EDWARDS 1956 b

/4/

EDWARDS 1956 b

Reprinted from
THE JOURNAL OF WILDLIFE MANAGEMENT
Vol. 20, No. 2, April, 1956

SNOW DEPTHS AND UNGULATE ABUNDANCE IN THE MOUNTAINS OF WESTERN CANADA

R. Y. Edwards [1]

British Columbia Forest Service, Victoria, B. C.

It is long established that "severe winters," or "hard winters," cause fluctuations in ungulate populations. Annual reports of the British Columbia Game Department have noted since 1912 that such winters may cause serious declines. Roe (1951) reports "hunters' traditions" as early as 1875 attributing bison decreases on the American prairies to severe winters.

Published accounts of ungulate mortality due to severe winters or deep snow involve a wide range of species in a large geographic area. Holzworth (1930: 23) notes that black-tailed deer on the islands of southern Alaska die in thousands during severe winters. Spiker (1933) considers deep snow as the only important factor in winter mortality of Adirondack white-tails. Rand (1947) concludes that severe winters with deep snow are the worst enemy of pronghorn antelope in Alberta. Murie (1944) records heavy losses in Dall sheep, and in moose, during severe winters with deep snow in Alaska. Roe (1951) quotes numerous historic references describing American bison declines because of snow, but discredits most of them in support of his thesis that man, not snow, was the bison's chief enemy. Cowan (1950) records a cold winter with deep snow that reduced mountain goat survival in the Canadian Rockies, and later (1952) calls winter the greatest enemy of goats. The latter paper also postulates the near extermination of elk in the Rocky Mountain region as a result of severe winters in the 1870's and in 1898, while Banfield (1949) describes an elk die-off in Manitoba because of severe winter conditions. Longhurst *et al.* (1952) show that deer die-offs in the Sierras of California have occurred mainly in years with heavy snowfall. Matthews (1952: 290) describes red deer declines in the Scottish highlands during severe winters. Wildhagen (1952) notes winter declines of reindeer in Norway, here possibly due to lichen ranges being covered with ice.

The pioneer detailed study of snow-ungulate relationships appears to be that of Severinghaus (1947). He showed that deer mortality in the Adirondacks of New York "varies from year to year with the severity of the weather" and that "deep snow is the principal weather factor involved."

From California to Alaska to New York, in a large part of North America subject to cold winters and frozen precipitation, no ungulate seems immune from the effects of winter with its snows, perhaps excepting caribou. This exception may exist more from lack of data than from lack of occurrence, as information from Norway suggests and as this paper will further support.

METHODS OF STUDY

This study had three parts. The first compared trends in average annual depths of snow with trends in the numbers of various ungulates. Data on ungulate populations were obtained from the annual reports of the British Columbia Game Department (Anon., 1909 to 1950). Weather data were gathered from the monthly reports of the Canadian Department of Transport (Anon., 1928–1950), and from the 1935–1952 Summary of Snow-survey Measurements in British Columbia (Anon., 1952). Data on snow depths are not common. Few weather stations in British Columbia have kept continuous readings of snow depths on the ground, and only three stations have data extending as far back as 1928. Snow-survey stations provide valuable data, but only a few have measurements dating from 1935.

Field work was the second phase of study, observing ungulate populations in selected areas (mainly in provincial parks), and interviewing observant people who knew the areas concerned.

The third and final phase was to examine wildlife literature for Alberta and Alaska to determine if conclusions reached for British Columbia applied to a greater area.

[1] I. McT. Cowan and R. W. Ritcey gave valuable assistance, commenting upon an early form of this paper.

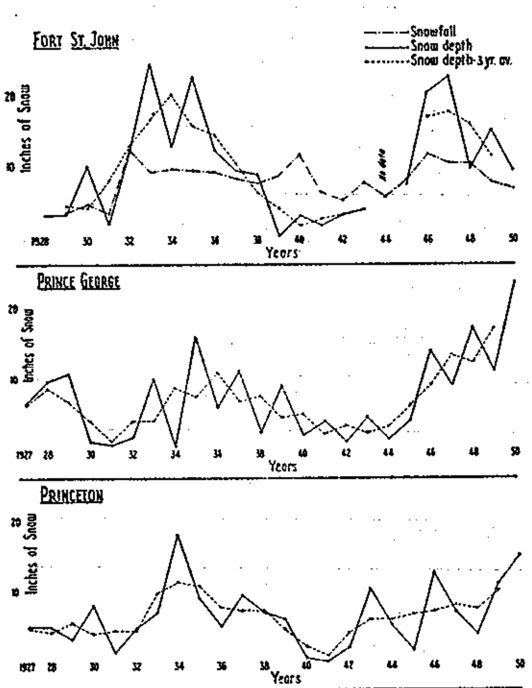

FIG. 1. Average monthly snow depths from three meteorological stations in British Columbia, with snow fall averages of monthly totals from one station. (Data from Canadian Dept. of Transport.)

SNOW DEPTHS IN BRITISH COLUMBIA

Trends in snow depth in British Columbia are shown in Figure 1. These data are from snow depth readings taken on the last day of each month. Points shown represent average monthly snow depths for the six months October to March inclusive, and each figure is plotted over the year of the last three of these months (*i.e.* winter of 1934–35 is plotted over 1935). The curves represent both annual averages and the results of smoothing these by three-year averages. The curves for Fort St. John show also average monthly snow precipitation. The difference possible between snow depths and snow falls in the same place is here evident.

Three localities are represented, Princeton in the dry grasslands of the south, Prince George in the spruce-balsam forests of the central part of the province and Fort St. John in the aspen parklands of British Columbia's "Peace River Area," east of the mountains and close to Alberta (Fig. 3). Two facts are evident from these curves. First, deep snow years and shallow snow years tend to be grouped into periods. For example, the periods 1933 to 1938, and from 1946 to the early 1950's may be designated as times of deep snows, while the period 1940

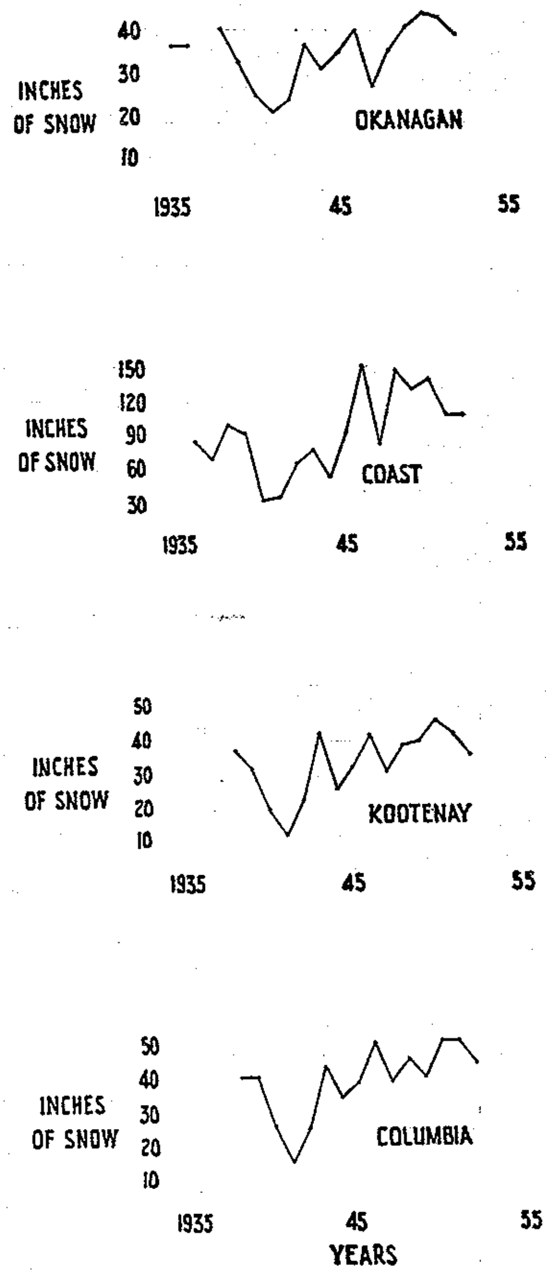

FIG. 2. March snow depths at high elevations in four parts of southern British Columbia. (Data from B. C. Dept. of Lands and Forests.)

to 1944 is one of shallow snows. Second, the curves show reasonably similar trends for the three places. There is evidence here that annual snow depth trends are similar over a large part of the province.

Provincial snow survey readings provide additional data. Figure 2 is based on these readings, and shows snow depth curves for four parts of southern British Columbia from 1935 to 1952. Each curve represents the average from five snow stations. The locations of these four regions are shown in Figure 3. All readings were taken at high

FIG. 3. Location of three meteorological stations and four regions supplying data for Figs. 1 and 2. Hatched areas are: 1—Coast; 2—Okanagan; 3—Columbia; 4—Kootenay. Dots in hatched areas indicate snow measurement stations.

elevations, usually in sub-alpine forest or above, and figures used are for the end of March which is considered by the office concerned with these measurements to be the end of the snow accumulation period. These four curves are similar in that they show a period of shallow snows about 1940 with increasing snow depths thereafter. Only deep snows in 1943 destroy evidence of progressively increasing snow depths through years in the middle 40's. Deep snows did not occur at lower elevations in 1943 (Fig. 1).

A shortcoming of all snow data used here is that they are not from winter ranges, nor even from winter range elevations, but are either from towns on the valley bottoms or from high elevations. Snow depth trends should be much the same regardless of elevation, but there can be exceptions. In the past winter (1953–54) snow depths were the deepest in at least eight years at sub-alpine elevations in the Cascade Mountains, yet twenty miles away and 1500′ lower deer ranges had the shallowest snow since the middle 1940's.

UNGULATE FLUCTUATIONS IN BRITISH COLUMBIA

Annual reports of the British Columbia Game Department provide a continuous source of information on game abundance in past years. These, from 1909 to the present, contain annual statements on game abundance applying variously to the whole province or to relatively restricted areas. In analysing these reports all statements of ungulate abundance were noted, and from these statements of declines, or of low population, were segregated. Figure 4 shows these

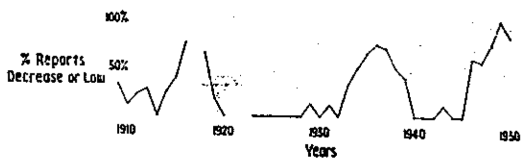

FIG. 4. Percentage of reports on deer, moose and caribou abundance reporting decreased or low populations. (Data from B. C. Game Dept.)

data applying collectively to deer, moose and caribou, wherein the number of statements of decline and low numbers are expressed as a percentage of the total number of abundance statements for each year. This method can show only trends, and some other limitations should be noted. It gives equal weight to statements covering areas of different size. In addition there is clear evidence in several reports of reluctance to report game declines. One reporter, for instance, after reporting increases for three years and reporting nothing useful in the fourth year, in the fifth year declares that "deer are again coming back." There can be no doubt, however, that in the aggregate these reports have caught the main trends of game populations from year to year, and it is trends that are of major concern here. Figure 4 suggests that there have been

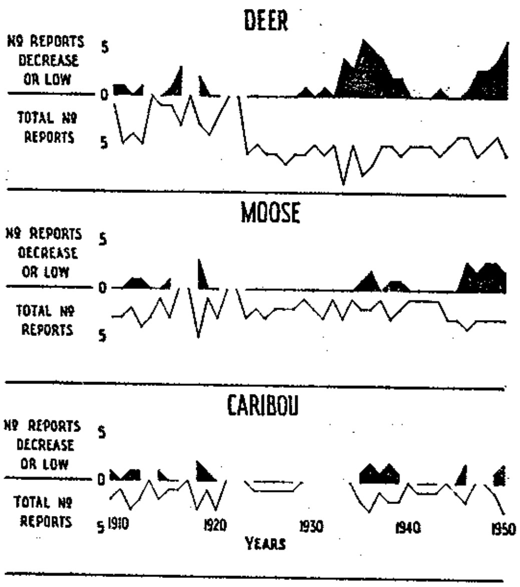

FIG. 5. Number of abundance reports compared with number of reports of decreased or low population. (Data from B. C. Game Dept.)

periods of abundance and scarcity, and Figure 5, in which deer, moose and caribou are dealt with separately, indicates that these three species have had similar trends of abundance. The data for caribou are not complete, but are at least highly suggestive.

In addition, these annual reports give information on mountain sheep in the so-called Cassiar country, roughly the north west quarter of the province. For some reason there were more reports from this remote region before the first war than there have been since. The sequence of reports, 1909 to 1919, shows that the Cassiar thinhorn sheep have followed the same trends as deer, moose and perhaps caribou in this period.

Mountain goats have been mentioned only nine times, with scarcity or decline noted twice, in 1946 and 1949.

Elk are mentioned fourteen times and reported as decreased only in 1909.

It is evident, then, that most ungulates in British Columbia declined in numbers at the time of the 1914–18 war, in the late 1930's and again in the late 1940's. There also appears to have been a period of scarcity just prior to 1909 for reports in that year note moose as "scarce until the past few years" but rapidly increasing, caribou had disappeared from the Itcha Mountains but otherwise were increasing, elk had suffered some mortality recently, and the Cassiar sheep were down. By 1910, white-tailed deer in southern British Columbia showed "extraordinary increases" after they "seemed doomed a few years ago," moose in the Fernie District were "gradually coming back" and deer in the Columbia valley were "more numerous than for years."

Between periods of scarcity there was notable abundance, most evident, of course, in the more common lowland species of the agricultural south. In these years there were numerous reports like "increasing rapidly" and "more plentiful than at any time in the memory of oldest residents."

Brian Williams, former Game Commissioner in this province, has also documented periods of scarcity and abundance, but he was regrettably unconcerned about dates. He states (1925) of mule deer that at the time of writing they were scarce, partly as a result of lack of protection during the war, but also because of cougars and coyotes. Previously there had been a time of abundance with heavy damage to agricultural crops. Before this, scarcity was general, and he explains the low numbers as due to market hunters, spread of civilization and Indians. Prior to this, again, "the whole of the dry interior simply swarmed with mule deer." In another book (1935) he records a "tremendous increase" in late years. This sequence is not easy to follow because of lack of dates, but deer scarcity is evident during the 1914–18 war and after it, with periods of abundance before and after. This much supports conclusions from Figures 4 and 5. Working back, there was another period of scarcity near and perhaps just after the turn of the century. Prior to this again, they "simply swarmed."

The evidence seems conclusive that ungulates in British Columbia have had successive periods of marked scarcity and abundance.

The curves for snow depth and ungulate abundance are similar for the twenty-year period in which snow data are available. Both show highs in periods of several years about the middle 1930's and late 1940's with a period of low values between. Close examination shows that high values in the ungulate curve are a few years later than in the snow curve. This is to be expected. The ungulate curve represents reports of decrease and low population. Ungulate scarcity would continue for several years after removal of the factor causing it.

FIELD WORK

While data on snow and population trends described above end in 1950, field work begun in 1949 brings the situation to the present and substantiates some of the data already given. This information is given in condensed form below. References to winters dated by a single year indicate the winter ending in the first half of that year. Places referred to are shown in Figure 6.

FIG. 6. Ten areas from which field data were gathered. 1—Tweedsmuir Park; 2—Sayward Provincial Forest; 3—Mount Seymour Park; 4—Southern Vancouver Island; 5—Manning Park; 6—Ashnola Region; 7—Vavenby Region; 8—Wells Gray Park; 9—Mount Robson Park; 10—Bowron Lakes Region.

Mule deer in Manning Park were numerous in 1946. The winters 1947–8–9 had deep snows and deer decreased in abundance. By 1952 recovery of numbers was evident and there was increasing abundance to 1955. Similar trends were noted in the Ashnola drainage, Wells Gray Park, Mount Robson Park and near Vavenby. Black-tailed deer populations behaved similarly in the Sayward Forest and southern Vancouver Island. Recent increases are evident also in Seymour Park on the mainland coast, but here the decline appears to have taken place in 1943, coinciding with a year of deep snows at high elevations (Fig. 2).

Moose in Mount Robson Park declined in numbers through the period 1948–9–50, and had recovered appreciably by 1952. Deep snows accompanied the declines. Similar trends were noted about the Bowron Lakes. In Wells Gray Park there was no serious die-off, but through these winters with deep snow moose were concentrated on the lower ranges to an extent not observed since.

Mountain caribou were decreased in Wells Gray Park by 1935, appeared to be especially scarce after 1945, then showed an apparent increase after 1952. There was a decline in Tweedsmuir Park and about the Bowron Lakes in the 1930's, with reports of increased abundance in the former in 1954 and 1955 suggesting a more recent decline. In Mount Robson Park there was a decline in 1945 or 1946, while increases were evident by 1952.

In Mount Robson Park and vicinity bighorn sheep declined an estimated 85 per cent through the winters 1948–9–50, and there was an elk die-off in Yellowhead Pass in 1949. Both species have increased since. Mountain goats in 1953 were still not recovered from a decline which occurred after the mid-1940's.

These data substantiate the curves in Figures 4 and 5 and extend our knowledge to the present. From all this information a pattern is evident, naturally best documented for deer which are most abundant and most closely associated with man at lower elevations, and poorly recorded for the wilderness species and those less widely distributed. There were periods of ungulate scarcity in the 1900's, 1910's, 1930's and 1940's with alternate periods of abundance. British Columbia is now experiencing such abundance, especially evident in deer from the Pacific slopes to the Rockies. The record of snow depths through these years of abundance is one of relatively snowless winters. It has long been known that deep snows may cause severe mortality in some ungulates, but the light cast by these data leaves no serious doubt that years of deep snow and scarce ungulates, and years of shallow snows and ungulate abundance, are both grouped into alternating periods of years. Further, all ungulates seem to be affected, although the data is admittedly inadequate for final conclusions for mountain goats, and perhaps caribou. Studies elsewhere have demonstrated severe effects from deep snow upon herds of mountain sheep and elk, substantiating conclusions from limited data in this study.

UNGULATE POPULATION TRENDS IN ALBERTA AND ALASKA

The purpose here is to briefly survey pertinent literature on ungulate populations in Alberta and Alaska to determine if there is indication of correlation with ungulate fluctuations in British Columbia.

Hewitt (1921) records a peak moose kill in Alberta in 1914, with a decline after the 1914–18 war. He also notes an increasing deer kill from 1907–14, and a decline from 1914–18. These indications of peak numbers in moose and deer in 1914 are in agreement with British Columbia data, but the effect of war upon the harvest is an alternative explanation.

Rand (1947) studied the history of pronghorn antelope in Alberta, and concluded that "bad winter weather is the worst enemy." Twelve cases of severe winters affecting antelope populations are recorded, five in 1906–7, five in the two winters 1935–6 and 1936–7, and two in 1944–5 (the data were gathered in 1945). The similarity of these mortality periods to those in British Columbia is marked. An absence of die-off reports during the 1914–18 war is noteworthy.

There is more published data on Alaskan ungulates, and some of them do not agree well with British Columbian information.

Williams (1952) presents some fragmentary data on deer numbers in south-eastern Alaska. There was a serious die-off in 1918, peak numbers in 1929, and a die-off in 1930.

Murie (1944) reports a Dall sheep die-off in the severe winter of 1928–29, after a peak population in 1928. A more severe die-off occurred in 1931–32. Scott *et al.* (1950) extend the record, reporting a decline through the first half of the 1940's and an increase in the last half.

Murie (*op. cit.*), for the Mt. McKinley area, reports moose scarce in 1922 and 1923, increased in 1927 and 1928 and decreased in the winter of 1931–32. Chatelain (1950) reports a peak moose population in 1925 and Spencer and Chatelain (1953) note declines, some of them minor, in 1913, 1916, 1922–23, 1936 and 1946. The last two papers refer to the Kenai Peninsula.

These Alaskan records are not similar to data from British Columbia. Die-offs of deer and sheep in the early 1930's and the trends of sheep populations in the 1940's do not coincide with major periods of decrease in British Columbia. Moose data also have dates not in agreement.

Recent publications by Scheffer (1951) and Leopold and Darling (1953) give detailed information on the rise and fall of the reindeer industry in Alaska. Reindeer are domesticated, it is true, but they are dependent upon wild ranges, and hence are subject to many influences affecting wild populations. Scheffer (*op. cit.*) shows that the peak was reached on the Pribilof Islands in 1938, and the major decline took place in 1939 and 1940. Leopold and Darling (*op. cit.*) report a die-off at the base of the Kenai Peninsula in the winter 1938–39. The same authors show figures for the entire Alaskan reindeer population indicating peak numbers in 1932, slightly reduced numbers by 1936 and a decline halving the population by 1940. By 1949 the total had dropped to 32,623 from the 1932 high of 625,000 or more. The first part of the reindeer crash occurred during or just after the ungulate declines of the middle and late thirties in British Columbia.

Analysis of all data for Alaska shows that about half of the die-off periods fall, wholly or in part, into the British Columbia die-off and low population periods. This does not appear to be significant.

DISCUSSION

It has been shown that years with deep snow and years of ungulate declines and low population tend to occur in groups, and these data indicate that deep snow periods are also periods of decreases in ungulate populations. In British Columbia, deep snow appears to be a major factor controlling the abundance of mule deer, black-tailed deer and moose. Less adequate information indicates that caribou, mountain sheep, white-tailed deer, elk and mountain goat are similarly affected. The data is more fragmentary than might be desired, the period of time under study is really quite short, but the evidence is remarkably clear-cut as far as it goes.

While snow depth appears to be a major

factor in the winter survival of ungulates there are undoubtedly other complicating factors. The abundance of food and cover, operating singly or together, could be major factors either increasing or decreasing the effect of deep snow.

It has been noted that moose in Wells Gray Park did not decline appreciably during the deep snow period of the late 1940's. By contrast during this same period of severe winters there were general moose declines throughout central British Columbia (Hatter, 1949). The failure of snow to seriously reduce the Wells Gray population is probably the result of the range being understocked relative to most good ranges in the province. Moose were late in arriving on the Wells Gray range. They appeared first in the early 1930's, and although numerous by the late 1940's, snows did not restrict travel and bury food to the extent that heavy mortality occurred. It is noteworthy that Spencer and Chatelain (1953) report that in the Susitna Valley of Alaska, moose appeared later than on some ranges where there have been die-offs, and the Susitna herd has had no large winter kills.

The operation of cover in offsetting the effect of deep snows was demonstrated on Vancouver Island in the late 1940's. Black-tailed deer flourish on large areas clear-cut and often burned by loggers. The type of logging practiced in the Sayward Forest is typical and here left square miles without standing trees, except in swampy areas and on thin outcrop soils atop hills. During the die-off period surviving deer inhabited these small and scattered patches of timber. The open slashings had food in abundance, but much of it was buried and the snow was so deep that the animals floundered in it. Recently these same areas have been relatively snowless and deer in a few years have become more abundant than they were before the decline. By 1950 a series of deep snow years had reduced the population alarmingly, but by the spring of 1952 it was easy to see over one hundred deer in a short evening road count.

One may conclude that food and cover can modify the effect of snow, and that the response to potentially similar snow conditions may be very different on different ranges.

It has been noted above that deep snows have been recognized as a factor in ungulate mortality for a long time and over a large area. Even casual observation can detect such mortality. It seems, however, to have been regarded as an occasional phenomenon rather than the major and recurring condition that it is. While Williams (1925) partially understood the affects of deep snow upon deer, and he clearly describes a series of periods of deer scarcity and abundance in British Columbia (see above), he suggests a long list of reasons for the die-offs which include market hunters, encroaching civilization, Indians with new repeating rifles, coyotes, cougars and lack of protection during a war. Similarly, in the annual reports of the Game Department many reasons are offered for ungulate decreases which occurred during deep snow periods. Severe winters and deep snow are often mentioned as partial factors, but wolves, cougars, coyotes, Indians, dry summers, ticks, hunters and railway gangs are often regarded as more serious. The interesting point is that nearly all of these supposed causes of disaster occurred in deep snow years. One can only conclude that while these diverse factors may have had their local importance, it is improbable that they caused the widespread declines observed. It requires some widespread phenomenon, like weather, to set so vast a stage as an entire province. Perhaps we must look upon ungulate declines as having primary and secondary, even tertiary and quaternary causes. Whether the animals die of starvation because of snow, of ticks because of near starvation, or by cougars because of ticks, the basic cause may be the same. Perhaps the real cause of ungulate scarcity in the past has been obscured by its more obvious associates.

Murie (1951) has pointed out that most efforts in ungulate management have attempted to maintain stable populations. His suggestion is that artificially induced fluctuations will better maintain our ranges. In British Columbia, on the other hand, our management efforts have been based upon a stable population concept while the animals have fluctuated in spite of us. The situation has been not unlike that of grouse management in the past. While grouse rose and fell with a certainty akin to the seasons, we blamed anything handy for the declines and praised our legislative wisdom during periods of increase and abundance.

Reactions to these ungulate fluctuations in the past have been anything but consistent. In areas where our criterion of abundance was the condition of range, heavy range use during deep snow years has led to diagnoses of overabundance. Resulting recommendations were heavier cropping. In areas where peculiarities of vegetation and range made actual counts of animals the best indication of abundance, declines in population have led to closed seasons so herds could recover. With the tools at hand both conclusions appeared logical at the time, but the possibility of having called two similar situations black in one case and white in another is all too apparent.

Where ungulates are under management for the hunting public, management action must change with the changing population. The crop should be heavy during periods of plenty. There is no more point in trying to stockpile deer than in trying to do so with fluctuating grouse. But population increases should be allowed, if indeed they can be prevented. If our aim was to hold populations at severe winter levels and our management should succeed in doing so, the resulting loss of good hunting could be greater than the loss due to die-offs. In addition, this study suggests that deep snow periods may be predictable to a degree and on a short term basis, for deep snow years tend to group. Early indications of entering a deep snow period may justify attempts to reduce herds, for a die-off is coming in any event.

Die-offs accompanied by heavy range use do not necessarily indicate a chronic condition of overpopulated range. At best a die-off indicates a temporary reduction of necessary range resources due to weather; at worst it brings about a major and permanent decline premature to when it would have come if severe winters had not occurred. This last, for instance, could be part of the cause of reindeer declines in Alaska in the late 1930's where overgrazing had, or had nearly, set the stage for a crash in any event. This is speculation, however, and is not supported by first hand information.

Mountain caribou in Wells Gray Park may have declined in a manner similar to these reindeer. A previous report (Edwards, 1954) indicates that this decline may be due to fire destroying winter range forests at low elevations. A major fire swept these valleys in 1926, and there were smaller fires of importance between that date and 1940. The first indication of caribou decline was noted in 1935, but it was not generally appreciated until two years later. It may be more than coincidence that the decline occurred in deep snow years. While range reduction by fire was probably a major cause of the decline, deep snows may have brought the full impact of range reduction into operation.

Consideration of deep snow periods also casts some doubt upon past analyses of ungulate-range relationships. Two ranges which appear to have the same resources in autumn, and therefore might be expected to winter equal numbers of animals, will in reality support very different populations if one has shallow snow, the other deep snow. This is almost self evident, but when dealing with the same range in different years the situation may be similar, seriously complicating attempts to estimate in autumn the amounts of forage or browse available in the coming winter. Again, in mountainous terrain at least, years of deep snow tend to concentrate ungulates at the lower elevations. Browse or range surveys in deep snow periods are likely to uncover "overuse of range" in these periods. But are such ranges over-stocked? Several years later the same herd, considerably increased in size, may be using the same winter range which has expanded into higher elevations because of snowless winters. There may then be much lighter use per unit of range. This condition has been noted on the winter range of the Wells Gray moose herd. The solution appears to be range surveys over a period of time, determining use levels with due regard for changes in winter range size.

Thus proper harvests in deep snow years are a matter for determination on each range. With the knowledge that die-offs may result from weather conditions that are temporary and that winter range overuse may be temporary and involve only part of a range, the choice of cropping lighlty to ensure maximum survival to more favourable winters, or cropping heavily to further reduce the herd and protect those parts of the range in use, depends upon the area and quality of unused parts of the range which will be used when snow conditions change.

Most of this discussion has been more theoretical than might be apparent. In British Columbia we can apply these management principles locally, but in view of the fluctuations which our ungulate populations have shown to the present time, apparently as influenced by winter weather conditions, there is some doubt that human harvests have had much influence upon ungulate abundance. There may be local exceptions, but one must conclude from the province-wide picture that our hunters have not been the efficient influence upon ungulate abundance that some would have us believe. The hunting public has hunted populations controlled in the long run by the size and excellence of our winter ranges and in the short run by the degree to which variable winter weather reduced the necessary resources on these ranges. As long as ungulate herds can increase rapidly from the effects of winters with deep snow, weather, not hunting, is the more important control over their numbers.

A different facet of the role of snow in ungulate management in mountainous terrain concerns human influences upon small areas of land essential for ungulate survival in winters with deep snow. These areas are usually on warm slopes at low elevations where most subject to the influence of man. Farming may result in range destruction, while livestock grazing, logging, fire and other influences may have equally drastic effects. Ungulate herds which populate large areas under favourable weather conditions may be exterminated if these small and only occasionally essential ranges are not available when needed. This appears to partly explain the disappearance of bighorn sheep from the rims of dry valleys in southern British Columbia. Agriculture simply crowded them from emergency winter range. A number of mule deer herds have been similarly affected, and the process is continuing. This trend is difficult to combat because the situation is not easy to see. There may be long periods of years without sufficiently severe winters to make these areas essential for survival. As a result, destruction of emergency range may not seriously affect the ungulate population using it for many years. This may have happened to the herd of caribou in Wells Gray Park, discussed above, which may still have adequate winter range for most winters, but which may not have range for high survival in severe winters.

Fluctuating snow depths and peculiarities of terrain may decree that a few acres are the key to adequate stocking over many square miles. The obvious solution is public acquisition of these key acres to ensure the maintenance of the public ungulate resource.

SUMMARY

There have been alternating periods of deep snow winters and shallow snow winters in British Columbia. Population declines in ungulates have occurred in deep snow periods. The record is most complete for mule and blacktailed deer and moose, but other species appear to have shown similar fluctuations.

Limited information from Alberta and Alaska indicates that the former has experienced similar weather and ungulate fluctuations, while the latter shows no conclusive agreement.

Ungulate declines in the past have been blamed on a long and varied list of supposed causes. Snow depths may be the primary cause of a number of factors observed in winter mortality of ungulates.

The seriousness of declines due to snow may vary with the ranges concerned. What appears to be over-use in deep snow years may involve only a small part of the range used at other times.

In British Columbia the record of ungulate fluctuations indicates that the human harvest is not a major population control, at least on the more common species.

Public acquisition of small areas of low elevation winter range may be essential to ensure ungulate abundance over many square miles.

LITERATURE CITED

ANON. 1909 to 1950. Reports. Provincial Game Commission. Prov. of British Columbia. Victoria.

ANON. 1928 to 1950. Monthly Reports. Meteorological Observations in Canada. Dept. Transport. Toronto.

ANON. 1952. Summary of snow-survey measurements in British Columbia, 1935 to 1952 inclusive. Dept. Lands & Forests, Victoria.

BANFIELD, A. W. F. 1949. An irruption of elk in Riding Mountain National Park, Manitoba. Jour. Wildl. Mgt., **13**: 127–134.

CHATELAIN, E. F. 1950. Bear-moose relationships on the Kenai peninsula. Trans. N. Amer. Wildl. Conf., **15**: 224–233.

COWAN, I. McT. 1950. Some vital statistics of big game on over-stocked mountain range. Trans. N. Amer. Wildl. Conf., **15**: 581–588.

———. 1952. Big game of the mountain province. Canada. Geog. Jour., **44**: 226–241.

EDWARDS, R. Y. 1954. Fire and the decline of a mountain caribou herd. Jour. Wildl. Mgt., **18**: 521–526.

HATTER, J. 1949. The status of moose in North America. Trans. N. Amer. Wildl. Conf., **14**: 492–501.

HEWITT, C. G. 1921. The conservation of the wildlife of Canada. Scribner's. N. Y.

HOLZWORTH, J. M. 1930. The wild grizzlies of Alaska. Putnam's. N. Y.

LEOPOLD, A. S. and F. F. DARLING. 1953. Wildlife in Alaska. Ronald Press. N. Y.

LONGHURST, W. M., A. S. LEOPOLD and R. F. DASMANN. 1952. A survey of California deer herds, their ranges and management problems. Calif. Dept. Fish and Game, Game Bull. No. **6**: 1–136.

MATTHEWS, L. H. 1952. British Mammals. Collins, London.

MURIE, A. 1944. The wolves of Mt. McKinley. Natl. Parks Fauna Ser. No. **5**.

MURIE, O. J. 1951. The elk of North America. Wildl. Mgt. Inst. Washington.

RAND, A. L. 1947. The 1945 status of the pronghorn antelope, *Antilocapra americana* (Ord), in Canada. Natl. Mus. Canad. Bull., No. **106**: 1–34.

ROE, F. G. 1951. The North American Buffalo. Univ. Toronto Press.

SCHEFFER, V. B. 1951. The rise and fall of a reindeer herd. Scient. Month., **73**: 356–362.

SCOTT, R. F., E. F. CHATELAINE, and W. A. ELKINS. 1950. The status of the Dall sheep and caribou in Alaska. Trans. N. Amer. Wildl. Conf., **15**: 612–625.

SEVERINGHAUS, C. W. 1947. Relationship of weather to winter mortality and population levels among deer in the Adirondack region of New York. Trans. N. Amer. Wildl. Conf., **12**: 212–223.

SPENCER, D. L. and E. F. CHATELAIN. 1953. Progress in the management of the moose of south central Alaska. Trans. N. Amer. Wildl. Conf., **18**: 539–552.

SPIKER, C. J. 1933. Some late winter and early spring observations on the white-tailed deer of the Adirondacks. Roosevelt Wild Life Bull., **6**: 327–385.

WILDHAGEN, A. 1952. Aktuelt om villreinen. Papers on Game Research, **8**: 50–57, Helsinki.

WILLIAMS, A. B. 1925. Game trails in British Columbia. Scribner's, N. Y.

———. 1935. Fish and game in British Columbia. Sun Directories, Vancouver.

WILLIAMS, J. P. 1952. Alaskan Adventure. Stackpole, Harrisburg.

Accepted for publication January 21, 1955.