determine if yearling males in the wild, breed as efficiently as those in captivity, and (3) determine what effects delayed breeding in cows has on their breeding time the following year.

Summary

Two 15-cow harems, exposed to three yearling or three adult bulls (groups 1 and 2, respectively), had conception rates of 85.7 (12 of 14) and 93.3 (14 of 15) percent, respectively. Seven in group 1 conceived between October 11-25, while fetal age estimates in group 2 indicated two peaks of conceptions, September 5 and 20, 1971. The earliest and latest conception dates were near October 5 and November 21, and September 5 and November 3, 1971, respectively, in groups 1 and 2. Data on velvet loss in the captive and hunted yearlings indicated that most antlers were polished or began peeling near October 1, 1971. The adults began polishing their antlers during the week of September 15, 1971.

Blood androgen levels of yearling and adult bulls suggested that peaks were reached in October, which followed a low in May. Blood samples from a yearling, isolated from group 1 at the time of velvet loss, failed to show an anticipated high level of androgen. This may have resulted from stress of isolation and subsequent illness. Low levels of blood androgen in male calves, yearling, and adults during the months from January to May over a three-year period indicated a state of relative inactivity occurred. Data suggested a recrudescent growth of testicular tissue had initiated a rise in blood androgen, which coincided with an increase in breeding activity.

Yearlings intermingled within the elk herd in a behavioral pattern comparable to that exhibited by 2.5-year olds during breeding season observations. Definite rutting behavior was observed in 3.5-year olds.

One adult and two of three yearlings, electro-ejaculated on March 3, 1970, produced a good quality semen sample. The yearlings

failed to produce a second sample. Yearlings, electro-ejaculated in January and February, 1971, produced one good quality semen sample. A second sample could not be collected during the following weeks. This was possibly due to electro-ejaculatory effects or reduced amounts of seminal plasma.

It was hypothesized that a delay in breeding onset by yearling male elk, in a herd where reproduction is yearling male dependent, may initiate a perpetual delay in calving dates. This alteration in annual reproductive cycles may decrease the percentage of subsequent viable yearling males, but also may be detrimental to calf survival. These factors, in effect, could lower pregnancy rates. Game managers, by controlling male hunting for one or more years, could possibly effect some return to normal reproductive cycles. Non-pregnant females would probably show an early estrus during the subsequent rut, but cows pregnant from a late conception may not.

OBJECTIVE 3

HORMONE INDUCEMENT OF TWINS IN ELK

Literature Review

Pincus (1965) claimed that primordial germ cells of an embryo originate in the endoderm and migrate to the genital ridge. These cells in a female embryo induce formation of fetal ovaries, and, he noted, act as stem cells for primordial ova present at birth. Female reproductive capacity ceases when these oocytes (totaling about 500,000 in the human) are depleted during repeated estrous cycles. Pincus argued that fertilization may be accomplished only if capacitated sperm are in the oviducts in close proximity to discharged ova.

Amoroso (1969) noted that ovulation is a process in time and appears to occur subsequent to a sudden increase in the secretion of a lutinizing hormone (LH) in conjunction with the secretion of follicle-stimulating-hormone (FSH). Pituitary gonadotropins are secreted following stimuli from releasing factors transmitted to the pituitary gland via a portal system from the hypothalamus.

Harris (1959) noted that the act of ovulation within the estrus cycle is essential for the continuance of the species. This includes: (1) the ripening follicle, (2) the follicle rupture and ovum discharge, and (3) synchronization of the behavioral response of the organism, so that at about the time of ovulation the female is receptive to the male and fertilization of the ovum is successfully achieved. Hansel, Armstrong, and McEntee (1958) reported that the bovine anterior pituitary is

stimulated to release LH during estrus (which initiates ovulation) by a neurogenic mechanism having a cholinergic component.

Labhsetwar (1970) reported neither FSH nor LH in sub-threshold doses would induce ovulation when given with an antiestrogen agent (an antihormone produced by an animal recipient in response to serial estrogenic injections), but were synergistic in potentiating the incidence of ovulation when given together.

Rowson (1951) and Dawson (1961) reported the induction of ovulation at any specific time could be produced by squeezing out the corpus luteum per rectum. Estrus occurred from two to four days afterwards, and was accompanied by ovulation. The onset of estrus after the expression of the corpus luteum was hastened by previous treatment with PMS.

Twinning in elk

Twins in elk are rare (West, 1941; Schwartz and Mitchell, 1945; Green, 1950; Murie, 1951; Kittams, 1953; Lang, 1958; and Flook, 1970). Johnansson (1932) reported 1.88 and 0.44 percent, respectively, as the incidence of twin births in dairy and beef cattle. Love (1955) noted elk on Elk Island Park produced five percent twins. Cowan (1950) reported 20-25 percent twins in an understocked herd in Watertown Park, Canada. These were observed during routine cow/calf counts by game wardens. Many writers including Harper (1966 and 1971) and deVos, Brokx, and Geist (1967) have commonly observed elk cows babysitting calves while their mothers feed at a distance. Accumulated data indicate an average elk herd probably contains less than 0.5 percent twins. Induced twinning in elk would be a beneficial technique to cause a rapid increase of a low productive or intensely-hunted elk herd. A theoretical 100 percent twinning rate would double elk production. Twinning also

would reduce the number of cows needed to be carried in the parent herd. Success in hormone inducement of multiple births would call for future studies to establish practical techniques for field application.

Except for the occurrence of identical twins (spontaneous division of a fertilized ovum), at least two follicles must be developed for subsequent release of ova, before twins can be produced. Before estrus there are many small growing follicles on the ovaries, but normally in elk only one is ovulated at a time.

Hormonal control of fertility in the bovine cow is mainly by two gonadotropins, FSH and LH (Gordon, Williams, and Edwards, 1962). They claim the main factor limiting numbers of ripening follicles is the amount of FSH present, as there are adequate amounts of LH present to ovulate considerably more than the one follicle which ripens. Scanlon, Screenan, and Gordon (1968) said the main factors controlling ovulation rates are the number of follicles capable of responding to PMS (equine gonadotropins, a major follicle stimulating hormone secreted by the endometrial cups between days 45 and 120 in pregnant mares) and the time interval elapsing between injection and estrus.

Morrison (1960b) counted the number of follicles present in pregnant and non-pregnant elk. He recorded only those follicles over 2 mm in size with large numbers being formed in both classes (see below). There was no difference between captive and wild animals.

Uterine conditions	No. elk	No. follicles per animal	No. of follicles 2-5mm	5-8mm	8-8 mm
Gravid	20	20.5	19.0	1.0	0.5
Non-gravid	24	16.5	19.2	1.8	0.5

(From Morrison, 1960b)

Kidder, Barrett, and Casida (1952) found normally occurring multiple ovulations of 13.1 percent in cattle produced only 1.92 percent twins. They noted significantly higher fertility in single ovulating than multiple ovulating cows.

Embryonic mortality

Williams (1933) thought twinning in cattle was "pathologic." Ruthardt (1935) reported calves born from multiple pregnancies showed a mortality of 8.2 percent stillborn and 9.2 percent deaths soon after birth. He theorized that multiple births must be hereditary, but recessive, as cows producing several sets of twins missed several years in between these sets. Woodward and Clark (1959) found twinning resulted in higher than average stillbirths. Hammond (1949) noted that all pregnant cows during studies on superovulation aborted at about five months when more than five corpora lutea were present.

Rowson, Lawson, and Moor (1969) indicated that embryonic survival is influenced by the relationship between the unilaterally located embryo, uterus and ovary. They noted the possibility that failure of migration of one of the eggs from an ovary with a double ovulation to the contralateral uterine horn creates a state of competition between the two developing embryos within the same horn. The result of such competition is a subsequent loss of one embryo.

	Percentage of animals carrying twins when ovulations occur:	
Number of animals	On a single ovary	One ovulation on each ovary
67 cows	28.6	61.5
69 sheep	57.6	75.0
195 goats	56.7	73.3

(From Rowson, Lawson, and Moor, 1969)

These authors had some success in producing twins in cattle by transferring viable ova from a donor cow to a recipient. They suggested that failure of migration of one egg when both were placed in one horn was the primary reason for failure of twinning. A secondary factor was that in the slaughtered animals about double the number of cotyledons were found stimulated when an embryo was developing in each horn, which probably affected embryo survival. Chapman and Dansie (1970) found transmigration of ova was normal in 50 percent of the pregnancies in muntjac deer (Muntiacus reevesi Ogilby). In fallow deer (Dama dama L.) Armstrong et al. (1969) noted transuterine migration occurred in 52 percent of wild deer and 28 percent of park deer. Transfer of one ova to each uterine horn by Rowson, Lawson, and Moor (1971) resulted in a 70 percent twinning rate.

Resorption may be a common method for reducing the number of fetuses in elk to one per pregnancy. Saunders (1955) reported a yearling contained a viable fetus in the right horn and another fetus being resorbed in the left. Haugen (1966) found a single resorbing fetus in a cow elk. Greer (1966) found one male twin in an early state of resorption on December 22. One resorbing fetus was diagnosed rectally in January, 1972 in this project.

A factor which may prevent twinning efforts in elk may be similar to that found in antelope (Antilocapra americana Ord) by O'Gara (1969). Although twin births were the rule, O'Gara noted three to seven ova were commonly ovulated, fertilized, and developed into blastocysts. When more than one embryo per uterine horn survived this early stage, O'Gara observed that the one distal to the corpus uteri was displaced as its membranes were pierced by the necrotic tip of the proximal

embryo. Hancock (pers. comm.) observed four embryos in a uterus from a cow killed during the hunting season. It is questionable whether all four embryos would have been carried full term, because of the aforementioned reasons.

Superovulation

Hammond, Hammond, and Parker (1942) found: (1) gonadotropic extracts of horse-pituitary gland, pregnant mares serum, and urine of pregnant women induced ovulation in sheep, and (2) administration of horse pituitary, a few days before the corpus luteum was due to regress, resulted in superovulation of up to 12 simultaneous ovulations at the succeeding heat. Cole and Cupps (1959) reported that spontaneous ovulation of four or more ova had been reported in goats following injection of 200-400 International Units (IU) of PMS. In sheep, they reported doses of 500-2,000 IU of PMS resulted in the shedding of as many as 26 ova, and simultaneous administration of progesterone was reported to increase coincident estrus. Successful superovulation of cattle has resulted from both PMS and pituitary gonadotropins (FSH or LH). Cattle given 3,600-4,500 IU of PMS followed 5-10 days later with sheep pituitary extract resulted in 38-160 ova being shed. The presence of a corpus luteum enhanced the effectiveness.

Umbaugh (1949) was unsuccessful in superovulation work with PMS and chorionic gonadotropic injections in cows, but was successful with pituitary gonadotropins. Using a pituitary extract pellet, followed by an intravenous injection, an average of 23.4 ovulations per cow was obtained.

Tanabe et al. (1949) found a larger number of ovulations occurred in the cow when an injection was given during the follicular stage

than when given during the luteal stage (5.3 to 0 fertile ova, respectively).

Investigators using PMS in cattle have consistently reported a wide variance in ovulation rates following administration of a standard dose of PMS (Scanlon et al. 1968). They found PMS stimulated the following effects:

Days of injection before estrus	Number of ovulations
2	2-0
3	6-0
4	8-4
5	12-7

However, they reported superovulation had no effect on apparent fertility rates.

Murphree et al. (1944) noted significant differences in effects of extracts due to different production dates. In studies on potential fertility in 24 superovulated ewes, they found seven had unfertilized ova and the remaining 17 had from two to 19 fertilized ova yielding a total of 153 fertile eggs.

Jones, Aziz, and Urbina (1961) reported clinical evidence that refractoriness to gonadotropins of animal origin developed after repeated administration, even though the duration of the initial administration was very short.

When the corpus luteum was present, Willett, MeShan, and Meyer (1948) found injections with gonadotropins and insemination produced pyometra and the ova were not fertilized.

Turman, Renbarger, and Stephens (1968), Schwartz and Shelby (1969), and Turman et al. (1971) were successful in producing multiple ovulations with subsequent multiple pregnancies by injecting gonadotropins two to three times during an estrous cycle.

The data presented indicate there should be no difficulty in increasing the number of eggs shed, but controlling the number of follicles ripened and ovulated may be a problem. Gordon et al. (1962) studied the effects of freeze-dried PMS injected generally on day 16 or 17 of estrous cycles of 525 cows from 317 Welsh herds. An increase in multiple conceptions was noted. In sheep they found PMS may give rise to litters ranging in size from two to seven lambs. While the ewe could sustain two to five lambs full term, this was not true in cattle.

Synchronization

Number of animals in a population, which show estrus during a 24-hour period, is proportional to estrous cycle lengths. Techniques which increase this number significantly, may be used to synchronize ovarian cycles (Lamond, 1964). Progesterone from a corpus luteum in a normal cycle, he claimed, inhibits maturation of graafian follicles (by action on the hypothalamus); corpus luteum regression initiates follicular maturation (by releasing hypothalamic activity, which stimulates anterior pituitary release of FSH for growth of a follicle); and estrus, ovulation, and a subsequent formation of a new corpus luteum follow.

Gomez and Erb (1965) reported progesterone and 20 Beta-hydroxy-delta-pregnene-3-one as the principal progestins in the CL of cycling and pregnant cows. Willett (1950) and Ulberg, Christian, and Casida (1951) gave repeated doses of progesterone in early work to alter the estrous cycle in cattle. They found estrus followed in a few days the

cessation of progesterone injections. Foote and Bennett (1968) reported 60 percent pregnancy rates in prepuberal ewes from a drug schedule of 12 mg progesterone bidaily for 14 days, estradiol 17-Beta on day one of progesterone injections, and 600 IU of PMS following cessation of progesterone.

Wagner et al. (1960) inhibited estrus for 12-16 days with a single injection of macro-crystalline suspended progesterone. Lamond and O'Brien (1960) found a six-day serial injection of progesterone in oil, followed with PMS, resulted in increased fertility in cows found open following exposure to bulls.

Nellor and Cole (1956) gave 540-1120 mg of crystalline progesterone to beef heifers and prevented estrus, regardless of the stage of the estrous cycle. Ovulations occurred in 95 percent of those treated. When equine gonadotropin was given 15 days following progesterone injection, estrus and ovulations occurred in 90 percent of the treated heifers within one to four days, but a very low conception rate of 17 percent was noted.

Injections of a micro-crystal progesterone suspension by Gordon (1963) seemed to adversely affect the normal expression of estrus. Fifty mg of progesterone in oil every two or three days inhibited estrus and ovulations for seven days, with 70 and 68 percent conceptions, respectively, for the "controlled" estrus as compared to 75 percent for controls. PMS was given to treated groups two days following the last injections of progesterone in oil.

Lamond (1964) noted: (1) suppression of ovarian activity with progesterone or progestogens probably limited fertility and/or (2) there were possible environmental factors influencing hormonal mechanisms

in bovine reproductive systems. Jainudeen and Hafez (1966) suggested that reduced fertility noted for the synchronized estrus was due to early embryonic mortality.

Foote et al. (1959) noted a tendency for heifers to become cystic or produce twin ovulations following removal of one or two corpora lutea from the ovaries.

Dawson (1961) reported 75 percent ovulations following corpora lutea enucleation with 50 percent of previously subestrous cases showing visible estrus. Schillings and Holm (1963) had two or four cows ovulate three and nine eggs with CL enucleation and split doses of 4-6,000 IU of PMS. Sorenson and Carroll (1969) found no effect on over-all conception rates by rupturing follicles or corpora lutea enucleation.

Evans and Dutt (1962) studied the effects of feeding medroxyprogesterone acetate (MAP) to ewes for varying numbers of days. They found 25 percent of those on seven-day treatment and 65 percent of those on 14-day treatment displayed estrus. They noted that more animals showed visible estrus when fed MAP for 21 days than for 14 days.

Hulet and Foote (1967) thought it important to precede the first dose of PMS with an adequate progestogen priming period. They noted the possibility that a priming period longer than 14 days may increase the percentage of ewes showing estrus and pregnancy. It was theorized that adequate progestogen would not only increase the estrous incidence, but create a more favorable uterine environment for developing embryos. Wiltbank and Kasson (1968) had comparable results feeding DHPA (16-alpha-17-dihydroxy-progesterone acetophenonide) for nine days, accompanied with an injection of estrogen to cause regression of any corpora lutea present.

Burfening and Van Horn (1970) found significant changes in ovulation rates by varying the day of PMS injection at the end of a 14-day feeding schedule of CAP (6-chloro-6-dyhydro-17-alpha-acetoxyprogesterone): Day 13, 3.6; day 14, 2.4; day 15, 1.9; and day 16, 1.8. Pretreatment with estradiol-17 Beta on day one of the feeding schedule increased the number of anestrous prepuberal ewes which expressed estrus, and also increased the percentage of ewes in estrus which became pregnant.

Reynolds et al. (1969) recorded significant differences in MAP and MGA (melengesterol acetate) plus repeated injections of FSH:

Drug	Percent showing heat	Percent pregnant	Number embryos
MAP	73	91	1.27
Control	81	85	0.85
MGA	93	57	0.64

They also recorded two degenerating embryos from a set of induced quintuplets.

Bellows, Anderson, and Short (1969) found best results from a total dose of 6.25 mg FSH-P given in split doses twice a day from day eight through 12 of a 11-day MAP feeding schedule. This dose schedule resulted in 2.1 ovulations and 93.8 percent fertilizations, while 12.50 mg or higher gave excessive ovarian stimulation. The addition of CMC (carboxy-methyl-cellulose) to FSH reduced the variability in numbers of corpora lutea induced by single doses of gonadotropins given by Mills and Vincent (1969). Bellows et al. (1970) fed MAP for 11 days, with a total dose of 6.25 mg of FSH-P given in split doses twice daily on days

8-12. This resulted in eight controls and 34 treated heifers, respectively, producing eight and 39 calves.

Robinson (1971) found great seasonal variation in all parameters of fertility when progestogen impregnated sponges were used. Spring treatment was followed by a low incidence of ovulations, a high incidence of "silent heats," and few pregnancies following insemination (13.6 percent), with most non-pregnant ewes becoming anestrous. Autumn treatment was followed by a high incidence of ovulation and estrus and a high pregnancy rate following a double insemination (82.5 percent) and few animals anestrous.

Gestation period in elk

Field observed copulation and calving has left the exact gestation period of elk to conjecture. Lantz (1910) gave 249 to 262 days. Most authors place the gestation period near these limits: Leopold (1933) quotes Lantz; Brown (1953), 8.5 months; Lang (1958), 250-263 days; Blunt (1962), 246-250 days; Harper et al. (1967) observed two cows carrying calves 258 and 265 days; Burton and Burton (1969), 249-262 days; but Bourliere (1964) gave 210-230 days. The latter author reported 234 days for the European red deer, while Burton and Burton (1969) gave 225-270 days; Brown (1953), eight months; Hamilton, Harrison, and Young (1960), 225-246 days; Larousse (1967), nine months; and Lincoln et al. (1970), 238 days.

It is generally believed elk calving peaks occur between May 20 and June 10, but Harper et al. (1967) found this to be highly variable: in 1957 the peak occurred in mid-May; from late May to early June in 1958; and they noted a lengthened calving period from May 28 to July 29 in 1960.

Methods and Materials

In trial I, 18 cows were divided into three groups of six each. The controls (group 1) received a blank Hydron implant.[1] Implants were placed subcutaneously on January 20, 1970 and left for 14 days. Group 2 received progestogen containing Hydron implants and 15 mg FSH suspended in CMC[2] (carboxyl-methyl-cellulose). Group 3 received the treated Hydron implants and 2,500 IU of PMS in aqueous solution. The gonadotropins were injected intramuscularly at the time of implant removal. Half of the animals in each group were laparotomized one week after implant removal, and the other half one week later. This technique permitted visual observations of ovarian response. The ovaries and uterus of each cow also were rectally palpated.

Trial II was initiated on April 6, 1970 with 16 animals from trial I re-allotted to two treatment groups. Animals in both groups received progestogen containing Hydron implants, as did groups 2 and 3 in trial I. In addition, group 1 received 15 mg FSH and group 2 received 20 mg FSH (IM) suspended in peanut oil. No control animals were included, because all were anestrous in trial I and rectal palpation at the beginning of trial II indicated they remained anestrous. Palpations were the same as in trial I. At the termination of trial II, all females were sacrificed to collect ovarian structural data and pituitary weights.

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[1] G. D. Searle, Chicago.

[2] Formula for CMC: 1 liter .9 percent physiologic saline solution
58 mg Carboxy-methyl-cellulose
8.6 ml Benzyl alcohol
3.7 ml Tween 80

This was mixed in 100 cc amounts with FSH in water added to a dilution of 5 mg per cc for 50 cc.

In trial III, 18 cows which had not been treated earlier were divided into three groups of six. The controls (group 1) received blank Hydron implants. The two experimental groups received progestogen containing Hydron implants. In addition, group 2 received 15 mg FSH suspended in CMC (IM), and group 3 received 20 mg FSH suspended in CMC. All animals were rectally palpated, blood sampled, and implanted with a Hydron on August 28, 1970. The implants were removed on September 16-17 and only the controls were rectally palpated and blood sampled. Two additional yearlings were treated with 15 mg FSH only.

All animals were moved to new 20-acre enclosures immediately following treatment. One cow from group 2 escaped in transit and another from group 3 lost a progestogen Hydron implant before FSH treatment and, therefore, was placed in the controls. One control animal suffered a leg fracture and was sacrificed. These losses and additions in cows resulted in the control group containing six cows, group 2 (15 mg FSH) with five, and group 3 (20 mg FSH) with five.

Three 2.5-year old bulls were placed in one enclosure with 16 cows. An additional 20-acre enclosure was opened to these animals about two weeks later. The two yearling females were placed in a pen with an adult and two yearling bulls. They were recaught two weeks later to observe ovarian structural activity. The females were rectally palpated and blood samples were collected from the bulls.

Almost continual behavioral observations were made for 10 days when light permitted. Eight days was thought to be the maximum time for effective hormonal activity.

Results and Conclusions

Trials I and II

Data for trial I are presented in Table 7. The controls produced only one follicle in six cows. FSH treated cows produced a mean of 2.4 follicles and corpora lutea the first week (1.33 CL and 2.0 follicles). PMS treated cows produced a mean of 9.67 follicles and corpora lutea (1.5 CL and 8.67 follicles). Six controls produced only three follicles the second week. Those FSH induced had a mean of 1.83 follicles and corpora lutea, while those PMS induced produced 5.2 follicles and corpora lutea per cow. One cow in the PMS group produced a total of 37 follicles the first week.

Data from trial II are presented in Table 8. Response was considered poor, as only two animals had formed a corpus luteum and follicle response was much reduced from trial I. The reason for the reduced response is not known, but may be due to a change in the anestrous condition of the cows, the carrier used for the FSH, or to refractoriness by the animal to the gonadotropin.

Estrus was not observed during trials I and II when treated cows were exposed to vasectomized bulls. Rump markers were used to indicate unobserved mounting by the bulls. Results from the markers were negative. Self-removal of the markers by the elk may have biased the results, although lost markers were promptly replaced.

The anestrous state in trials I and II may have affected estrous incidence and ovulation rates in treated cows. Dermody, Foote, and Hulet (1970) and Robinson (1971) found significant seasonal differences in ovulation rates with progesterone synchronization.

Table 7. Response of elk to hormone treatments (trial I).

Treatment	Cow identity	2/10/70 No. CL	2/10/70 No.[a] follicles	Operated 1st week	2/17/70 No. CL	2/17/70 No.[a] follicles	Operated 2nd week
Group 1							
Control	5	0	0	x	0	1	
	21	0	0	x	0	0	
	1	0	1		0	0	x
	18	0	0		0	1	x
	9	0	0	x	0	0	
	20	-	-		0	1	x
% Response		0/5=0 1/5=20			0/6=0 3/6=50		
% $\bar{X}$		1/1=1.00			3/3=1.00		
% Response		1/5=20			3/6=50		
Group 2							
FSH	2	0	4	x	1	1	
	19	1	2	x	2	0	
15 mg in							
CMC	13	2	1		2	0	x
2/3/70	3	1	0		2	0	x
(IM)	6	0	1	x	1	0	
	10	-	-		1	1	x
% Response		3/5=60 4/5=80			6/6=100 3/6=50		
$\bar{X}$		4/3=1.33 8/4=2.00			8/6=1.33 3/3=1.00		
Ovulation range		0-2			1-2		
% Response (CL & Fol.)		5/5=100			6/6=100		
$\bar{X}$		12/5=2.40			11/6=1.83		
Group 3							
PMS	7	1	4	x	1	2	
	4	0	37	x	-	-	
2500 IU	7	2	4		4	4	x
aqueous	12	0	1		2	2	x
2/3/70	14	1	3	x	2	2	
(IM)	11	2	3		4	3	x
	0/0	4/6=67 6/6=100			5/5=100 5/5=100		
	$\bar{x}$	6/4=1.5 52/6=8.67			13/5=2.60 13/5=2.60		
Ovulation range		0-2			1-4		
% Response (CL + Fol.)		6/6=100			5/5=100		
$\bar{X}$		58/6=9.67			26/5=5.20		

[a]Includes only follicles 10 mm or larger.

Table 8. Response of elk to hormone treatments (trial II).

Group 1 (15 mg FSH) 4/27/70				5/4/70	
Cow identity	#CL	# Follicles[a]		#CL	# Follicles[a]
1	0	15	9	2	0
20	0	2	6	0	0
11	0	4	3	0	2
2	0	1	7	0	1
%	0	4/4=100		1/4=25	2/4=50
$\bar{x}$	%	22/4=5.5		2/1=2	3/2=1.5
% Response	4/4=100			3/4=75	
$\bar{x}$	22/4=5.5			5/3=1.66	
Ovulation range	0			0-2	

Group 2 (20 mg FSH) 4/27/70				5/4/70	
21	0	1	13	1	0
17	0	2	19	0	1
14	0	3	5	0	2
18	0	1	12	0	0
%	0	4/4=100		1/4=25	2/4=50
$\bar{x}$	%	7/4=1.75		1/1=1	3/2=1.5
% Response	4/4=100			3/4=75	
$\bar{x}$	7/4=1.75			4/3=1.33	
Ovulation range	0			0-1	

[a]Includes only follicles 10 mm or larger.

In trial I, experimental animals were laparotomized for visual observation of the ovaries and recording of follicles and corpora lutea (Follis, Foote, and Spillett, 1972). Results from rectal palpation provided similar results.

All females were sacrificed at the termination of trial II (April 28, 1970 and May 4, 1970) and numbers of follicles and corpora lutea noted (Table 3), and pituitary glands collected. The mean weight of anterior pituitaries from 16 adult females was 1.373 grams. The mean error was 0.317, and the range, 0.907 to 2.123 grams. Anterior pituitaries collected from an adult bull on November 28, 1971,weighed 2.096 grams; from a spike on December 9, 1971, 1.270; and from a fetal calf on April 6, 1970, 0.176.

Females in trial III were palpated on August 28, 1970, with no ovarian structural activity recorded. All seven controls palpated on September 16 and 17 had functional ovaries, five with follicles and two with single corpora lutea, which indicated ovarian activity had been initiated since August 28.

The two yearling females treated with 15 mg of FSH and held in a small pen with several bulls were rectally palpated on October 2, 1970. Both had a corpus luteum on each ovary, with one ovary containing a follicle. This was a good indication that ovarian activity was induced in most of the experimental animals by the exogenous gonadotropins. No yearlings became pregnant, due probably to various stress factors. However, in these two animals the lack of progesterone priming of the hypothalamus also could have failed to induce estrus and to create a favorable uterine environment for ova survival and development (Hulet and Foote, 1967).

Trial III, estimated conception dates

Nine of 16 cows were pregnant on January 8, 1971. Eight of these conceived between September 30 and October 15 and produced single calves between June 15 to July 17, 1971. No conceptions were estimated to have occurred during the hormone affected period. Absence of twinning may have been from poor conception due to synchronization and superovulation techniques, stress factors, or resorption processes in multiple births.

All pregnancies were diagnosed by rectal palpation. Group 1 (controls) had three of six pregnant (three of four adults), group 2 (15 mg FSH) had three of five pregnant (three of four adults); one pregnancy was only 50 days, which indicated a conception date of November 19 or 60 days after the treatment period. Group 3 (20 mg FSH) had three of five pregnant (three of four adults).

Four cows were estimated to be 100 days pregnant, and four were estimated to be 90 days. This would place conception dates from September 30 to about October 15, 1970. This was one to three weeks after the treatment period.

Interestingly, 75 percent pregnancy rates resulted in the adult segment of all three groups. No yearling pregnancies occurred.

It was not possible to palpate twin fetuses in any of the cows. Twinning also could not be determined from palpating the ovaries for multiple corpora lutea, as pregnant elk usually form post-conception accessory corpora lutea (Halazon and Buechner, 1956).

If the cows conceived on September 20, 1970, parturition should have occurred 249-262 days later (Lantz, 1910). This indicated the earliest date for calving should have been May 25, 1971, and the last

June 8. However, only single calves were born from June 15 to July 17, which suggests, if conceptions did occur during the treatment affected period, the embryos did not survive. This agrees with the estimated conception dates, which would have occurred at subsequent estrous cycles.

Effects of stress from handling and moving during the experiment and lack of optimal nutrition during the previous winter, augmented by an increase in body temperature from continuous exposure to the summer sun, possibly contributed to an absence of conceptions during the hormone affected period. Fertilization may have occurred, but implantation apparently did not.

Discussion and Recommendations

A great deal of emphasis has been placed on stress effects during this experiment. Morrison (1960a) and Trainer and Lightfoot (1970) noted stress affected normal reproductive physiology and behavior. Handling captive animals for jugular venapuncture in this project caused physiologic changes. Values of SGOT (serum glutamic-oxalacetic transaminase) rose from about 100 to 275 units within a few hours, probably due to excessive tissue necrosis (Franzmann and Thorne, 1970). Tests for calcium, inorganic phosphorous, glucose, BUN (blood urea nitrogen), and lactic dehydrogenase also varied significantly, but not as dramatically as SGOT (see Objective 4).

The experimental herd initially was held captive near a busy road in small pens. These factors added stress to those already present from necessary handling of the animals. Morrison (1960a) recorded an absence of breeding under similar conditions. To reduce stress factors,

the treated animals (groups 2 and 3) were not palpated nor blood sampled when they were moved to larger and more isolated enclosures on September 16 and 17, 1970.

The three bulls in captivity polished their antlers about August 17, 1970. Tsalkin (1944) stated that estrus in the female red deer begins two to four weeks later than the male's mating period. This coincides with the generally recognized rutting peak of the Rocky Mountain elk in the middle to latter part of September. Trial III was initiated August 28, 1971, which permitted removal of the follicle inhibiting progestogen containing Hydrons during the rutting peak.

All treated elk were synchronized to begin estrus between September 18 and 20. As estrus begins 36 to 72 hours following withdrawal of progesterone (Willett, 1950 and Ulberg et al. 1951), all Hydrons were removed September 16 and 17. It was estimated that estrus and ovulations, under hormonal effects, could have occurred up to September 25.

Robinson (1970) found a "fixed time" of 2-2.5 days following withdrawal of progestogen impregnated sponges the best time to inseminate ewes. He noted 61.8 percent lambing with this method, as compared to 39 percent lambing with ewes inseminated at ram detected estrous periods.

Roche and Crowley (1971) attempted to increase the fertility of progestogen treated ewes by hand-mating, thereby controlling the time interval between mating and ovulations.

Tranquilizers were not used during the transfer, due to their possible effect on ovulation rates. Pincus (1965, p. 57) gave the following effects of various compounds on quantified ovulations.

Drug	Dose per animal (mg)	Mean no. eggs	Effect
Sparine	0.5	0	⁄⁄⁄
Chlorapromazine	0.125	2.2	⁄⁄
Chlorapromazine	0.25	0	⁄⁄⁄
Cortisone	3.0	4.8	⁄
Progesterone	0.5	0	⁄⁄⁄

⁄ - Slight inhibitory effect
⁄⁄⁄ - Strong inhibitory effect

Riera et al. (1970) noted that serum levels of LH rose sharply in prepuberal ewes 24 to 36 hours after PMS, 8-16 hours after estrogen, and 44 hours after HCG (human-chorionic-gonadotropins) injections. It was assumed that a similar rise appeared in elk injected with FSH.

FSH induced follicles secrete estrogen, which causes the hypothalamus to produce an LH-releasing factor. This causes the anterior pituitary to secrete LH, which subsequently has an ovulatory effect on the follicle. Laboratory tests to determine the time of the LH peak in elk sera following estrogen injections were unsuccessful. Either an estrogen injection did not induce an LH peak, as described above, or the elk sera reacted non-specifically with an ovine LH protein on which the tests were based.

Sexual behavior data, i.e., flehmen and repeated mountings during the hormone affected period indicated the harem bulls were behaviorally ready for copulation. All cows had been exposed to these viable bulls since August 28, the first day of the experiment. Aforementioned stresses may have prevented normal reproductive cycles from occurring in the controls. Ovarian structural activity was observed rectally in the control elk when they were moved from the small to large enclosures, which indicated the possible occurrence of "silent heats." These same stresses occurred in the treated animals. Follicle and corpora lutea

counts in the next trial should be made three to five days after gonadotropic injections.

Observations reported from synchronized superovulation experiments on other species (Hammond, 1949; Nellor and Cole, 1956; Gordon, 1963; Lamond, 1964; Jainudeen and Hafez, 1966; and Scanlon et al. 1968) indicate a low percentage of animals exhibit estrus. Of those exhibiting estrus, a low percentage of conceptions occur. And, of multiple ovulations with conception, many embryos are aborted or resorbed.

Fourteen of 15 untreated or unhandled adult cows became pregnant in a study completed in 1971 when exposed to three adult bulls, and 12 of 14 untreated or unhandled adult cows became pregnant when exposed to yearling bulls (see Objective 2). Data indicate a reduced pregnancy rate in the twinning experiment.

It is recommended superovulation trials be conducted in conjunction with a proposed paired trial of the yearling bull breeding capacity study. These trials should be initiated in the adult bull harem with experimental animals immobilized in the enclosure during the rutting season. A hormone schedule similar to trial III, but with the addition of a pretreatment injection on the day of Hydron placement of estradiol-17 Beta. Burfening and Horn (1970) claimed the use of this estrogenic hormone increased the incidence of estrus.

Newborn calves should be taken from their mothers between one and two days of age for domestication. The handling of cervids in prolonged captivity has been discussed by Bagley (1952), Knorre (1959), Yazan and Knorre (1964), Dzieciolowski (1969), and Youngson (1970). Daily human contact, it is hoped, would

aid in providing a tame elk herd, which would promote successful hormone and estrus behavioral studies. This gentleness would aid in collection of valuable physiologic data, which in spite of being collected in an artificial environment, would increase the future efficiency of big game management.

Sexual behavior

Observations of sexual behavior for 10 days, following treatment and movement to the new enclosures, indicated that de-antlering did not affect rutting activity of the males. This observation is supported by Lincoln et al. (1970). Night observations were unsuccessful, although a full moon was present on some nights. The bulls attempted to mount, but invariably the females shied away. In the mornings it was common for some cows to have flattened hair on the rump, indicative of possible mounting during the night. One morning six cows were observed to have flattened rump hair.

No estrous females were observed during the 10-day observation period. All three of the 2.5-year old bulls displayed breeding behavior, although a dominant harem bull was not apparent. One bull gradually withdrew from the rut activity, while the two remaining bulls shared in physically checking the cows for estrus. Fighting between these two bulls occurred each evening.

One bull began to demonstrate dominance within a few days and became the alpha male. He and the beta male checked each cow for signs of estrous receptivity by nosing the vulva, often followed by flehmen (lip curl) (Schneider, 1930).

On September 18, 1970, alpha used a stream for a wallow. Immediately upon arising from the wallow, he challenged beta. In the

ensuing fight, beta was pushed backward at least 100 yards. This incident appeared to initiate a slight dominance over beta, but nightly encounters continued.

No harem was formed. The bulls passed freely among the cows at any time. Gamma bull did not approach the other bulls, but appeared to be content to intermingle with the cows, although he seldom nuzzled any of them. He gradually seemed to become sexually disinterested in the cows.

Alpha or beta were intensely interested at times in one or two cows, but the females never seemed receptive, and the bulls would eventually leave them and return to the main herd.

On September 19, 1970, alpha was definitely interested in two 12-year old cows born and raised in captivity, White 3 (15 mg FSH) and Green 3 (control). When the herd was pregnancy tested in January, 1971, Green 3 was pregnant and White 3 was not.

On September 19, 1970, a yearling bull was released into the large enclosure to possibly create more competition and movement in the harem. The yearling did not join the harem for about 30 minutes, but eventually proceeded to court a cow and was driven away by alpha. The bulls checked the cows for estrus throughout the day, but no female sexual activity was evident. At 6:55 p.m., the bulls became very playful and, with the yearling bull leading, they ran and chased each other for over an hour. At 8:00 p.m., beta entered a wallow, from which he joined alpha for a sparring match until 9:00 p.m. Neither appeared dominant. Visibility then became difficult until 6:00 a.m., which gave the bulls nine hours of darkness in which unobserved breeding could have taken place.

The harem feeding habits consisted of alternately feeding and resting throughout a 24-hour period. Their body condition appeared good.

Flehmen by the bulls was the most definite sign of sexual attentiveness. The bulls would nuzzle the cows' vulva and often exhibit flehmen. Similar sexual behavior continued near the same tempo until observations ceased on September 27. No copulations were observed.

Summary

Three synchronized superovulation trials were conducted in an attempt to induce twinning in elk. Trial 1 and II were in an anestrous season with vasectomized bulls. Trial III was timed for the rutting peak in September, 1970. Progestogen containing Hydron implants were used to synchronize elk in all trials. Gonadotropins were administered on the day Hydrons were removed.

FSH suspended in CMC was superior to PMS alone or FSH in peanut oil. In trial I, FSH injected elk produced a mean of 2.4 follicles and corpora lutea the first week (2.0 follicles and 1.33 CL); PMS injected elk produced a mean of 9.67 follicles and corpora lutea the first week (8.67 follicles and 1.5 CL). Response in trial II from two levels of FSH in peanut oil was low.

Hydrons were implanted in 18 cows on August 28 and removed September 16 and 17, 1970, in trial III. No functional ovaries were recorded at the beginning of the trial. Six control cows revealed functional ovaries when blank Hydrons were removed. Two groups of six cows received 15 and 20 mg FSH in CMC, respectively, when treated Hydrons were removed. No conceptions apparently occurred during the

subsequent eight-day hormone affected period, which ended about September 25. Nine of 12 adults (including three of four controls), and none of four yearlings became pregnant. Two of six yearlings were lost from the trial. Eight pregnant cows were estimated, both rectally and from date of calving, to have conceived between September 30 and October 15. Two additional yearlings were given gonadotropins without synchronization. Although functional ovaries were palpated rectally two weeks later, neither became pregnant.

OBJECTIVE 4

COLLECTION OF BASIC PHYSIOLOGIC, PARASITIC, AND DISEASE INFORMATION

Literature Review

There is a paucity of information available on blood chemistry for North American cervids. Rosen and Bischoff (1952) and Bandy et al. (1957) presented blood chemistry levels as a reflection of nutritional conditions in deer. Studies identifying deer groups by hemoglobin fractions were conducted by Miller, Haugen, and Roslein (1965) and Johnson et al. (1968). Fourteen biochemic parameters for deer sera were reported by Tumbleson et al. (1968). They related changes to age variation. LeResche (1970) discussed 15 biochemic parameters for moose (Alces alces).

Only one paper discussed hematologic values of elk. Herin (1968) presented 13 biochemic parameters for trapped elk, which he compared to normal levels for domestic animals.

Methods and Materials

Jugular blood samples were collected for reproductive observations via venapuncture during routine trapping and handling procedures. Blood was collected in two Vacutainer[1] vials (collection vials with a vacuum). One was used for serum studies and the other, which contained anticoagulant EDTA (ethylene-diamine-tetraacetate), was used

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[1] Becton and Dickenson, Rutherford, New Jersey.

for whole blood studies. Blood was collected in 50 ml syringes during 1971 and 1972 to provide additional serum for hormone analysis. The serum was separated by allowing the blood to clot.

Table 9 identifies the method of analysis and units of measure used for samples collected during the project.

Four laboratories cooperated in the blood study: (1) United States Department of Agriculture Poisonous Plant Laboratory (PPL); (2) Intermountain Laboratories (IL), Salt Lake City; (3) Utah State University Meats and Physiology Laboratories (MPL); and (4) the Utah State University Veterinary Diagnostic Laboratory (VDL), Logan, Utah.

Elk fecal pellets, randomly collected from captive and free-ranging elk, were analyzed at the Veterinary Research Laboratory (VRL) at Montana State University, Bozemen, to determine the presence of Dictyocaulus larvae.

Male reproductive tracts were collected from yearlings and adults killed during an early October elk hunt on the National Elk Refuge, Jackson, Wyoming. Specimens were immediately fixed in 10 percent acetate buffered formalin. They were cut from paraffin sections and stained with Hematoxylin and Eosin. Testicular sections also were stained with Iron Hematoxylin. Yearling and adult male reproductive tissues were compared as to size and structure.

Results and Conclusions

Sample size variations reflect a loss of laboratory personnel, change in priorities, and cost relationships. Numbers of samples from captive elk are greater than those from free-ranging elk in most tables, and reader's interpretations should acknowledge this fact.

Table 9. Test identification, cooperating laboratories, method of analysis, and units of measures for blood component analyses.

Test	Cooperating laboratories[a]	Method of analysis	Units of measure
1. WBC - White Blood Cells	PPL	Coulter counter	per cu mm
2. RBC - Red Blood Cells	PPL	Coulter counter	per cu mm
3. Hb. - Hemoglobin	PPL	Beckman (model B) Spectrophotometer	grams/100 ml
4. PCV - Packed Cell Volume	PPL	Micro-hematocrit	percent
5. BUN - Blood Urea Nitrogen units	PPL	Sigma technique	Sigma units
	IL	Auto-analyser[b]	mg/100 ml
6. SGOT - Serum glutamic-oxalacetic transaminase	PPL	Reitman-Frankel	Units
	IL	Auto-analyser	mU/ml
7. LDH - Lactic dehydrogenase	PPL	Cabaud-Wroblewski	Units
	IL	Auto-analyser	mU/ml
8. Alkaline Phosphatase	PPL	Sigma technique	Sigma units
	IL	Auto-analyser	mU/ml
9. Total protein	PPL	Viuret reaction - Gornal modification	grams/ml
	IL	Auto-analyser	grams/ml

Table 9. Continued

Test	Cooperating laboratories[a]	Method of analysis	Units of measure
10. Albumin	PPL	Paper electrophoretic separation	grams/100 ml
11. $Alpha_1$, 12. $Alpha_2$, 13. Beta, and 14. Gamma (globulin fractions)	PPL	Paper electrophoretic separation	grams/100 ml
15. Glucose	PPL	Beckman's modified samogyi	mg/100 ml
	IL	Auto-analyser	
16. Creatinine	PPL	Jaffe reaction using a Folin-Wu filtrate	mg/100 ml
17. Uric acid	IL	Auto-analyser	mg/100 ml
18. Cholesterol	IL	Auto-analyser	mg/100 ml
19. Total bilirubin	IL	Auto-analyser	mg/100 ml
20. Inorganic phosphorus	IL	Auto-analyser	mg/100 ml
21. Calcium ion	IL	Auto-analyser	mg/100 ml
22.-26. WBC differential count (cells/cu mm)	PPL	Coulter counter	cells/cu mm
27. Serology 1. *Brucella abortus*	VDL	1. Card or plate test	titer
2. *Leptospira pomona*		2. Plate agglutination	titer

Table 9. Continued

Test	Cooperating laboratories[a]	Method of analysis	Units of measure
28. Progestin assay	MPL	Murphy (1967) modified	ng/ml
29. Androgen assay	MPL	Hopwood (pers. comm.)	ng/ml
30. Larvae counts for Dictyocaulus spp.	VRL	Baermann technique	larvae/gram
31. Histology of male yearling and adult reproductive systems	HPL	Microscope	ocular estimate

[a]PPL - Poisonous Plant Laboratory
IL - Intermountain Laboratories
MPL - Meats and Physiology Laboratories
VDL - Veterinary Diagnostic Laboratory
VRL - Veterinary Research Laboratory
HPL - Histo-pathology Laboratory

[b]Technicon's SMA 12/60 Autoanalyzer, Technicon Corp., Tarrytown, N.Y.

Table 10 compares values reported for adult big game and domestic animals. Columns 1 through 9 are for wild animals and the remaining columns for domestic sheep, goats, and cows. Variations in reported units of measure render the comparison of some values difficult.

Variations in sample collection procedures also complicate the picture. Herin (1968) reported elk body temperatures averaged 107.7°. Drastic alterations of body functions such as this undoubtedly change some test results. Wilbur and Robinson (1958) recorded a significant change in potassium blood levels from the normal shock syndrome in hunter-killed animals. Franzmann and Thorne (1970) reported variations in blood values from bighorn sheep collected (1) during live trapping, (2) two days later, and (3) after 12 days in captivity.

Comparative data, where sample size warranted (at least three samples and a ratio of 5/1), include significant differences projected at .01 and .05 levels for: sexes (Tables 11 and 12; reproductive status (Table 13); between free-ranging and captive (Tables 14, 15, and 16); and variations in serial values (Figures 5, 6, 7, and 8).

Sexes

Table 11 compares blood values between male and female elk. Significant differences between sexes ($P < .01$) were found for alkaline phosphatase and ($P < .05$) for number of leucocytes (WBC) and gamma globulin.

Table 12 indicates significant differences between sexes in (1) yearlings ($P < .01$) for alkaline phosphatase and total protein and (2) adults ($P < .01$) for hemoglobin and ($P < .05$) for alkaline phosphatase.

Table 10. Hematologic values for five big game species and three domestic species.

Adults	Elk			Moose	Deer			Rocky Mountain bighorn sheep		Domestic		
	1 Free-ranging	2 Captive	3 Free-ranging	4	5 White-tailed Captive	6	7 Mule deer (Calif.)	8 Free-ranging	9 Captive	10 Sheep	11 Goat	12 Cow
1. WBC[a]	6866	7046	5559	3463	--	3200	--	--	6668	8000	8-1200	9000
2. RBC[a]	10.982	10.779	--	--	--	17.04	10.1	--	10.8	12	13	7.0
3. Hb[b]	20.94	18.89	18.3	14.34	--	20.8	16.4	17.8	18.6	12	11	11
4. PCV[c]	53.3	51.9	46.3	37.68	--	56.3	44.8	44	53	48	28	53.9, 35
5. BUN[d]	36.04	23.36	--	9.81	25	--	--	8.7	--	8-20	13-28	16-27
6. SGOT[e]	90.59	89.76	--	1.80 mU/ml	131 (KU)	--	--	137	--	12-8	--	--
7. LDH[e]	892	903	--	389 mU/ml	--	--	--	--	--	--	--	--
8. Alkaline Phosphatase[d]	2.057	3.048	--	67.9 mU/ml	14 (KAU)	--	--	--	--	--	--	--
9. Total Protein[b]	7.10	7.57	5.6	6.66	7.6	8.1	--	5.6	7.6	5.81	5.38	7.6
10. Albumin[b]	3.78	2.80	2.25	3.9	--	5.15	--	--	4.5	3.07	3.96	3.63
11. $Alpha_1$[b]	.442	.478	3.39*	--	--	.68	--	--	3.1*	2.31*	2.71*	3.97*
12. $Alpha_2$[b]	.597	.747	--	--	--	--	--	--	--	--	--	--
13. Beta[b]	.949	1.047	--	--	--	1.12	--	--	--	--	--	--
14. Gamma[b]	1.983	2.195	--	--	--	1.15	--	--	--	--	--	--
15. Glucose[f]	183	233	--	115	125	8.19	--	88	--	35-60	35	40-70
16. Creatinine[f]	2.83	--	--	--	--	--	--	--	--	1-2	1-2	1-2

Table 10. Continued

Adults	Elk			Moose	Deer			Rocky Mountain bighorn sheep		Domestic		
	1	2	3	4	5	6	7	8	9	10	11	12
	Free-ranging	Captive	Free-ranging		White-tailed Captive		Mule deer (Calif.)	Free-ranging	Captive	Sheep	Goat	Cow
17. Uric acid[f]	.38	--	--	.702	--	--	--	--	--	.05-2	.3-1	.05-2
18. Cholesterol[f]	79.43	--	--	85.74	97	--	--	67.5	--	100-150	--	50-230
19. Total bilirubin[f]	.65	--	--	.45	.5	--	--	--	--	--	--	--
20. Inorganic Phosphorus[f]	3.72	--	--	5.8	9.60	--	--	4.1	3.1	5.12	--	5 (plasma)
21. Calcium[f]	9.21	9.4	--	11.4	10.9	--	--	9.2	11.6	12-16	--	10.9
22. Neutrophils[e]	44	47.5	61	--	--	--	--	--	48	30	36	28
23. Lymphocytes[c]	48.4	40	36	--	--	--	--	--	45	62	56	58
24. Monocytes[c]	.6	1.2	--	--	--	--	--	--	2	2.5	2.5	4
25. Eosinophils[c]	7	11	15	--	--	--	--	--	4	5	5	9
26. Basophils[c]	.1	1.1	--	--	--	--	--	--	--	0.5	.05	0.5

*Total globulin
KAU - King Armstrong Units
KU - Karmen Units

[a] cells/cu mm
[b] grams/100 ml
[c] percent
[d] Sigma units
[e] units/ml
[f] mg/100 ml

Key:

Columns 1-2 - Follis
3 - Herin (1968)
4 - LeResche (1970)
5 - Tumbleson et al. (1968)
6 - Johnson et al. (1968)
7 - Rosen and Bischoff (1952)
8 - Franzmann and Thorne (1970)
9 - Woolf and Kradel (1970)
10, 11, 12 - Frandson (1965), Schalm (1965), McDonald (1969), Franzmann and Thorne (1970), Kirk and Davis (1970), and Swenson (1970)

Table 11. Blood values comparing sexes of calves, yearling, and adult elk grouped together.

Test	Females			Males			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
WBC[a]	95	6849	1780	16	8140	2116	*
RBC[a]	96	10.76	1.34	17	11.41	1.42	NS
Hb[b]	95	19.05	16.57	17	18.96	16.49	NS
PCV[c]	97	51.98	33.16	16	52.44	33.46	NS
BUN[d]	136	29.10	14.08	18	26.91	13.02	NS
SGOT[e]	165	88.4	35.01	21	90.17	35.71	NS
LDH[e]	158	884	318	20	886	319	NS
Alkaline Phosphatase[d]	170	2.46	1.61	22	5.08	3.33	**
Total protein[b]	181	7.34	.95	19	7.10	.92	NS
Albumin[b]	93	2.89	.78	8	3.21	.87	NS
$Alpha_1$[b]	94	0.47	.33	8	0.45	.31	NS
$Alpha_2$[b]	93	0.74	.28	8	0.57	.21	NS
Beta[b]	93	1.04	.31	8	0.93	.28	*
Gamma[b]	93	2.19	.80	8	1.55	.57	NS
Glucose[f]	55	186	44	7	221	53	NS
Creatinine[f]	67	2.84	.37	4	2.90	.38	NS
Uric Acid[f]	13	0.39	.19	3	0.33	.15	NS
Cholesterol[f]	13	80.54	8.86	3	74.67	8.21	NS
Total Bilirubin[f]	13	0.65	.19	3	0.69	.20	NS
Inorganic Phosphorus[f]	11	3.41	1.5	3	4.89	2.15	NS
Calcium ion[f]	11	9.16	4.12	3	9.49	4.27	NS

Table 11. Continued

Test	Females			Males			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
Neutrophils[c]	29	45	11.0	4	43	10.6	NS
Lymphocytes[c]	29	44	10.5	4	44	10.3	NS
Monocytes[c]	29	1.1	0.1	4	0.75	0.08	NS
Eosinophils[c]	27	9.1	5	4	12.3	6.7	NS
Basophils[c]	29	0.7	.08	4	1.5	.16	NS

* - P< .05
** - P< .01
NS - non-significant

[a] cells/cu mm
[b] grams/100 ml
[c] percent
[d] Sigma units
[e] units/ml
[f] mg/100 ml

Table 12. Significant differences[a] in blood biochemic tests between sexes of (1) yearling and (2) adult elk.

Test	Females			Males			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
(1) Yearlings							
Alkaline Phosphatase[b]	19	2.28	1.7	10	5.60	4.3	**
Total Protein[c]	21	6.78	3.86	11	7.21	4.11	**
No significant differences found in tests:							
BUN			Creatinine				
SGOT			Neutrophils				
LDH			Lymphocytes				
Glucose							
(2) Adults							
Hb[c]	87	18.9	16.8	9	20.4	18.2	*
Alkaline Phosphatase[b]	151	2.48	1.54	12	4.65	2.88	**
No significant differences found in tests:							
WBC			LDH				
RBC			Total Protein				
PCV			Monocytes				
BUN			Eosinophils				
SGOT							

* - $P < .05$
** - $P < .01$

[a]Tests were conducted for significance when sample size permitted (at least 3 samples and a ratio of 5/1).

[b]Sigma units
[c]grams/100 ml

Table 13. Significant variation in blood biochemic values between non-pregnant and pregnant yearling and adult elk.

Test	Non-pregnant			Pregnant			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
WBC[a]	87	6974	1813	8	5489	1427	*
Hb[b]	88	18.88	16.43	7	21.17	18.42	**
BUN[c]	93	27.48	13.14	43	32.59	15.58	*
Alkaline Phosphatase[c]	120	2.69	1.74	50	1.91	1.23	**
Albumin[b]	85	2.80	0.72	8	3.88	1.00	**
Basophils[d]	22	0.917	.098	7	.143	.015	*

No significant differences found in tests:

RBC	Creatinine
PCV	Uric Acid
SGOT	Cholesterol
LDH	Total Bilirubin
Total Protein	Inorganic Phosphorus
$Alpha_1$	Calcium ion
$Alpha_2$	Neutrophils
Beta	Lymphocytes
Gamma	Monocytes
Glucose	Eosinophils

* - $P < .05$
** - $P < .01$

[a] cells/cu mm
[b] grams/100 ml
[c] Sigma units
[d] percent

Table 14. Comparisons of blood values from free-ranging and captive elk with yearlings and matures combined (1969-71).

Test	Free-ranging			Captive			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
LDH[a]	76	863	312	98	903	326	NS
Alkaline Phosphatase[b]	82	2.22	1.93	110	3.49	3.04	**
Total Protein[c]	83	7.01	.90	117	7.54	.97	**
Albumin[c]	9	3.78	.96	92	2.83	.73	**
$Alpha_1$[c]	9	.44	.31	93	.48	.33	NS
$Alpha_2$[c]	9	.597	.224	92	.739	.278	NS
Beta[c]	9	.94	.28	92	1.04	.31	NS
Gamma[c]	9	1.98	.74	92	2.16	.81	NS
Glucose[d]	48	183	43	14	215	50	*
Creatinine[d]	69	2.86	.37	2	2.55	.33	NS
Neutrophils[e]	10	41.2	9.9	23	46.7	11.2	NS
Lymphocytes[e]	10	51.9	10.6	23	40.8	8.4	**

* - $P < .05$
** - $P < .01$
NS - non-significant

[a] units/ml
[b] Sigma units
[c] grams/100 ml
[d] mg/100 ml
[e] percent

Table 15. Comparisons of blood values from free-ranging and captive yearling elk (1969-71).

Test	Free-ranging			Captive		
	Number	Mean	Standard deviation	Number	Mean	Standard deviation
SGOT[a]	21	77.3	39.9	8	89.1	46 NS
LDH[a]	21	776	329	8	903	382 NS
Alkaline Phosphatase[b]	20	2.3	1.7	9	5.9	4.38 **
Total Protein[c]	22	6.79	3.87	10	2.23	4.12 **
Glucose[d]	17	183	41.5	3	186	42 NS
Creatinine[d]	20	2.82	.34	2	2.55	.31 NS
Neutrophils[e]	3	35	9.8	2	38	10.7 NS
Lymphocytes[e]	3	60	10.2	2	49	8.4 NS
Monocytes[e]	3	67	.067	2	1.5	.15 NS
Eosinophils[e]	3	4.33	4.2	2	10.8	10.5 NS
Basophils[e]	3	0	0	2	.5	.1 NS

* - P< .05
** - P< .01
NS - non-significant

[a]units/ml
[b]Sigma units
[c]grams/100 ml
[d]mg/100 ml
[e]percent

Table 16. Comparisons of blood values from free-ranging and captive mature elk (1969-71).

Test	Free-ranging			Captive			
	Number	Mean	Standard deviation	Number	Mean	Standard deviation	
WBC[a]	10	6160	1601	92	7046	1832	NS
RBC[a]	10	10.982	1.406	95	10.779	1.380	NS
Hb[b]	10	20.94	17.53	95	18.89	15.8	**
PCV[c]	10	53.3	34.3	96	51.9	33.4	NS
BUN[d]	42	36.04	15.24	87	23.36	9.88	**
SGOT[e]	61	90.59	33.96	96	89.76	33.66	NS
LDH[e]	59	892	312	90	903	316	NS
Alkaline Phosphatase[d]	39	2.057	1.27	101	3.048	1.88	**
Total Protein[b]	61	7.095	0.96	107	7.57	1.03	**
Albumin[b]	9	3.78	0.97	87	2.80	.72	*
$Alpha_1$[b]	9	.442	0.312	88	0.478	.338	NS
$Alpha_2$[b]	9	.597	0.22	87	0.747	.28	NS
Beta[b]	9	.949	0.28	87	1.047	.312	NS
Gamma[b]	9	1.983	0.73	87	2.195	.808	NS
Glucose[f]	31	183	44	11	233	53	*
Neutrophils[c]	7	43.8	10	21	47.5	10.9	NS
Lymphocytes[c]	7	48.4	9.6	21	39.9	7.9	*
Monocytes[c]	7	0.57	0.06	21	1.16	0.12	NS
Eosinophils[c]	7	7	3	19	11	5.05	NS
Basophils[c]	7	.14	.22	21	1.2	1.1	**

* - $P < .05$
** - $P < .01$
NS - non-significant
[a]cells/cu mm
[b]grams/100 ml
[c]percent
[d]Sigma units
[e]units/ml
[f]mg/100 ml

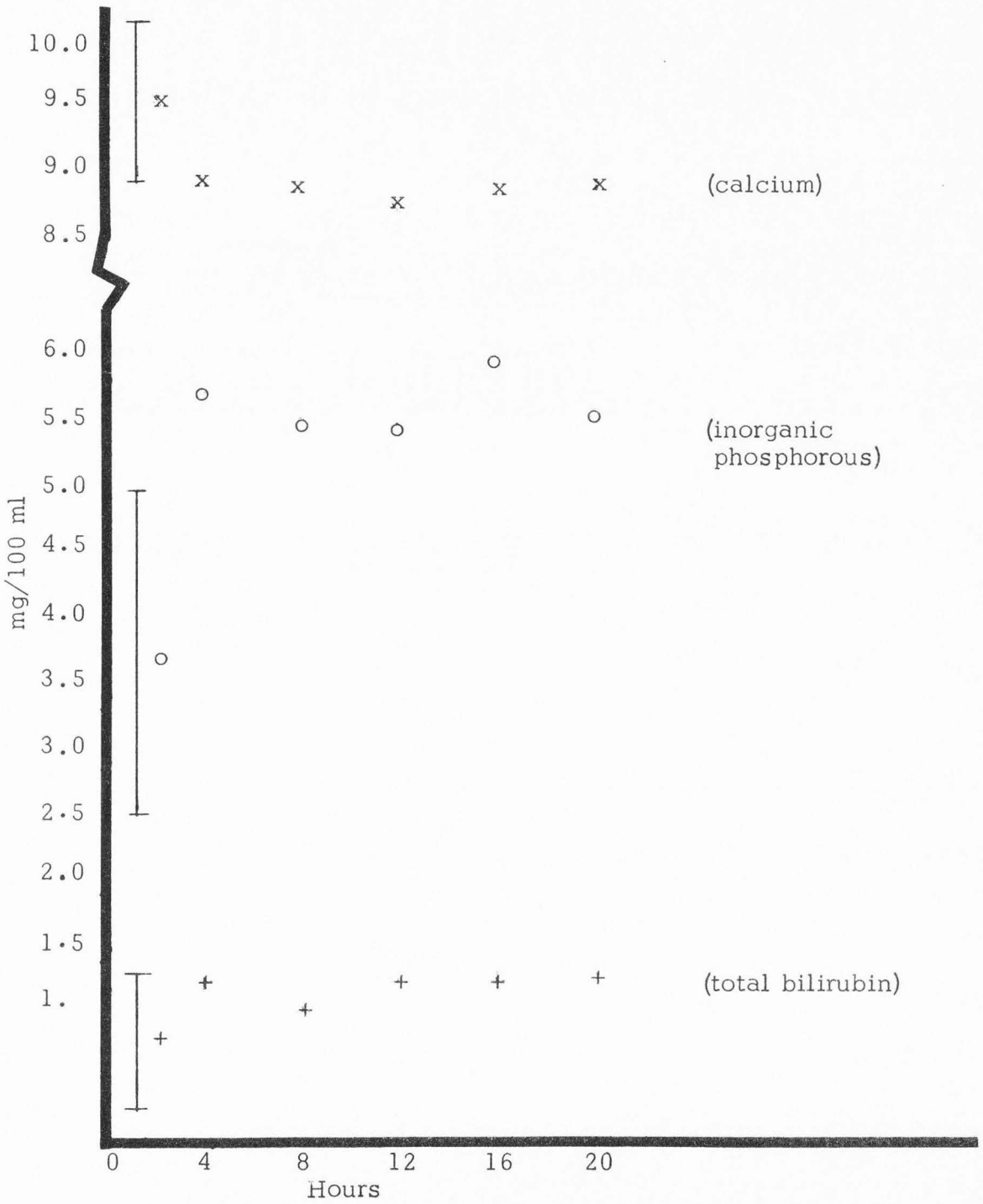

Figure 5. Changes plotted for subsequent serial values to an initial blood value at hour zero for calcium ($P < .05$), inorganic phosphorus ($P < .05$), and total bilirubin (non-significant) bracketed with a 95 percent confidence interval.

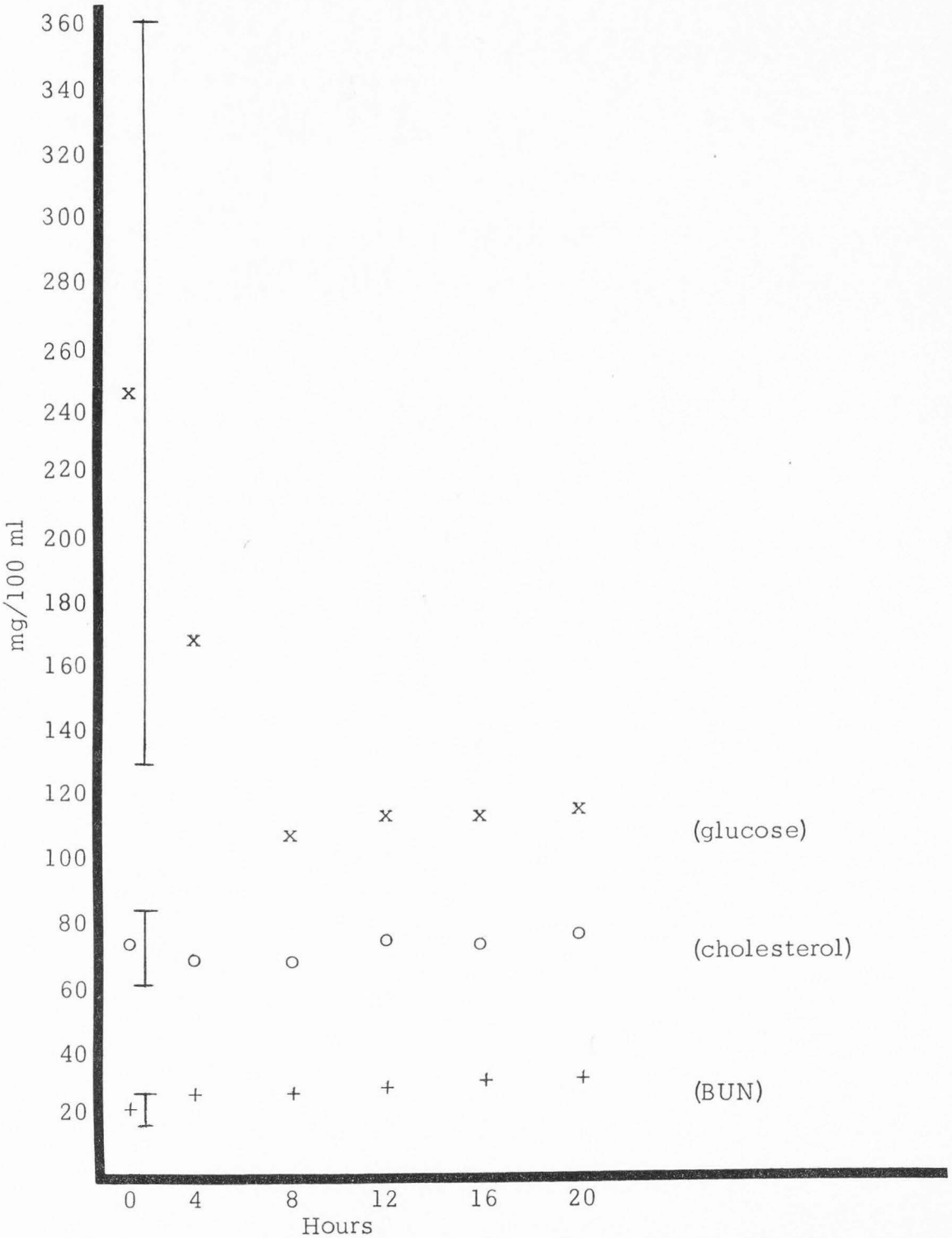

Figure 6. Changes plotted for subsequent serial values to an initial blood value at hour zero for glucose ($P < .05$), cholesterol (non-significant) and blood urea nitrogen (BUN) ($P < .05$) bracketed with a 95 percent confidence interval.

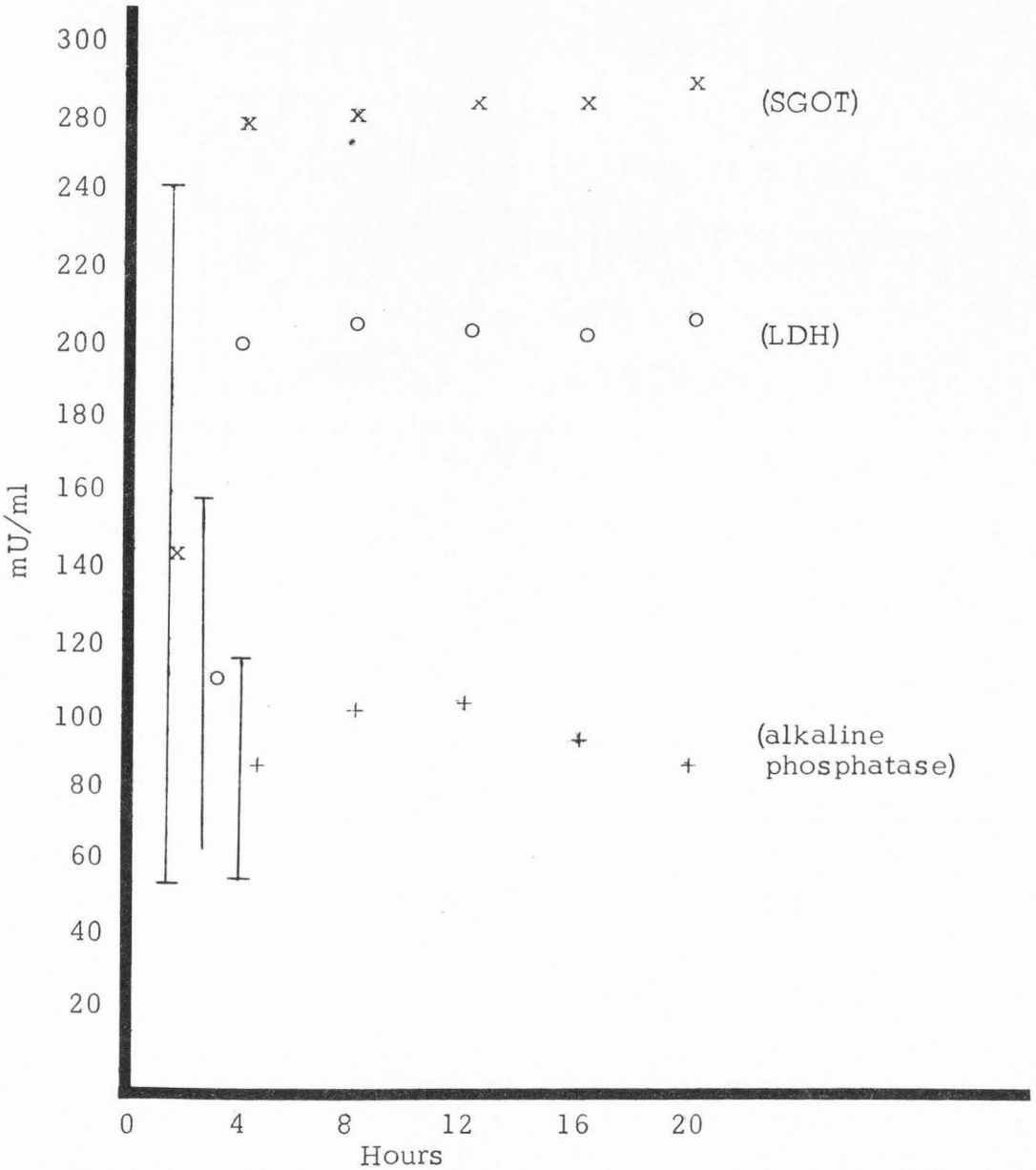

Figure 7. Changes plotted for subsequent serial values to an initial blood value at hour zero for serum glutamic-oxalacetic transaminase (SGOT) ($P < .05$), lactic dehydrogenase (LDH) ($P < .05$), and alkaline phosphatase (non-significant) bracketed with a 95 percent confidence interval.

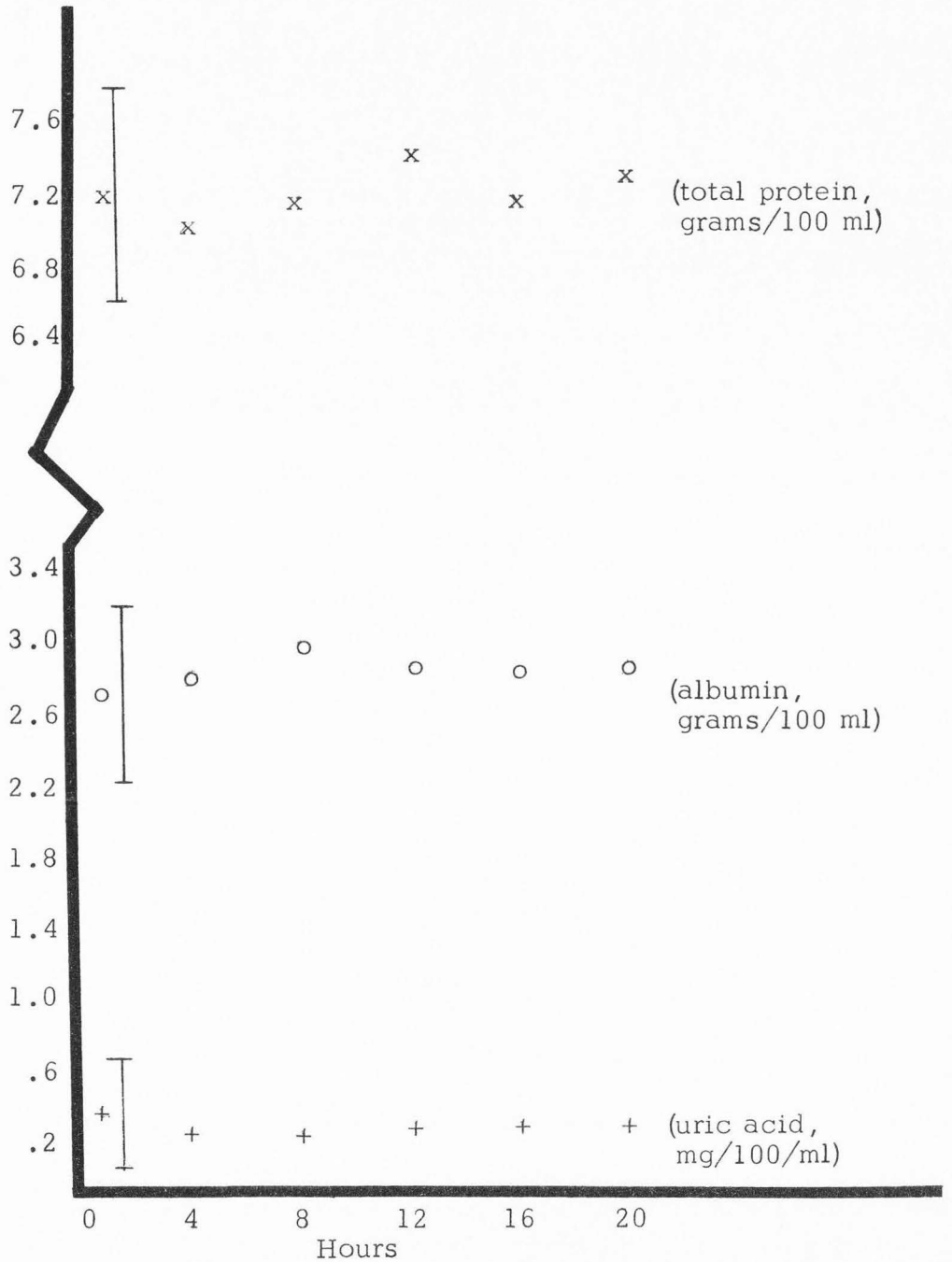

Figure 8. Changes plotted for subsequent serial values to an initial blood value at hour zero for albumin, uric acid, and total protein (all non-significant) bracketed with a 95 percent confidence interval.

Reproductive status

Table 13 indicates significant differences between values of non-pregnant and pregnant elk ($P < .01$) for hemoglobin, alkaline phosphatase, and total protein and ($P < .05$) for WBC, percent basophiles, and BUN.

Free-ranging and captive

Table 14 compares blood values from free-ranging and captive elk. Significant differences ($P < .01$) were noted for alkaline phosphatase, total protein, albumin, and percent lymphocytes and ($P < .05$) for glucose. Table 15 shows significant differences in yearlings ($P < .01$) for alkaline phosphatase and total protein. Table 16 shows significant differences in matures ($P < .01$) for hemoglobin, BUN, alkaline phosphatase, total protein and basophiles, and ($P < .05$) for albumin, glucose, and lymphocytes. Table 17 gives combined hematologic values for free-ranging and captive calves.

Tests during a 20-hour period

Table 18 gives the values for 12 tests on initial blood samples drawn from two mature and one yearling captive female elk. Five additional samples, taken at four-hour intervals, were used to determine if significant changes occurred following the initial tests (Figures 5, 6, 7, and 8). A 95 percent confidence interval brackets the initial values. A significant change ($P < .05$) followed the initial test in Figure 5 for calcium ions and inorganic phosphorus, Figure 6 for glucose and BUN, and Figure 7 for SGOT and LDH. Significant changes noted in the six tests may have been caused by (1) results of the initial excitement, (2) continued excitement due to handling stress, or (3) an antithesis or a calming effect. Continued excitement was due to blood

Table 17. Hematologic values from free-ranging and captive calves during the 1969-1970 winter.

Test	Number tested	Mean	Standard deviation
WBC[a]	49	6379	1778
RBC[a]	50	12.14	1.23
Hb[b]	49	19.77	2.93
PCV[c]	52	51.06	5.56
BUN[d]	39	23.77	10.69
SGOT[e]	54	118	48
LDH[e]	51	987	349
Alkaline Phosphatase[d]	53	3.89	1.8
Total Protein[b]	43	6.97	1.07
Albumin[b]	19	2.95	.63
$Alpha_1$[b]	19	.50	.14
$Alpha_2$[b]	19	.67	.26
Beta[b]	19	.88	.37
Gamma[b]	19	1.38	.81
Glucose[f]	5	194	31
Creatinine[f]	4	2.6	.36
Neutrophils[c]	35	30.5	12.4
Lymphocytes[c]	35	62	12
Monocytes[c]	35	.8	.9
Eosinophils[c]	35	4.8	4.6
Basophils[c]	35	.7	1.4

[a]cells/cu mm
[b]grams/100 ml
[c]percent
[d]Sigma units
[e]units/ml
[f]mg/100 ml

Table 18. Blood values from the initial samples collected serially from three elk at four-hour intervals during a 20-hour period.

Test	Number	Mean	Standard deviation	Standard error	Range
BUN[a]	3	19.53	1.95	1.13	17.9-21.6
SGOT[b]	3	86.0	10.0	9.0	68-100
LDH[b]	3	111.0	25.0	14.0	85-136
Alkaline Phosphatase[a]	3	148.0	51.0	29.0	117-208
Total Protein[c]	3	7.26	0.305	0.18	6.99-7.18
Albumin[c]	3	2.74	0.253	0.15	2.53-3.02
Glucose[d]	3	244.0	62.0	36.0	190-327
Uric Acid[d]	3	0.396	0.153	0.09	0.28-0.57
Cholesterol[d]	3	71.0	6.2	3.6	56-82
Total Bilirubin[d]	3	0.639	0.268	0.16	0.48-0.95
Inorganic Phosphorus[d]	3	3.64	0.678	0.39	2.86-4.05
Calcium ion[d]	3	9.49	0.356	0.21	9.12-9.89

[a]Sigma units
[b]units/ml
[c]grams/100 ml
[d]mg/100 ml

sampling by two men every four hours; a calming effect may have occurred between these four-hour intervals, during which the animals appeared to become quiet and consumed about 15 pounds of hay each.

Serology

Serological tests for 101 blood samples collected between 1969 and 1971 indicated an absence of Brucella abortus and Leptospira pomona infections. This is in contrast to Redfearn and Robbins (1970) who recorded about 35 and 60 percent infection rates, respectively, for B. abortus in elk cows and bulls at the National Elk Refuge, Jackson, Wyoming.

Hormones

Progestogen assays revealed means and standard deviations of 4.19 and 1.62 ng/ml and 7.17 and 3.16 ng/ml, respectively, for non-pregnant and pregnant cows ($P < 0.10$). The range for the two groups was 2.65 to 7.29 ng/ml and 3.06 to 16.89 ng/ml, respectively, for non-pregnant and pregnant cows. Unsuccessful attempts have been made to assay the samples for progesterone, which it was hoped would increase the efficiency. Additional hematologic experimentations are needed to obtain an efficient analysis for differentiating between non-pregnant and pregnant elk.

Parasites

Results of a Dictyocaulus (lung worm larvae) survey in free-ranging and captive elk, based on randomly collected fecal pellets are given in Table 19. The recorded increased incidence of larvae, expected in the closely penned animals, was probably due to fecal contamination

Table 19. Results of Dictyocaulus larvae counts from fecal pellets of captive and free-ranging elk (1969-71).

Date	Number of elk	Percent positive
11/13/69	6 captive	67
11/18/69	9 captive	45
11/23/69	9 captive	67
12/22/69	15 captive	13
1/9/70	11 captive	18
1/16/70	11 free-ranging	0
1/23/70	24 free-ranging	0
1/30/70	5 free-ranging	20
2/8/70	13 free-ranging	0
4/8/70	17 captive	53
8/28/70	19 captive	79
1/25/71	10 free-ranging	0
2/7/71	4 free-ranging	0
3/6/71	11 free-ranging	0

of the feed. A much slower increase of larvae incidence in the wintering elk on the Hardware Ranch meadow was expected, but was not evident. Winter samples were not collected after March 6, 1971.

Histology

Microscopic examinations of tissues from yearling and adult testicles, epididymides, seminal vesicles, prostate and bulbo-urethral glands and the penis were compared for differences in size and structure. These tissues indicated spermatogenesis had occurred in yearlings and adults, agreeing with yearling studies by Conaway (1952), Harper (1966), and Flook (1970). Size and structure between the two age groups were examined with the aid of Dr. James L. Shupe, veterinary pathologist, with the Utah State University Department of Veterinary Science. The examinations emphasized the lack of development in the yearlings. Macroscopically, yearling reproductive tracts were recognizable, due to their small size. Also, one could predict microscopically the origin of the tissue examined.

Information indicates that, even though testicular sperm densities in the majority of the yearling bulls examined were equal to adults (Harper, 1966), fewer sperm probably would be produced by a smaller reproductive tract. It is generally known that a surplus of spermatozoa are included in most mammalian ejaculates. Therefore, fewer sperm in a yearling ejaculate would not necessarily reduce their breeding capacity.

The use of tame elk possibly would permit measurements of daily sperm production (DSP). Swierstra (1971) found histological sections were best for determining DSP, but Lino, Braden, and Turnbull (1967)

demonstrated that counting of spermatozoa in the urine of unejaculated males was much simpler. In rams, they found a mean of 88 percent of the DSP was excreted in urine.

Nutrition

Table 20 lists ingredients of a special pelleted formula fed free-choice with grass hay. The formula was developed by Dr. Lorin E. Harris, nutritionist in the Utah State University Department of Animal Science. Nutrition was considered the most important environmental variable affecting the study. Ocular observations of body condition were used to judge elk nutritional conditions. Body condition was judged excellent during the latter three-fourths of the study. Poor animal condition the first fall was due mainly to the lack of a balanced ration. A change from a commercial grade to a special pellet formula appeared to correct the problem.

Discussion and Recommendations

It was not intended to attempt indepth interpretations of data collected under this objective, but rather to present basic information obtained in conjunction with the reported reproductive studies.

Data presented from this objective reveal the magnitude of variations which occur when testing captive or wild trapped animals. Data from three captive elk tested at four-hour intervals (see Table 18 and Figures 5, 6, and 7) cogently demonstrate this fact. Although sample size was small, values from six tests indicated significant differences ($P < .05$) occurred. Data in the figures indicate blood values had reached new levels subsequent to the initial test, which

Table 20. Pellet formula[a] for elk to be fed free-choice with grass hay.

173.8 lbs.	Corn
1450.8 lbs.	Cottonseed meal 40 percent
207.6 lbs.	Alfalfa meal
33.4 lbs.	Dicalcium phosphate
37.4 lbs.	Trace Mineral Salt
97.4 lbs.	Dry Molasses
7.5 lbs.	Vitamin A (13,620,000 units per pound)
5.0 lbs.	EDDI[+b] (ethylene-diamine-dihydriodine)
2012.9 pounds[c d]	

[a]Calculated by Dr. Lorin Harris, Department of Animal Science.

[b]EDDI added to aid in prevention of pododermatitis caused by Spherophorus necrophorus.

[c]An initial 100 pounds of mixture is processed and discarded to clean the mixer of previous feed additives.

[d]Pressed into 15/64 inch pellets.

remained constant for 12 to 16 hours. Extended sampling should be conducted in future studies.

Serology indicated an absence of B. abortus and L. pomona infections. Future tests for a large group of Leptospira spp. have been planned in cooperation with the Utah State University Veterinary Diagnostic Laboratory. Appropriate surveys are necessary to provide continuous monitoring of disease trends in wild animals.

Accurate hormone assays in elk are urgently needed for basic experimentations into the reproductive physiology of big game ruminants. These would include: (1) gonadotropic hormones, i.e., FSH, LH, and prolactin, and (2) steroid hormones, i.e., estrogens, androgens, progestogens, and corticoids. Expanded experimentation with hematologic analyses are needed to determine pregnancy status of big game. Elk seasonal reproductive cycles, similar to other North American big game ruminants, offer an opportunity to obtain accurate pregnancy correlations between data obtained from rectal palpation and hematologic tests.

Information collected on Dictyocaulus infestations of captive elk reflected the pen conditions. Continuous fecal contamination of feed was directly responsible for an increase in larval counts, which rose from 0 on March 6, 1970, to 52.9 and 78.9 percent, respectively, on April 8 and August 25. A similar increase was expected after several months of feeding on the meadow at Hardware Ranch. No evidence, however, of a demonstrable Dictyocaulus infestation in the free-ranging elk was recorded. Winter feeding operations were apparently not of sufficient duration for a parasitic build-up.

Microscopic examinations of tissue from reproductive tracts of male yearlings and adults were included to observe a possible age

differential in spermatogenesis and accessory gland structure. No differences in organization or function were apparent. Differences in size and structure, however, were easily observed. As the males age, the glands enlarge and probably become more active during each annual recrudescent period. Flook (1970) noted an annual increase in the size of elk testicles and accessory glands from calves to six-year old bulls.

Early nutritional problems were corrected with the use of a special pelleted formula, fed free-choice with grass hay. The effects of nutrition on fecundity has been reported by many authors, including Cowan (1950), Casida (1959), Cross (1965), Sadlier (1969b), Skinner and Van Zyl (1969), and Morrison (pers. comm.). Future reproductive experiments should continue the feeding program in progress. Elk cannot be forced to eat all the hay offered as they may waste 25 to 30 percent. Hay and pellets must be given free-choice to maintain the animals in prime condition, which is mandatory for reproductive trials.

Summary

Data presented from blood analyses include: total leucocytes (WBC) and a WBC differential, erythrocytes, hemoglobin, packed cell volume (PCV), blood urea nitrogen (BUN), serum glutamic-oxalacetic transaminase (SGOT), lactic dehydrogenase (LH), alkaline phosphatase, total protein, albumin and fractions alpha$_1$, alpha$_2$, beta, and gamma, glucose, creatinine, uric acid, cholesterol, total bilirubin, inorganic phosphorus, calcium ions, progestogens, and serology for Brucella abortus and Leptospira pomona.

Comparisons between blood values reported for big game and domestic animals are presented. Collection of blood samples at

four-hour intervals during a 20-hour period indicated significant differences ($P < .05$) between initial "trapped" samples and subsequent "at rest" samples. Significant differences were noted at the .01 or .05 level in various tests between sexes, non-pregnant and pregnant, and free-ranging and captive of different ages. Significant differences ($P < .10$) were noted in progestogen tests between non-pregnant and pregnant elk. Captive elk were positive and free-ranging were negative for Dictyocaulus infestations. Microscopic differences were noted in size and structure of tissues from yearling and adult male reproductive tracts. Nutritional conditions of experimental elk were considered excellent when fed a special pelleted formula free-choice with grass hay.

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APPENDIX

Flow-chart 1. Expected and observed cow/calf ratios projected from associated pregnancy rates in adult and yearling elk palpated during the winters of 1969-70 and 1970-71.

A. The 1969-70 winter pregnancy rates of 100 percent in adults and 0 percent in yearlings produced a 100/55 cow/calf ratio in August, 1970. A ratio of 100/59 was expected assuming no deaths in cows or calves.

January, 1970			Pre-rut, 1970	
Cow/calf ratio: 100/60 (observed)			Cow/calf ratio: 100/55 (observed)	
100 ♀ adults	130♀	77 matures (100% pregnant)	→ 77 matures	→ 77 calves
30 ♀ calves		23 yearlings (0% pregnant)	→ 23 2.5-yrs.	→ 0 calves
30 ♂ calves		30 calves	→ 30 yearlings	→ 0 calves
160		130	130 "adults" to	77 calves equals a
			cow/calf ratio: 100/59 (expected)	

B. The 1970-71 winter pregnancy rates of 82 percent in adults and 17 percent in yearlings produced a 100/40 cow/calf ratio in August, 1971. A ratio of 100/50 was expected assuming no deaths in cows or calves.

January, 1971			Pre-rut, 1971	
Cow/calf ratio: 100/68 (observed)			Cow/calf ratio: 100/52 (observed)	
100 ♀ adults	134♀	77 matures (82% pregnant)	→ 77 matures	→ 63 calves
34 ♀ calves		23 yearlings (17% pregnant)	→ 23 2.5-yrs.	→ 4 calves
34 ♂ calves		34 calves	→ 34 yearlings	→ 0 calves
168		134	134 "adults" to	67 calves equals a
			cow/calf ratio: 100/50 (expected)	

♀ - female
♂ - male

VITA

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