OVERGRAZING ON WESTERN RANGELANDS
WITH SPECIAL REFERENCE TO THOSE OF BRITISH COLUMBIA

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ABSTRACT

Overgrazing and its effects has been the subject of controversy and debate in North America for over half a century. It has been referred to as such and in connection with other work in annual reports, editorials, farmers' bulletins, livestock journals, technical papers and political debates. While there are numerous papers dealing totally or in part with one or more of the aspects of overgrazing, few if any deal with the combined effects of overgrazing on the native vegetation, the domestic livestock, the soil, and the wildlife of the west. A study has been made of its effects on rangelands of the west with the intention of encouraging a system of range utilization in British Columbia which will enable the ranchers to derive the greatest possible benefits from the interior range lands without suffering the harmful effects that overgrazing exerts on the grazing environment.
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"God has lent us the earth for our life. It is a great entail. It belongs as much to those who are to come after us as to us and we have no right by anything we do or neglect, to involve them in any unnecessary penalties or to deprive them of the benefit which was in our power to bequeath."

Ruskin.
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OVERGRAZING ON WESTERN RANGELANDS

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I. INTRODUCTION

The range areas of western North America have been described by some as a desolate deserted region, grazed to barrenness, buffeted by dust-storms, gutted by erosion gullies, pocked with gopher holes and blowouts, scented with the pungent odour of sagebrush and strewn with the skeletons and remains of grazing livestock, each a mute symbol of the destruction brought about by overgrazing.

Others claim that there has been very little change in the vegetation and topography throughout the years of grazing and that there is no cause for alarm.

While ranges may be found to support the beliefs and contentions of both groups, it is well to study the former condition of rangelands in order that the actual conditions may be analyzed.

It is difficult to imagine the West as it is described by the early "voyageurs" who told of the tremendous areas of grassland, rolling hills, and mountains, populated only by
wandering bands of game such as elk, antelope and buffalo
and nomadic bands of Indians such as the Cree, Blackfoot and
Navajo. It is estimated (230) that before settlement by
the white man the virgin range covered the western two-thirds
of the United States and Canada. Excluding such non-grazable
land as mountains, deserts, dense forests and tundra, the
range comprised almost 850 million acres in the United States
alone.

Needless to say, within this area there are tremendous
variations in vegetation, topography, soil and climate. Re-
construction of the virgin range picture will indicate the
range types that were found by the early pioneers. While
most classifications of the virgin range differ somewhat (214,
242, 230) due to the investigator's interpretations of what
constitutes a major or separate range type, all are basically
similar. In describing the virgin range of the United States,
the classification selected is that used by Stoddart and
Smith (214). The classification of the grazing lands of
Canada is that presented by Clark (45, 46, 47) and his staff.

A. MAJOR RANGE REGIONS OF THE UNITED STATES

Nine major grazing regions are recognized by Stoddart and
Smith (214), each with a distinct vegetational composition.
Because of the interplay of soil, climate, and topography,
clearly defined boundary lines between the regions are
impossible. These regions are classified as follows:
(1) Tall Grass; (2) Short Grass; (3) Desert Grass; (4) Bunch
Grass or Palouse Grass; (5) Northern or Intermountain Shrub; (6) Southern Desert Shrub; (7) Chaparral; (8) Pinon-Juniper; and (9) Coniferous Forest.

(1) The Tall Grass Region

This region, often called true prairie, totalled some 252 million acres which extended from Manitoba to Texas along the Mississippi River watershed in a strip ranging in width from 50 to 500 miles (214). The moisture efficiency was high, the area receiving from 25 to 40 inches of precipitation throughout the grazing season. The soil is black and rich and the topography smooth and rolling. The vegetation was abundant and productive, being 2 to 3 feet tall on the drier slopes and 4 to 5 feet tall on the bottom lands (230). In this area, buffalo (204) ranged in uncountable herds and almost every species in the plant association was both palatable and nutritious (230). Throughout the tall grass region the carrying capacity was high; only three-quarters to one and one-half acres being required to supply one animal month of grazing. Early pioneers found that the vegetation did not cure well when left standing and hence little late fall or winter grazing was available.

(2) The Short Grass Region

This area, found to the west of the tall grass region, included approximately 280 million acres (214) in its virgin

\^E.T. Seton estimated the buffalo population at 50,000,000 head.
state. It extended from the Texas Panhandle in the south to Alberta and Saskatchewan in the north, from the foothills of the Rocky Mountains in the west to approximately the 100th meridian in the east where it merged with the tall grass region (230). In all, it formed a belt some 300 to 600 miles wide. The average rainfall of the area is much lower than that of the tall grass region, being about 13 inches in the north and somewhat higher in the southern plains. The soil was brown and lacked humus, the topography vast and uniformly level. The vegetation, as the regional name indicates, was short, consisting then as it largely does now of such hard curing species as grama, buffalo, wheatgrasses and spear-grasses. In this area game birds, rodents, small mammals, antelope and buffalo (129) utilized the forage throughout the entire year. The hot dry summer winds cured the forage which maintained its nutritive value throughout the fall and winter months (42). The grazing capacity of the short grass region was about 2.5 to 4 acres per animal month in the north and increased to 5 to 10 acres per animal month in the south. There is some controversy among noted ecologists (129, 242) as to whether the short grass region is a distinct region or whether it is and was merely a sub-climax of a mixed-grass association brought about by the repeated heavy grazing of such animals as antelope and buffalo.

(3) The Desert Grass Region

This area, synonymously called the semi-desert grass region (255) occupied some 93 million acres and was confined
to the southern portions of New Mexico, Arizona, and Texas. It was found to be much the driest of the rangelands, having low rainfall (10 to 12 inches per year) and excessively high evaporation rates and temperatures (214). From east to west the topography changed from broad, flat plans and low hills to mesa tops and finally to lower slopes of the mountains. The soils are characteristically red and yellow. The vegetation of the region was found to be highly variable, ranging from an open grassland to patches of desert shrubs. At the time of pioneer grazing this area is reputed to have had a carrying capacity of 20 acres per head per year on a sustained year round grazing basis.

(4) The Bunch Grass Region

This region occupied intermountain areas from Alaska and interior British Columbia through western Montana, southwestern Idaho, eastern Washington and Oregon to central California and portions of Nevada (242). The precipitation of the bunch grass region is low, ranging from 8 to 20 inches per annum. Most of this falls during the period from early September to early April (214).

The soils under well developed bunch grass were found to be black, high in lime, organic matter and were very productive. Under less well developed stands, the soils were shallow, brown, rocky and unsuited to cultivation. The virgin or climax vegetation was dominated by bluebunch wheatgrass, a highly nutritious and equally palatable species. Other
species evident in the association were Idaho fescue, giant wild rye, and spear grasses. Prominent forbs were balsam root, mountain dandelion and hawksbeard (230). Clements (48) described an area in California, over 100 miles in extent, which consisted mainly of needle grasses.

No question is so debated by western ecologists (214) as that of the climax relationships of the bunchgrass lands to the south. It is agreed that true grassland is normal in the far northern areas and on the higher, moister foothills and benches farther south. There is disagreement, however, as to just how much of the grassland has been invaded by sagebrush owing to improper grazing. Many prominent ecologists (242) maintain that much of southwestern Idaho and large areas of eastern Washington, western Montana, northern Nevada and Utah are climax grassland. Research and early records tend to bear out this viewpoint in many respects. On the other hand, the climatic studies do not lend support to the contention that the climax is grassland since grasslands elsewhere in the world receive most of their precipitation during the growth period (190). Climatically, it would seem that this region is a transition between open parkland and shrub regions. Under climax conditions this area could support one head per animal month on only 2.2 acres.

(5) The Intermountain Shrub Region

The virgin intermountain shrub region lay between the Rocky Mountains and Cascade Ranges. This region, some 96.5
million acres in extent, was found in Utah, Nevada, and parts of the adjacent states (214). Precipitation over the area is more abundant in the dormant season while the summers are hot and dry. The annual precipitation in the region is 6 to 20 inches. The virgin soil varied from yellow to brown, was shallow and rocky, and had little or no profile development. The topography was rough and irregular. It is believed (242) that originally this region was dominated by wheatgrasses with sagebrush and other brush species occurring only as subdominant associates or as local dominants. The U.S. Forest Service estimated (230) that only 2.8 acres were required per animal month on the good sagebrush lands which are today the apparent climax.

(6) The Southern Desert Shrub Region

The southern desert shrub region, located in the vast arid lands of southern California, southern Nevada, southwestern Arizona, sections of southern New Mexico and western Texas, contained approximately 51 million acres. However, in its virgin state only 25 million of these acres were found to be grazable. This region was also found to have the most xeric of North American climates (214). Precipitation is far below optimum for plant growth, being only 3 to 5 inches annually, and in extreme cases it is known to total less than one inch for a given year. The potential evaporation from a free water surface may reach 120 to 130 inches per year. It was noted that the precipitation reaches its peak in the late
summer although some sections get late winter rains. Temperatures as high as 130°F. are not uncommon. Pioneer travellers were impressed (230) with the bizarre and varied appearance of the plants on these sunscorched desert lands. The U.S. Forest Service (230) described the vegetation as follows:

"There was little uniformity in the plant cover. Gray stretches of desert saltbrush formed dense thickets 3 or 4 feet tall in valleys. Over extensive tracts, widely spaced creosote bushes gave the appearance of scrubby orchards. On the surrounding hills and ridges were varied forms of cacti, century plants, agaris and yuccas. Over most of the range palatable forage was provided by mesquite browse and weeds which sprang up after rains. The vegetation became more abundant as the higher elevations were reached and at the highest points within the type were such true forage species as grama grasses, saltgrass and three-awn grass."

It was calculated that under virgin conditions the carrying capacity of the southern desert shrub region was about 4.5 acres per animal month (214).

(7) The Chaparral Region

Plummer (162) has stated that the word "chaparral" is of Mexican origin. It originally meant evergreen scrub oak but has since come to refer to any scrub type. Because of the widely different habitat conditions, and the resultant differences in the plant associations, the chaparral has a greatly varied range use. Stoddart and Smith (214) have divided this region into three sub-groups for classification and description. They list these as follows: California chaparral, oak scrub, and mountain brush.

The California chaparral occurs over large areas of
southern California and southern Arizona. The total area is some 5.5 million acres. The density of the chaparral increases with the elevation especially on the northern slopes. The upper limit was found at about 8000 feet where it gives way to the coniferous forest. Under virgin conditions this area was almost entirely ungrazed.

The oak type also occupies large areas in the west. As the name implies, the principal vegetation was the many species of oak which ranged from scattered clumps to a dense brush stand.

The mountain brush type exists as a narrow transition zone between the coniferous forest and grasslands. It was noted to be typically a southern type found principally in Utah, Arizona, Colorado and New Mexico (214). This area possessed considerable grass and forb growth as an understory. The shrubs through their high nutritive value made this type valuable for grazing despite the draught and rough topography which characterized the region.

(8) The Pinon-Juniper Region

This region is characteristically southern with only scattered stands occurring north of the 42nd Latitude. The stand did not occur on the west coast, nor did it cover large areas east of the Rocky Mountains (230). These low-growing open forests of pinons, pines, and junipers occurred over 74 million acres in Colorado, westward to central Oregon, and south through the foothills country of Utah, Nevada, eastern California, Arizona, and New Mexico (230). This region was
found at elevations of 4000 to 6000 feet. The area is steep and erosion removes the soil rapidly. Low precipitation, usually below 16 inches, and high temperatures result in low organic matter production, leaving an unproductive soil. The pinon-juniper region was an important forage resource. The wide spacing of trees permitted the development of considerable browse such as mountain mahogany, bitterbrush and cliffrose, as well as many palatable grasses and forbs. The carrying capacity of the virgin range was 3 to 4 acres per cow month.

(9) The Coniferous Forest Region

The coniferous forest region occupying the higher moisture regions of western North America is characterized by evergreen trees mostly of the genera *Pseudotsuga*, *Pinus*, *Picea*, and *Abies*. The precipitation ranges from 15 to 100 inches, the altitude from sea level to 12,000 ft. The soils are characteristically acid. Under virgin conditions, open stands of small trees in the southwest and Rocky Mountain foothills support a dense undergrowth of forage plants, whereas many of the dense stands and tall-growing forests of the northwest support little or no grazable undergrowth. Many forests were found to have large open parks supporting excellent stands of grass. Also of note were the sub-alpine and alpine meadows. On the ecotone between the forests and the grasslands or shrubs, the southern slopes supported a grassland vegetation, while the forest occupied the moist shaded slopes. Under
virgin conditions the grazing capacity of the open forest types was found to be approximately 4.0 acres per animal month (230).

B. MAJOR RANGE REGIONS OF CANADA

The virgin range areas of Canada, like the United States, were found in the west, namely, Manitoba, Saskatchewan, Alberta and British Columbia.

On the Canadian plains the vegetation was mainly grassland although shrub and forest communities were found in the sandhill regions, in the Cypress Hills, and in the Rocky Mountain foothills. Four main regions, principally in grass, are recognized, namely, tall grass, short grass, mixed grass, and submontane regions. The extent of these regions is shown in Figure 1.

Like the tall and short grass regions of the Canadian plains, the bunch grass and coniferous forest regions of British Columbia are merely the northern extensions of the regions bearing the same name in the United States.

(1) The Short Grass Region

As previously mentioned the short grass region in Canada is merely an extension of that region in the United States. However, that region is so vast that conditions found in the Canadian or northern extremities of the region differ somewhat from those found in the more southern section and accordingly the Canadian section warrants some further explanation.
The Canadian short grass region is found west of the tall grass region in an area of low rainfall. The average rainfall, similar to that found in the northern short grass region of the United States is approximately 13 inches per year (47) but the mean temperature is somewhat lower and the Precipitation-to-Evaporation Ratio (P/E Ratio) is higher. Under virgin conditions the soil is found to be brown, lacking humus and shows a distinct calcium layer 15 to 18 inches below the surface (46). Plant growth was generally shorter than within the other Canadian grassland associations. Not only were the dominant species naturally low growing, but they did not grow much taller under more humid conditions. While it was found that much of the region was not suitable for cereal crops, these areas were able to provide excellent pasture since the native grasses cured well and were also palatable and nutritious.

It was found (46) that under virgin conditions the carrying capacity of this region was approximately 4 acres per cow month.

(2) The Mixed Grass Region

As Figure 1 indicates, the mixed grass region forms a semi-circular belt around the northern limits of the short grass region. No doubt its presence is due to several factors. Because of the cooler temperatures and better moisture conditions (both contributing to a higher P/E Ratio) than those found in the short grass region, there is a richer flora and
generally taller growth present. It is difficult to separate the short grass region from the mixed grass region because of the broad transition zones where the short grass gives way to mixed grass associations and Brown soils give way to Dark Brown.

The flora of the virgin mixed grass region was found to consist of both short and medium-tall grasses and from this characteristic the region derived its name. Practically all the grasses (46) which occurred in the short grass region were also present in the mixed grass region although they occurred

Figure 2. Mixed grass prairie and hay meadows in southwestern Saskatchewan. The Cypress Hills, south of Maple Creek, Saskatchewan, are shown in the background.
in different proportions. However, several species were found which were not present in the short grass region, namely such dominants as short-awned porcupine grass, northern wheatgrass, rough fescue and green needlegrass. It was found that under virgin conditions the carrying capacity of this region was approximately 2.5 acres per cow month (46).

(3) The Submontane Region

This region occurs adjacent to the mixed grass region at higher latitudes and altitudes in the Cypress Hills, Rocky Mountain foothills and northern prairies (47). It is also associated with cooler temperatures and slightly moister conditions than those under which the mixed grass region is developed. Although the region is found for the most part on the Black Soil Zone, it may also develop on the Shallow Black and in some cases the Dark Brown Soil Zone. Under virgin range conditions, rough fescue was the dominant grass species, while other important species were June grass, awned wheatgrass, Idaho fescue and oat grass. Forbs were relatively abundant and aspen, roses and willows were particularly prevalent along coulees and northern slopes. Pine trees were found in the ecotone between the grasslands and forest.

Under virgin conditions, the carrying capacity of this region varied from 1.25 to 2 acres per cow month.

(4) The Bunch Grass Region

As previously mentioned, this region was found in the intermountain areas of interior British Columbia where it was
confined to the valley bottoms and adjacent slopes. The grassland area, totalling some 3 to 4 million acres (227) is an extension of the bunch grass region of the United States (242). The precipitation is low, varying from 8 to 20 inches. Three main subdivisions or communities similar to those described by Daubenmire (64) in Washington are evident (206). On account of their vertical distribution, these plant communities were designated as the Lower, Middle and Upper Grassland zones.

The Lower Grassland belt occurred at elevations of 1100 to about 2300 feet and coincided with the Brown Earth zone. From 2300 to 2800 feet was found the Middle Grassland zone, associated with Dark Brown soils. The Upper Grassland zone extended from the upper edge of the Middle Grasslands to the forest edge at about 3200 feet and coincided with the Black Earth zone. All three grassland communities were dominated under virgin conditions by perennial bunch grasses, the basis for the area's classification. Under virgin or climax conditions, the carrying capacity of this area was similar to that of the bunch grass region in the northwestern United States.

(5) The Coniferous Forest Region

In British Columbia and Alberta the coniferous forest region occupied the higher moister regions. As previously mentioned, the dense stands and tall-growing forests supported little or no grazable undergrowth. This was
particularly true in areas of high rainfall. In British Columbia the coniferous forest region was the last to be claimed for summer grazing. It is estimated that there are about 10 million acres of coniferous forest capable of supporting this type of grazing (227). As was the case with the B.C. grasslands, this region was divided into three communities. They are the Montane, Subalpine and Upper Subalpine forests (64) and coincide with the Lower, Middle and Upper Podsols respectively. Shrubs flourish in the Montane zone where the tree cover is fairly open. Grasses and other herbs grow well in both the Montane and Upper Subalpine communities, but are less vigorous and common in the Subalpine zone. The Upper Subalpine is characterized by differences in tree density and growth as well as by the presence of extensive treeless meadows which produce large amounts of grasses and sedges.

Since the coniferous forest region was the last to be utilized for grazing and since it is capable of supporting summer grazing only, far less grazing harm has been done in this region than elsewhere. Under virgin conditions, the grazing capacity of the open coniferous forest region was found to equal that of the areas classified similarly in the northwestern United States.
Figure 4. Livestock grazing a native meadow in the Montane Forest near Pass Lake, B.C.

C. GRAZING HISTORY OF THE WESTERN RANGLANDS

Before the present range condition is discussed, it is well to trace, in brief, the history of livestock grazing over the rangelands of western North America. History's first mention of the introduction of domestic grazing animals to western North America was in 1521 when Villalabos introduced Andalusian cattle to Mexico. In 1540 Coronado led the "Conquistadores" from Mexico onto the plains of lush grass that is now Texas (230). With his expedition were bands of horses, cattle and sheep. It is believed that the sheep
perished but cattle and horses survived and to some degree were again domesticated by the Indians. By 1800 these "wild" horses and "wild" cattle, and Indian livestock in general were well developed as far north as British Columbia (87). By this time the Spanish Mexicans had developed the practices of branding, roping, the stock saddle, and many other features which are still prominent in our present day methods of range livestock management.

By 1800, before the settlers from the United States had crossed the Alleghanies, the Spanish and Mexicans had established from San Diego north on the west coast. (In western Canada during the same period of time the Hudson's Bay Company paid little attention to the vast grazing areas of Alberta and Saskatchewan since buffalo hides and wolf skins, the principal commodities of the plains, were not highly prized by the Company.)

In 1821 the Mexican government invited Americans to settle in Texas and by 1830 the great "hide and tallow" empire of Borden was well established. Since the area of production was so far removed from the centers of population, these were the only commodities that could be marketed. In 1834, Dana in his Two Years Before the Mast noted that a single trading vessel picked up 40,000 hides at three California ports, San Diego, Monterey and Santa Barbara during one trip.

By 1840, the Hudson's Bay Company had established herds of horses and cattle at its post at Kamloops, B.C. The year
1850 witnessed the trailing of the first great herds of Texas longhorns to Ohio. The practice of trailing increased throughout the west until 1885. In 1858 gold was discovered in central British Columbia; soon afterwards cattle were being trailed even to this then-remote part of the Northwest. From January, 1861, to December, 1862, for example, 4,817 cattle, 3,396 horses, 770 mules, and 1,310 sheep were recorded at the Canadian Customs, Osoyoos, B.C. during their northward trek (234). Among noted pioneers who drove cattle to B.C. about this time were Jerome Harper, who established the Harper Ranch north of Kamloops in 1862, and his brother, who established the famous Gang Ranch in 1863. The year 1863 also witnessed the establishment of the ranching industry at the mile houses along the Cariboo Road. By 1872, ranching was well developed in the Nicola, Okanagan, and Kamloops areas and British Columbia was producing one half its beef requirements.

The decade 1870 to 1880 brought many more changes in B.C. ranching amongst which were such noteworthy events as the establishment of communication throughout the Okanagan in the form of a wagon road. Cattle, too, were first trailed from the Similkameen Valley to Hope and the coast markets. About the same time (1871, 1872) in Alberta, the McDougall brothers brought 150 head of horses and cattle to Morleyville west of Calgary. This decade of the '70's also witnessed the establishment of the West's first Stockmen's Association.
It has often been said that the next decade (1880-1890) was the most eventful in western ranching history, both in the United States and in Canada. In the United States, 1883 marked the rise of cattle ranching as "big business". In Wyoming alone, 20 large cattle companies were formed with a total capitalization of over $12,000,000 (150). Of these, the Union Cattle Company was incorporated for $2,000,000; the North American Cattle Company and the Searight Cattle Company for $1,000,000 each. Wyoming was merely a representative area; the same thing was happening or had happened up and down the Great Plains from Montana to Texas. The XIT outfit in the Texas Panhandle ran about 150,000 head on 3,000,000 acres of land -- 25 miles east and west by 200 miles north and south (24). Outfits of 5,000 to 10,000 head were common on the plains and in the Southwest, and properties of small owners were often consolidated by purchase or by incorporation.

In western Canada too, ranching became "big business", viz., the formation of the Douglas Lake Cattle Company (1886) and the Gang Ranch (1880) in British Columbia; the Bar U financed by Allens of Montreal, the Waldron and Oxley Ranches by British capital and the Cochrane Ranch, in Alberta. By 1884 forty-one companies and individuals held unfenced leases on the short grass prairies of Canada with leases totalling almost 3 million acres over which 47,000 head of cattle grazed. The settlement of Indians on reservations during the 19th Century is a factor that did much toward permitting the
establishment of ranching in the West. As long as the Indians laid claim to grazing lands, the ranching industry was impaired or prevented, depending on the disposition of the tribes occupying those regions. There are many accounts in the literature of strife and bloodshed stemming from this very claim.

The Canadian Pacific Railway reached the prairies in 1883 thereby providing a means of access to the rich eastern markets and transportation west for the farmsteaders and settlers. In 1885 the Riel Rebellion troops proved a market for beef and in 1887 the first shipment of beef to the United Kingdom via the C.P.R. was completed. By 1885 a total of more than 5 million head of cattle had been driven northward from Texas (150) mainly to rail centers for shipment East.

Other important changes were in the making at this time. The calf crop had risen to 25 percent, purebred cattle were introduced to the West, viz., the importations of purebred Herefords, Shorthorns and Devons by the Utah Mormons, Shorthorns by the Oxley Ranch (Alberta) and pedigree bulls by the Cochrane Ranch (Alberta). Also of revolutionary importance was the change in ranch management and the decline of the "Spanish" influence. Prior to the severe winters of 1882-83 and 1886-67, no winter feed had been prepared; with the heavy losses experienced during these winters it became evident that hay production was necessary to offset these losses in the future. Some conservationists have claimed that this was one of the first steps toward overgrazing.
The decade 1880 to 1890 saw the rise of the western sheep industry, widespread farm settlement throughout much of the west, of irrigation, and of the initiation of government grazing controls. The addition of large numbers of sheep and farming settlement to areas already carrying maximum numbers of cattle precipitated many violent disagreements regarding the use of rangeland. In California, the gold boom resulted in an increase in sheep numbers from one million in 1859 to 6.9 million in 1880, while in 1882 there were 5.2 million in New Mexico and 5.7 million in Texas (280). These vast numbers of sheep, appearing almost without warning on the fully used cattle ranges not only aroused deep resentment among the cattlemen but had a dire effect in causing even further exhaustion of the range forage. In some instances, since cattle fences did not stop the sheep, hay fields were invaded and the crop destroyed.

Settlement which competed with both the cattle and sheep industries further intensified the already severe range use. In many areas, especially mountain and foothills localities, settlement claimed much of the spring and fall range which was, even at that time, in short supply. For many years, ranchers had no protection since settlers were given priority in land usage. However, not all the influences of settlement and cultivation were harmful to the range. Irrigation to increase forage production complemented the grazing lands providing feed for stock during periods of short supply.

Since barbed wire had become common, the great cattle
drives from the southwest to the eastern States had ceased or swung north to the Canadian Plains. In British Columbia the Kettle Valley line (completed in 1897) created in its construction a ready market and once again the grazing industry in British Columbia was rejuvenated.

At the turn of the Century investigators began to publish warnings (92, 93, 18, 168, 91) of the harm that the "get-rich-quick" methods of grazing were doing to the ranges. In the United States the reports varied from interviews with "old-timers" in the grazing districts to detailed statistical reports. At this time it was generally agreed that range deterioration was traceable to two mistaken ideas; firstly, that the range can carry the maximum number of stock without deterioration year after year and, secondly, that in order to get the most out of a range it must be stocked to its maximum carrying capacity.

These ideas, needless to say, were put into practice and gradually vast areas of "unlimited" grazing lands were reduced, not only by cultivation, irrigation, erosion, and fencing, but also by overgrazing. It is now a matter of history (Figure 5) that in every range region, overgrazing has resulted in a reduction in carrying capacity (230). Needless to say, the reduction is not universal in all areas throughout each region, but it is upon the average forage production per acre and the total palatable forage production per area that livestock units are produced.

The fact that overgrazing is present to such a marked
Figure 5. Depletion in the Carrying Capacity of the Major Grazing Regions.
degree introduces many complex problems in range management and livestock production. Is the reduction in palatable forage production the only problem? Does overgrazing upset the ecological balance? May this upset manifest itself in such areas, in the form of floods, dust storms, erosion and increases in harmful insect populations, rodents and predatory animals? Does overgrazing result in a reduction in desired wildlife numbers? Does it cause increases in mechanically injurious and poisonous plant populations?

The literature covering the subject is extensive and absorbing. It is the purpose of this Thesis to collect, disseminate and critically discuss some of the controversial problems of overgrazing with a view to applying the information gained to the problems of overgrazing present throughout the range areas of British Columbia.
II. THE EFFECTS OF OVERGRAZING ON NATIVE VEGETATION

To the plant ecologist, the range manager, and the conservationist, the terms used to describe grazing regions and vegetational conditions present no problem since they constitute a component part of their technical vocabulary. To the layman, however, this terminology serves only to confuse. The numerous combinations of factors affecting rangeland vegetation have resulted in correspondingly numerous descriptive terms. However, the general use of these terms has rendered useless many exact definitions. Others have become so restricted in their application that it is difficult to employ them. Several classifications of the native vegetation have been made by ecologists that in part are applicable to range usage. In spite of this it is generally desirable to deviate from these classifications and delimit vegetation largely according to grazing value. An example of such a classification has been presented in the Introduction.

The terms grazing type and vegetation type are not distinct in their usage and may refer to various kinds of species or to various vegetation densities of approximately the same species combination, often referred to as sub-types. Many vegetation types are recognized by technical range managers. These types have no ecological basis but are
determined, rather, by the dominating species or what appears to be dominating. The term vegetation region is suggested to apply to broad classes of vegetation including areas dominated by several species.

Plant ecologists generally agree that not only is the vegetation constantly undergoing various kinds of change but also that the increasing habit of concentrating attention on these changes instead of studying plant communities as if they were static entities leads to a far greater understanding of the nature of vegetation and the part it plays in the world. A great part of vegetational change is generally known as succession which has become a recognized technical term in ecology (220).

A succession is a continuous process of change in vegetation which can be separated into a series of phases. Generally speaking, however, it is the process whereby one species or association of species replaces another. Among the natural causes of successional change are changes in soil and climatic fluctuations. Induced succession, i.e., that resulting from some biological disturbance such as grazing or insect invasion, leads away from the normal or climax condition.

A climax is a relatively stable state reached by successional change. Change may still be proceeding within a climax, but if it is too slow to be appreciated or too small to affect the general nature of the vegetation, the apparently stable phase must be called a climax. The highest types of
vegetation characteristic of a climatic region and limited only by climate form the *climatic climax*. Other climaxes may be developed by other factors such as soil types, grazing animals, fire, etc. (220).

An inspection of plant societies shows that they are far from uniform. In many cases principal or secondary species may form minor groups called *communities*. Communities are easily recognized in the case of species where individuals grow in groups.

Many other terms such as *association*, *ecotone*, *dominant*, etc., are commonly used throughout the literature, each serving to render ecological discussions more exacting. The true value of these terms and their meaning, however, can only be maintained by a strict and proper usage. The origin and usage of such terms is both interesting and absorbing. Unfortunately, it is not possible to enlarge further at this point.

**A. EFFECTS ON GRAZING ASSOCIATIONS**

In order that plants in an association may grow, they must absorb water and essential plant-food elements from the soil and transfer them to the leaves where photosynthesis manufactures the materials which make possible further growth, the development of seeds, and, of prime importance in range forage management, the storage of food for winter maintenance and the beginning of herbage growth the following spring. If the photosynthetic parts are removed by grazing before nutrients
have been synthesized to take care of the essential growth functions, the plants' vigor will be sapped. If the nutrient supply is inadequate, the plant may die. It is therefore vitally important to have a substantial leafage available on plants throughout the growing season.

In the range areas of the west there is a somewhat critical balance between the moisture available for plant growth and the needs of the plant cover, with a resulting competition for moisture. When grazing is introduced and the range is overstocked, the palatable plants are grazed first and severely and hence they suffer most in this intense competition. The inevitable reduction in basal area of the palatable plants reduces the competition for the sub-dominants giving them a chance to increase in density. When overgrazing is continued unpalatable species become dominant.

Overgrazing for a prolonged period of time is indicated by the vegetation present (120), especially by the scarcity of the preferred range plants and the prevalence of annual weeds and grasses. Signs which are also evident are the presence of dead and partly dead stumps of shrubs, damage to tree reproduction, and erosion and barrenness of the soil, usually marked with stock trails. These plant indicators are invaluable in determining the effects of overgrazing on the native vegetation.

(1) The Value of Plant Indicators in Determining Range Utilization

Sampson (175) states that the plant indicator concept is
based on a cause-effect relationship, where the effect is taken as a sign of the cause. All plants are a measure or indicator of their environment. Because growth and plant production are governed by the habitat, any plant species may serve as an indicator of the conditions of its habitat. However, only a few species are selective enough to be considered as good indicators. Clements (49) states:

"The problem of indicator values is chiefly one of analyzing the factor complex, the habitat, and of relating the functional and structural response of both plant and community to it."

Needless to say, a plant species that is found in a variety of circumstances is far less reliable as an indicator of range conditions than one requiring more exacting growth conditions. Dominants which do not enjoy an especially wide range are considered better indicators usually because they react more violently to the changes in habitat. Similarly, a group of plants or an association is regarded as a better index of range grazing conditions than one species. The vegetation will indicate a condition of overgrazing, however, only when the forage present has been correlated with the soil structure, transformation of aspect, and with a reliable history of economic utilization (175).

Clements (49) considers the dominant species which comprise a climax association to be the most reliable indicators. He urges the use of keen judgment in selecting plant indicators. Survival under heavy grazing may indicate that the plant is unusually resistant to grazing, trampling, or that
it is unpalatable throughout all or part of the grazing season.

(a) Indicators of Range Forage Deterioration in Western North America

Range indicators provide the means of assessing range conditions and range happenings (217). They indicate the physiological condition of an association and the changes in the soil. Range indicators may be used to interpret varying degrees of overgrazing. However, unless the term is qualified, its application may become erroneous for destructive overgrazing may only be one of the contributory factors leading to range deterioration. These range indicators are exceedingly important in recognizing the initial decline or rise in range forage condition.

According to Talbot (217), indicators of range deterioration may be divided into several groups, namely, range deterioration well under way, evidence of past damage to the range, indicators of unsatisfactory soil conditions, and doubtful indicators of range conditions. Sampson (175) summarizes these points as follows:

Range deterioration well under way is shown by weakened vitality of the principle forage species, limited, or the absence of reproduction of the most palatable species, close grazing of species of low palatability, a thinning ground cover of the entire vegetation, replacement of the good forage plants by those regarded as of little value, evidence of relict forage plants, incipient gullying and evidence of
increasing soil erosion.

Evidences of past range damage are a relative absence of formerly abundant forage plants, foliage and branches of the taller browse plants trimmed back as high as the animals can reach, dead remnants of the browse species of low stature, abnormal abundance of those species which persist and reproduce after more palatable species have disappeared, and accelerated soil erosion accompanied by gullying.

Indicators resulting principally from unsatisfactory soil conditions as a result of overgrazing are given in Section IV but may be briefly mentioned as those found in conjunction with other indicators. These are: a lack of a normal amount of organic matter between groups of herbs or shrubs, an incomplete soil profile with the possible absence of the $A_0$ and $A_1$ layers, and the conspicuous presence of bunch grass hummocks, indicating general sheet erosion in the absence of gullies.

Doubtful or less reliable indicators of a deteriorating range are local denudation of the soil, sometimes caused by slipping or displacement, or by congregation of grazing animals on a restricted area; increases in poisonous plants resulting from a favorable successional reaction; general appearance and condition of the grazing animals, as where overstocking of an area for a single season is the principal contributing factor; and condition of the timber reproduction.

The forage indicators used to determine the degree of grazing vary with the local areas and individual plant
Figure 6. Pasture sage. An indication of long continued overgrazing of the rangelands of Southern Saskatchewan.

Figure 7. Cactus (Spiny Opuntia), another indicator of long continued overgrazing of the rangelands of Southern Saskatchewan.
associations within these areas. In northern Arizona, Arizona fescue (*Festuca arizonica* Vasey\textsuperscript{H}) and mountain muhly *Muhlenbergia montana* Nutt.) serve as indicators of overgrazing (61). Clarke (45) studied short grass areas in southern Alberta and Saskatchewan which were similar in all respects except the intensity of grazing. He found that in overgrazed pastures needle and thread grass (*Stipa comata* Trin.), June grass (*Koeleria gracilis* Pers.) and bluegrass species (*Poa spp.*) were among the first to be eliminated. Indicators of overgrazing were broom-weed (*Gutierrezia sarothrae* Britt. and Rushy) and prairie sage (*Artemisia frigida* Willd.).

Jardine and Anderson (120) classify indicators of overgrazing as follows:

1. Predominance of annual weeds and grasses
2. Predominance of weeds and shrubs of little or no value to livestock
3. Dead or partly dead stumps of shrubs
4. Noticeable damage to tree reproduction
5. Erosion and barrenness

They state that these indicators are relatively more indicative of sheep than of cattle damage. However, when overgrazing reaches the stage that it can be recognized by these symptoms the appearance of the deteriorating range is very similar for both classes of stock.

Daubenmire (65, 66) in studying the effect of overgrazing on the bunchgrass areas of northwestern United States found that in near virgin stands, on a dry matter basis at the time

\textsuperscript{H}The authority for the botanical names will only be given the first time mentioned.
of maximum growth, the forage association was 85 percent bluebunch wheatgrass (*Agropyron spicatum* Pursh.), 5 percent Sandberg's bluegrass (*Poa secunda* Presl.), and 5 percent cheatgrass (*Bromus tectorum* L.). As the intensity of grazing increases, bluebunch wheatgrass (*Agropyron spicatum*) is gradually replaced, mostly by small unpalatable dicotyledons.

If the native prairie is grazed only during fall and winter, the vegetation is only slightly altered.

Observations made in Utah (159) showed that the areas of spring-fall ranges long protected from grazing and fire support a good cover of plants palatable to livestock. The chief forage plants on these areas include highly palatable perennial grasses, chiefly bluebunch wheatgrass (*Agropyron spicatum*), beardless wheatgrass (*Agropyron inerme* Rydb.), bluestem wheatgrass (*Agropyron Smithii* Rybd.) and Sandberg's bluegrass (*Poa secunda*). Perennial grasses represent 49 to 81 percent of the total plant cover. Sagebrush (*Artemisia tridentata* Nutt.) is unimportant in such areas, occupying an average of slightly less than 10 percent of the plant cover. Annual grasses, principally downy brome or cheatgrass (*Bromus tectorum*) weeds, and shrubs other than sagebrush, are all relatively unimportant.

Observations on similar areas that have been subjected to heavy grazing showed in every case a serious depletion of perennial grasses, a decided increase in density of sagebrush, in some cases a sharp increase in the density of poor perennial weeds and annual grasses, and a decrease in the total plant
density. These vegetational changes have resulted in reductions of 40 to 75 percent in the carrying capacity of the areas studied.

Throughout the literature there are many papers dealing with the indicators of overgrazing and range conditions in every major region and in almost every district. These papers and discussions by such noted authorities as Weaver, Albertson and others (223, 240, 237, 246, 248, 1, 2, 3) in the tall grass and short grass areas of Kansas, Nebraska and the surrounding areas; Clarke, Tisdale and Campbell (34, 37, 38, 39, 45, 46, 47, 228) in the range areas of western Canada; Daubenmire (66, 65, 67) in the Palouse areas of northwestern United States; Sampson and Barnes in California (175, 176, 11, 174) and Stoddart and Hanson in Utah (211, 212, 214, 213, 100, 99, 98) have all made noted contributions in their respective areas and to studies of range management in general. It is impossible, at this point, to present an adequate discussion and analysis of these papers. However, a short discussion of the effects of overgrazing on the rangeland vegetation of southern British Columbia will give some indication of the effects of overgrazing on the climax species of the Lower, Middle and Upper Grassland areas.

(b) Indicators of Range Forage Deterioration in Interior British Columbia

The grasslands of southern British Columbia may be found in the valleys of the interior and on the surrounding hillsides. The altitude of these areas varies from 1000 to
approximately 3000 feet above sea level. The total extent of these grasslands include approximately 3 to 4 million acres (227) and constitutes the basis for the grazing industry of this province. The climate of the open or grassland ranges is relatively warm and dry. This may be shown in Table I.

### TABLE I

Average Annual Precipitation and Temperature of Centers in the Grassland Areas of B.C. (227)

<table>
<thead>
<tr>
<th>PLACE</th>
<th>ZONE</th>
<th>AVE. ANNUAL PPT.</th>
<th>MEAN TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tranquille</td>
<td>Lower Grassland</td>
<td>8.0&quot;</td>
<td>July 70°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>January 25°</td>
</tr>
<tr>
<td>Ashcroft</td>
<td>&quot;</td>
<td>6.9&quot;</td>
<td>No Record</td>
</tr>
<tr>
<td>Merritt</td>
<td>&quot;</td>
<td>8.6&quot;</td>
<td>No Record</td>
</tr>
<tr>
<td>Vernon</td>
<td>Upper Grassland</td>
<td>15.2&quot;</td>
<td>July 68°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>January 23°</td>
</tr>
<tr>
<td>Vavenby</td>
<td>Montane Forest</td>
<td>14.5&quot;</td>
<td>July 63°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>January 19°</td>
</tr>
<tr>
<td>Big Creek</td>
<td>&quot;</td>
<td>12.2&quot;</td>
<td>July 56°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>January 15°</td>
</tr>
</tbody>
</table>

The soils vary from Brown to Black (206), each type being associated with one of the principal grassland associations. The vegetation is divided into three relatively distinct zones in the grasslands which give way to the Montane Forest which is used for summer and early fall grazing only.

The Agropyron-Artimesia association is found on the Brown soils of the Lower Grasslands. The climax vegetation of this area was composed of a sparse ground cover of bluebunch wheatgrass (*Agropyron spicatum*), Sandberg's bluegrass (*Poa secunda*), sagebrush (*Artimesia tridentata*) and a few perennial forbs.
Very little of the area remains in climax vegetation, being dominated by such successional plants as sagebrush (Artemisia tridentata) and other semi desert shrubs and plants (228).

Figure 8. Serious Overgrazing on the Lower Grasslands near Kamloops, B.C. resulted in this Excessive Stand of Sagebrush.

On the sandier slopes the dominant species include needle and thread grass (Stipa comata), sand dropseed (Sporobolus cryptandrus A. Gray), and rabbit brush (Crysothamnus nauseosus Pall.)

The Middle Grasslands are dominated in the climax stage by the Agropyron-Poa association. This type of grassland is associated with Dark Brown soils. The principal species of this climax type are bluebunch wheatgrass (Agropyron spicatum) followed by Sandberg's bluegrass (Poa secunda). Tisdale
reports (228) that in the climax, shrubs are limited to one species, that being rabbit brush (Crysothamnus nauseosus). Under conditions of severe grazing this association has given way to two communities. The first is dominated by needle and thread grass (Stipa comata). The climax species bluebunch wheatgrass (Agropyron spicatum) and Sandberg's bluegrass (Poa secunda) are still represented in the association but in reduced proportions. Annual species such as cheatgrass (Bromus tectorum) and little bluebur (Lappula occidentalis Greene) are present in relatively larger numbers than in the climax association. The second community is dominated by cheatgrass (Bromus tectorum). These areas vary in sizes.

Figure 9. Middle Grasslands between Pass Lake and Kamloops, B.C. Note the topography and research enclosure.
up to as much as two or three square miles (227) of the Middle Grasslands. This is particularly noticeable in the Nicola and Thompson Valleys. This community has developed from the previously Stipa-Agropyron-Poa type as a result of continuous overgrazing. The plants of the climax association that survived have become small, lacking both in basal area and vigor.

The Upper Grasslands are dominated in the climax association by bluebunch wheatgrass (\textit{Agropyron spicatum}) and rough fescue (\textit{Festuca scabrella} Torr.). This area receives more moisture per annum than does either of the other two zones and the soils are classed as part of the Black Soil zone (206). The climax association contains two poisonous plants, two-coloured larkspur (\textit{Delphinium bicolour} Nutt.) and death camus (\textit{Zyadenus venerosus} S. Watt). As in the case of the middle grassland, severe grazing has resulted in the evolution to two major Upper Grassland communities. These have been identified (228) as the Stipa-Poa and the Poa-Bromus communities. A large portion of the Upper Grassland zone is occupied by the Stipa-Poa community, which is dominated by two perennial grasses, Columbia needle grass (\textit{Stipa Columbiana} Macoun) and Kentucky bluegrass (\textit{Poa pratensis} L.). Neither of these grasses are abundant in the climax association. Kentucky bluegrass (\textit{Poa pratensis}) is found chiefly (206) on areas that were somewhat sheltered and where the soils were fine and deep. Columbia needle grass (\textit{Stipa Columbiana}) was found to dominate in areas that were more exposed and where the soil was coarser. Balsam root
(Balsamorhiza sagittata Nutt.) and ghost's beard (Tragopogon pratensis L.) are two of the forbs commonly found in this community.

The Poa-Bromus community is usually dominated by Sandberg's bluegrass (Poa secunda), but cheatgrass (Bromus tectorum) is dominant in some areas while being much less important in others. This community is produced under conditions of severe grazing. Not only are the main grasses but also many tall-growing forbs of the Agropyron-Festuca climax and the Stipa-Poa community are rare or lacking in the Poa-Bromus type. Many of these plants, while not eaten to any extent on moderately grazed lands, are grazed readily on overstocked ranges and their populations consequently become markedly reduced.

It may be seen that the vegetation of the southern interior of British Columbia is quite comparable to some of the range areas in the states of Washington, Oregon, Idaho and Utah. Bluebunch wheatgrass (Agropyron spicatum) is common throughout these areas as it is the presence and relative abundance of species such as sagebrush (Artemisia tridentata), rabbit brush (Crysothamnus nauseosus) and balsam root (Balsamorhiza sagittata).

(c) Indicators of Proper Forage Utilization

The carrying capacity of semi arid grassland such as range is low compared with pastures under more humid conditions and in addition, the principles of grazing management differ. Great areas of range have been ruined by
overgrazing, due either to overstocking of the entire area or to badly distributed stocking consequent upon inadequate management. The results are again a deterioration of the original vegetation under the constant grazing and trailing of stock, through the ecological stages of retrogression characterized by the development of poorer types of perennial grasses, annual grasses, weeds and in some cases bushes and scrub.

In order to maintain range forage production at its highest level, and restore depleted ranges, the better forage plants must be properly used. But what is proper use? The answer requires a knowledge of the resistance to grazing of several hundred species which furnish both the bulk of the feed and watershed protection. However, in a land that requires 20 to 100 or more acres to support a cow on a year-long basis (35), the area that can be inspected with necessary frequency by one stockman is so small a proportion of the whole that the actual degree of utilization each season is necessarily very difficult to determine. In fact, except on very small study plots, or pastures, the degree of utilization is commonly based entirely on judgment acquired from experience. But where continued productivity or gradual death of a good forage grass may depend upon a difference in foliage removal of as little as 10 percent, a more accurate measurement is necessary.

Talbot (217) found that indicators of satisfactory range forage use are:
(i) vigorous appearance and luxuriance of the forage stand;
(ii) absence of accelerated soil washing;
(iii) slight or no use of unpalatable species;
(iv) lack of extensive areas overrun by palatable plants;
(v) absence of serious injury to timber reproduction.

Depleted ranges and ranges in varying degrees of deterioration show improvement with the thickening of the stand of the desirable forage species and when gullies are being naturally reclaimed.

An infinite number of questions must be answered in setting up utilization standards for any particular range units. For example, what are the species that do or should furnish most of the forage at different seasons of the year? What are their life histories, and how do the different classes of stock relish them? What is the natural plant succession, how is it affected by overgrazing and the various other degrees of utilization, and what stage can or should be maintained under grazing use? Even when proper utilization has been determined for a species or grazing association under one set of conditions, what adjustments must be made when the association is severely depleted, and what precautions are necessary for extreme drought or where special land services such as watershed protection, timber production, or wildlife are important or dominant?

These problems are especially difficult as a result of
the range resource, both as to composition, form, habitat, and in production, one year with another.

(2) Classification of Vegetation for Determining the Degree of Overgrazing

The recognition of range condition is facilitated by an accurate analysis of the vegetation and the degree of deterioration from the climax association or the highest type of vegetation the area would naturally support; the prescription of corrective measures requires that the various degrees of deterioration or range condition must be classified.

A modification of six condition classes used in range investigation by the Soil Conservation Service in the Pacific Northwest of the United States is now presented. These classes can be applied to conditions in British Columbia to determine present or past use. Range classifications of any kind should be based on plant species subject to livestock utilization as the classification is designed primarily to facilitate correct grazing use of the forage species.

(a) Excellent or Class A Condition

This class is composed of climax associations for the most part with little or no replacement by an introduction of non-climax species. The species that were formerly dominant over the entire rangeland of British Columbia will still occur as dominants in excellent range and will occur in essentially their original abundance. In the other classes to be discussed the relative abundance of these species will
have been modified, or they will have been eliminated and replaced by plants lower in the succession. Indicators of this class, in the Lower Grasslands of British Columbia, will be such plants as bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa secunda*).

A range in excellent condition will have been rarely if ever overgrazed either seasonally, by a particular class of stock, or year long. If overgrazing has been present it will have been of short duration only. Under these conditions it is evident that there is adequate salt and water available and that good management principles are in force. Little or no modification of the grazing system employed need be undertaken. No run-off control measures need to be taken on ranges in this condition.

(b) Good or Class B Condition

In this class, climax species still form the bulk of the plant cover, but there are some non-climax species present in the associations. One or some of the dominants in the climax association may have replaced other members of the association. For example, in British Columbia Lower Grasslands, bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa secunda*) will still predominate. However, cheatgrass (*Bromus tectorum*) will be evident in some localities as well as sagebrush (*Artimesia tridentata*). Sandberg's bluegrass (*Poa secunda*) will usually be more abundant than on Class A ranges, but under certain types of grazing (class overgrazing by sheep) it may be completely
replaced by bluebunch wheatgrass (115).

A range in this condition is not considered overgrazed but when it does occur it is the result of overestimation of the grazing capacity, the wrong class of stock or a temporary shortage of feed during a drought. Correction of the fault will be sufficient to remedy this overuse and further deterioration will be prevented.

These ranges will require few or no remedial measures except occasional minor modifications of some phases of management in water retardation and flood control.

(c) Fair or Class C Condition

Under fair condition, the climax association is showing signs of depletion and a rather heavy infestation of annuals and non-climax perennials is evident. A sub-climax species may or may not have become dominant. Under these conditions the bluebunch wheatgrass (Agropyron spicatum) will be definitely weakened and Sandberg's bluegrass (Poa secunda) may or may not have suffered as well. Cheatgrass (Bromus tectorum) will be far more plentiful than on good ranges and in some areas sagebrush (Artemisia tectorum) or rabbit brush (Crysothamnus nauseosus) will be present affecting both the appearance and the carrying capacity of the range.

A range in fair condition will be considered overgrazed and one or more of such cardinal principles of good range management as proper seasonal use, proper numbers, proper
class of stock, and proper distribution, will have been violated. This condition may be the result of drought, but in British Columbia it will probably indicate either an overestimation of the amount of forage available, the wrong class of livestock, too early spring grazing, or the failure to remove the stock from spring pastures soon enough to permit seed production. On Class C ranges, which are found to be grazed by the right number of stock, a variation in the grazing system must be introduced. It is not uncommon to find fair range interspersed among areas of otherwise good or excellent condition. In this event a close scrutiny of the management practices must be undertaken and corrective measures applied. In most cases it will be found that the trouble lies in poor distribution of the stock as a result of inadequate berding, watering facilities or improper salting. Ranges in fair condition should not be grazed to full capacity but should be given a safety margin to allow recovery. If this is not permitted, the ramifications of overgrazing will result.

These ranges will usually call for check dams or other localized flood controls.

(d) Poor or Class D Condition

Under these conditions a major portion of the plant association is composed of sub-climax species while under conditions of accompanying topsoil erosion both these and the climax species may be lacking. Bluebunch wheatgrass (*Agropyron spicatum*), although usually still present, will be
scattered and badly stunted plants. The ground will appear to be covered with cheatgrass (*Bromus tectorum*) interspersed with sagebrush (*Artemisia tridentata*) and rabbit brush (*Crysothamnus nauseosus*).

Rangeland in this condition is indicative of long, continued overgrazing and a general abuse of the principles of range management. A marked reduction in livestock numbers, often coupled with drastic changes in the other management practices, is necessary if the rangeland is to be saved and recovery undertaken. A rather heavy grazing of annual plants and grasses may be justified in the event that such ranges constitute a fire hazard. However, care must be taken to make sure that the stock is removed as soon as the stock begins to utilize the shoots of perennial grasses. Reduced livestock numbers will favour the desirable climax species, and unless erosion has removed the topsoil (26), the climax perennials will return to comprise an excellent or good range with consequent higher carrying capacity and greater protection against erosion.

Flood control on these ranges will necessitate drastic changes in management practices with more frequent instances of structural control of local areas.

*(e) Very Poor or Class E Condition*

When ranges are classed as very poor, the climax vegetation is absent while non-climax species, often unpalatable, poisonous, or mechanically injurious, predominate.
Under conditions such as these in interior British Columbia bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa secunda*) will have disappeared. Cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola pestifer* A. Nells.), tumblemustard (*Norta altissima* L.) and sagebrush or rabbit brush will dominate, although there may be large amounts of bare ground, particularly in years of poor growing conditions.

Very poor ranges usually indicate long-continued overgrazing by one class of livestock. This condition may also be the result of, or be aggravated by improper seasonal or rotational use. In general, ranges in this condition should be closed to grazing of any type until the climax species or desired perennials are present in sufficient number to permit at least a classification of fair. Localized areas showing a very poor condition resulting from local concentration as, for example, from too many stock watering or salting at a given point, can usually be corrected through the location of additional salting points and water holes in accordance with the principles of good range management. It may necessitate the closing of the watering holes in the sections of the range areas falling into this classification.

Soil losses from range in this condition may be so severe as to prevent or indefinitely delay complete recovery. This factor must be carefully considered, both in determining the rate of recovery and revegetation by native species and in projects of artificed reseeding. If in a flood area, these ranges should be closed to grazing to
facilitate special flood treatment.

**Figure 10.** A well managed watering place in Southern Saskatchewan. Note the abundance of forage and the condition of the livestock.

**Figure 11.** A poorly managed watering place in Southern Saskatchewan. Note the denudation of the ground and poor condition of the livestock.
(f) Depleted or Class F Condition

Into this class fall nearly deseeded areas such as bed grounds and stock trails that are almost worthless for grazing because of extreme and repeated abuse. The climax species bluebunch wheatgrass (*Agropyron spicatum*) and Sandberg's bluegrass (*Poa secunda*) will have been killed out. Cheatgrass may be present but in many places it will have been removed either by grazing or trampling. Sagebrush (*Artemisia tridentata*) and rabbit brush (*Cryothamnus nauseosus*) will be severely grazed, broken and trampled by the stock while Russian thistle (*Salsola pestifer*) may either be very abundant or temporarily removed by grazing.

Seldom do areas such as these result from overgrazing alone, but, in part, from excessive trampling and erosion as well as fire. Where this condition exists on livestock driveways an alternate route should be employed. The heavy concentration of stock around waterholes can be remedied by providing additional watering facilities or by salting and herding so as to prevent unnecessary trampling and grazing in the immediate vicinity of the waterholes.

Figures 10 and 11 show the effect of stock on the vegetation around two watering places in Saskatchewan. Figure 10 shows a watering place constructed in co-operation with the P.F.R.A. and around which the principles of good range management have been applied. Figure 11 shows a watering place which is too far removed from the next waterhole. The stock were permitted to concentrate in the area resulting in
the very evident denudation of the land. It is well to point out that the type and conscientiousness of the rancher shows up in his cattle. In the properly managed range we see well bred cattle in good condition; on the poorly managed range the cattle are of non-descript breeding and are in relatively poor condition.

On F Class areas structural control and reseeding will be required in many cases to expedite recovery and hasten reduction of excessive soil and water losses.

### TABLE II

Grazing Capacities of Various Condition Classes on Open Grass and Shrub Ranges near Dayton, Washington (115)

<table>
<thead>
<tr>
<th>Area</th>
<th>Range Type</th>
<th>Condition Class</th>
<th>Grazing Capacity/100 acres</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPEN</td>
<td>A</td>
<td>144</td>
</tr>
<tr>
<td>PATIT CREEK</td>
<td>GRASS</td>
<td>B</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHRUBS</td>
<td>B</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>POMEROY</td>
<td>OPEN</td>
<td>A</td>
<td>127</td>
</tr>
<tr>
<td></td>
<td>GRASS</td>
<td>B</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td></td>
<td>23</td>
</tr>
</tbody>
</table>

While this table was prepared from data gathered in Washington, the general plant associations are similar to those in British Columbia. The various grazing condition classes have been summarized in Table III.

Regardless of the exact cause of overgrazing, the first step is to stop the type of misuse of the land that has caused
<table>
<thead>
<tr>
<th>Condition Class</th>
<th>Predominating Vegetation</th>
<th>Management Practices Responsible for Condition</th>
<th>Revisions required in Present Practices</th>
<th>Erosion or Flood Control Measures Indicated</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXCELLENT CLASS A</td>
<td>Climax</td>
<td>Correct numbers, class distribution and seasonal use</td>
<td>None</td>
<td>Continuation of present management practices</td>
</tr>
<tr>
<td>GOOD CLASS B</td>
<td>Primarily climax, non-climax plants beginning to invade</td>
<td>Numbers, class, distribution &amp; seasonal use usually correct. Class may occasionally be wrong; or carrying capacity overestimated</td>
<td>None; slight reduction in numbers, or change in class of stock.</td>
<td>Adoption of recommended management practices</td>
</tr>
<tr>
<td>FAIR CLASS C</td>
<td>Climax, but becoming depleted; non-climax species becoming abundant</td>
<td>Usually overgrazed; may be the wrong class of stock; maldistribution or wrong season of use</td>
<td>Reduction in numbers; change of class; change of season or redistribution</td>
<td>Adoption of recommended management practices. May require occasional structural control</td>
</tr>
<tr>
<td>POOR CLASS D</td>
<td>Climax, but seriously depleted; non-climax species predominate</td>
<td>Heavy or long continued overgrazing; improper class of stock; maldistribution or wrong season of use</td>
<td>Drastic reduction in numbers, or change in class of stock. Seasonal grazing of annuals to reduce fire hazard</td>
<td>Adoption of recommended management practices, often accompanied by some structural control &amp; possibly reseeding</td>
</tr>
<tr>
<td>VERY POOR CLASS E</td>
<td>Non-climax annuals and perennials</td>
<td>Severe overgrazing, wrong class of stock, wrong season of use, or improper distribution</td>
<td>Close to all grazing except for restricted seasonal use</td>
<td>Close to all grazing. Reseeding may be necessary. Some structural control usually required.</td>
</tr>
<tr>
<td>DEPLETED CLASS F</td>
<td>None or few non-climax species</td>
<td>Severe overgrazing, wrong class of stock, wrong season of use, trampling, or improper distribution</td>
<td>Close to all grazing</td>
<td>Close to all grazing. Reseeding and structural control usually required.</td>
</tr>
</tbody>
</table>
the trouble, whatever the cause may have been. This immediately brings in the economic factor. The area to be treated may be far from any town or community and may be uninhabited except by the grazers whose land use may be difficult to change without an economic upheaval.

(3) The Value of Range Surveys in Determining Range Utilization

Few range management programs can be fully effective unless based on a thorough knowledge of the vegetation of the range unit under consideration. This knowledge includes much more than present grazing capacities; it is intrinsically a knowledge of present vegetation considered in terms of the most desirable vegetation that might grow on the range unit involved (115). It is also a knowledge of the specific land use practices that have resulted in the present vegetation and of the remedial measures that will restore deteriorated areas. It is, in short, necessary to recognize differences in range condition and to differentiate between top condition and deteriorated ranges, to classify different degrees of deterioration, and to prescribe corrective measures.

Range surveys have as their objective the furnishing of information necessary for sound range management of each area surveyed. Their primary purpose is to collect data which indicate how much and what kind of use may be made of the range forage crop annually without injury to the forage, soil, or to other natural renewable resources of rangelands. The survey systematically notes the amount of vegetation present
and its value to grazing animals. It is fully concerned with gathering additional facts relative to managing the range resource.

Data from range surveys offer a dependable basis for drafting recommendations to manage ranges such as crown grazing lands, leases, forest reserves, or ranges privately owned. On ranges grazed by an individually owned herd of cattle or sheep, range surveys serve as a basis for a future management policy. The data applied to maps acts as a guide to numbers of stock which may be placed on the land, the correct season and length of grazing and the correct location of salt and water. Areas subject to erosion, predators, rodents and poisonous plants can be clearly marked and the necessary corrective steps undertaken.

The objectives of these programs are to improve the existing economic and social conditions which are directly correlated with the maintenance of these natural renewable resources. In Western Canada, rangelands are highly important to the economy of Canada as well as the commonwealth and as such problems connected with management of the rangelands must be given serious consideration.

Range management plans resulting from analysis and interpretation of range surveys must not approach the range problems solely from the resource management standpoint. Effort must be made to harmonize the efficient harvest of range forage with the social and economic welfare of the population depending on the rangeland resources for a living.
Range management and range surveying are, therefore, instruments designed to assist in solving the complex problems that evolve in an attempt to maintain livestock, forage, and the other natural resources produced on rangelands.

Most controversy over the results of range surveys centers on their estimates of grazing capacity, especially if these estimates happen to be considerably lower than the numbers of animals being grazed on the range under consideration. In every case, the survey should be followed by an intensive, objective range inspection in the following year to decide whether the results obtained are sound. If this study indicates the grazing capacity estimates made the previous year are too low, the survey should not be discredited and ignored for the relative values between the various sections of the range may still be used and the whole carrying capacity estimate may be raised or lowered as the situation requires.

Apart from finding a clue to grazing capacity, the range manager finds in the range survey data a most systematic and impersonal appraisal of range values, range problems and range conditions. The initiation of good range management to date has been seriously handicapped through the lack of these fundamental studies.

The objectives of range surveys and research in the range country of Canada and the United States are essentially similar. The practices of range management best adapted to the conservation of the land and consistent with maximum utilization, restoration, and maintenance of the forage supply and
the most effective production of livestock are now widely applied. They have been enumerated by W. R. Chapline as follows:

(a) Deferred and rotation grazing (which permits full use of forage but delays grazing until after seed dissemination) on a different portion of the range each year.

(b) Later opening dates for ranges, more in harmony with readiness of plants for grazing.

(c) A fairly good basis for determining the approximate grazing capacities of mountain range types.

(d) Improved methods of grazing sheep and goats, such as open and quiet herding and bedding them down in a new place every night to avoid damaging the range through trampling and localized overgrazing.

(e) Obtaining the better distribution of cattle on the range through well placed watering facilities and better salting methods, thus bringing about even and more effective use of the available range forage.

B. THE EFFECTS ON INDIVIDUAL PLANTS

While the ultimate unit of study in grazing management is the individual plant, it can hardly be divorced entirely from the myriads of factors which compose its environment or, in short, from the ecological association. The physiologist is able to focus his undivided attention on the individual plant, the range specialist or range ecologist, however, cannot be so specific. The physiologist may speak in detail of plant food reserves in the individual plant, how they accumulate, how they are translocated; the range ecologist, unfortunately, can only interest himself in the food reserves as they influence
reproduction, forage production, winter hardiness, and re-growth in broad terms, and how range management of the association may be influenced.

Grazing, regardless of the season, has a marked effect on the metabolic activity of a plant. With the removal of foliage, photosynthesis is reduced and hence there is a reduction in root reserves, root production, and forage production. Under moderate grazing, less forage may be produced, but the increase in quality of forage will compensate for this reduction (214).

(1) Effect on Plant Roots

With overgrazing there is, as previously mentioned, a reduction in photosynthesis and hence a reduction in growth of the entire plant, both foliage and roots. This is very important under such conditions since it is necessary for the plant to have ready access to soil nutrients in order that the photosynthetic parts of the plant are well supplied with these nutrients necessary to replace the grazed foliage. Root development is of far greater importance in semi-arid regions such as rangelands than under conditions of more abundant soil moisture. Therefore, under conditions of moisture shortage, overgrazed plants suffer more than normally or undergrazed plants.

Under conditions of overgrazing, wet soils are compacted to a considerable degree (139). This makes them poor moisture absorbers and prevents normal root development. Hanson (102)
in studying the effect of overgrazing on awnless wheatgrass (*Agropyron inerme*) found that the roots only penetrated 44 cm., while on ungrazed areas they penetrated more than 65 cm. This lack of adequate root development impedes forage development during periods of moisture shortage (210).

(2) Effect on Plant Reproduction

With overgrazing, not only is the root development reduced, but the plant reproduction is also impaired. While it is not so important to have a high rate of reproduction because of the longevity of the perennial plants comprising the climax associations, it is important to have replacements for those plants destroyed by the grazing livestock. This may introduce many problems for the range manager. These animals may graze the plant so heavily that they do not permit the development of a seed stalk. They may also disrupt the physiology of the plant to such a degree that seed setting is not permitted. Hanson and Stoddart (102) studied the seed of awnless wheatgrass (*Agropyron inerme*) on overgrazed and properly grazed rangelands. They found that there was no significant difference in the vitality of the seed produced. However, when these two men considered the number or volume of seeds produced, they found a striking difference. Properly grazed stands were found to produce 50 times as many viable seeds as overgrazed stands.

Not all range species reproduce exclusively by seeds. Many, especially in the moister areas and grasslands at
higher altitudes, reproduce by creeping rootstalks, rhizomes, or stolons. However, the effects of overgrazing are similar to those when plants reproduce solely by seed (103).

It is therefore established that overgrazing is detrimental to both the development, reproduction and longevity of the palatable range plant as an individual and in a grazing association. What effect will this reduction have on the percentage composition of the climax association, in competition with the unpalatable species of the association or invaders such as mechanically injurious or poisonous plants? What effect will these changes have on the condition and numbers of livestock grazing on such ranges? What effect will the changes in vegetation have on the soil in such an area? These questions can only be answered after careful study and keen observation.
III. THE EFFECTS OF OVERGRAZING ON DOMESTIC HERBIVORES

On grassland ranges that have been overstocked to such an extent that overgrazing has resulted, the associations of palatable, perennial grasses and forbs give way to associations of low value, less palatable grasses, forbs and brush. The reasons for this change have been discussed (II). The effects of the shortage of palatable species are far reaching and of grave importance to the producer for many reasons, both direct and indirect. These effects are shown in Figure 6 and are discussed in the following order: the influence of overgrazing on meat and wool production, upon calf and lamb crops, and upon death losses including those from poisonous plants, starvation, predators and disease. The hypothesis that the greater the numbers of stock per area, the greater the return to the operator does not necessarily apply in a long-term rangeland grazing program and in some cases it does not apply throughout short-term programs. The reasons for this are discussed as well as the limited amounts of data available permit.

In studies such as these, the methods are complicated by the necessity of including such variable factors as vegetation, topography and genetic make-up of the animals. It is also exceptionally difficult to compare and analyze such factors as
Figure 12. The Effect of Overgrazing on Domesticated Livestock Production.
vigor, disease resistance, and grazing efficiency in the livestock. Therefore, due to the complexity of the methods necessary to analyze the large numbers of variable factors which must be considered in order to test the hypothesis, many workers have ignored this section of the research work. While effects of overgrazing on the vegetation and on the soil are fairly well known, the studies concerning the effects on domestic grazing animals have hardly begun. There is a definite need for a great deal of work in this field if the problems of meat production and its interrelationships are to be solved.

A. INFLUENCE ON MEAT AND WOOL PRODUCTION

The prime objective of the ranching industry is the production of large amounts of high quality beef, mutton, lamb and wool. This production should be based on a long-term program, the value of the produce to be considered as a running average over long periods of time rather than on the production of one or two years of intensive grazing. Very often stockmen are interested in the animals alone and, if the animals are vigorous and thrifty, they believe that management is adequate and overgrazing absent. Though such an index to range conditions appears superficially to be sound, an inadequacy lies in the fact that animals may appear thrifty without making economical gains.

Studies have shown that cattle, though occasionally making some gain on too heavily used ranges, do not gain
nearly as much as on properly used ranges (88). In southern Utah, on heavily grazed range, a study of mixed cattle showed that gains came in the early season and that later on some of these gains were lost. This was probably due to the presence of short-lived annuals such as cheatgrass (*Bromus tectorum*) that produced forage until the advent of hot weather when they dried up and/or set seed, becoming unpalatable or mechanically injurious. The average weight increases over the grazing season were 55 to 90 pounds, depending on the age of the stock. The gains were much lower than should be expected. Losses in weight did not begin immediately with full utilization of the forage but occurred some time after overgrazing had been reached.

Sarvis (177) in studying the rate of gains under different intensities of grazing found that cattle made average gains ranging from 294 pounds in 70-acre pastures down to 180 pounds in 30-acre pastures. The quantity of pasture removed was 51 percent on 100-acre pastures and 98 percent on the 30-acre pastures. The 2 percent carry-over is considerably lower than the 45 percent carry-over recommended by the Dominion Department of Agriculture (46).

Overgrazing results in a reduced yield of palatable, perennial grasses (II). This palatability factor assumes special importance from the standpoint of forage species when selective grazing over extensive areas such as rangeland is practised (15). Observations made by the author on sheep range in the Kamloops area have shown that sheep when placed
on new range choose certain favoured palatable species before they resort to normal systematic grazing. When bands of sheep are placed on upper grassland ranges, it is not uncommon to see them fan out, circling the range at a fast walk or trot in an attempt to crop the wild peavine (*Lathyrus orecholeucus* Hook.) present in the plant association. At the same time, much of the nutritious but less palatable forage is trampled and rendered useless for later grazing. Now these observations were not made on overgrazed land but the principle applies equally well and the stock under such conditions may excessively trample many of the reproductive shoots and young plants while looking for palatable species in associations of low palatability.

This movement has a marked effect on the meat producing ability of the livestock. While Bull and Rusk (31) found that exercise has no effect on the toughness of beef and causes no significant changes in the flavour or other factors of palatability, they did find that it required considerably more nutrients per 100 pounds gain. On overgrazed land, then, the situation is even more acute since the grazing animal must graze more forage per unit gain than on an area where the forage is plentiful. Doran (75) found that under conditions contributory to overgrazing, sheep may lose about 2 hours feeding time a day and consequently cause a great reduction in the condition of the lambs. It also causes excessive travelling.

Two opinions exist concerning the forage consumption of
animals on overgrazed pasture. Raymond (167) found that the amount eaten daily was almost independent of the grazing available but increased only with body size. Johnstone-Wallace (122) studied the grazing behavior of cattle, finding that they showed no inclination to extend the grazing period per day beyond 8 hours, even when herbage consumed fell as low as 30 to 45 percent of the amount normally grazed. In the first case, it is believed that the animals will travel farther to get the same amount of forage nutrients but spend increased amounts of energy in order to harvest the feed, thereby making a lower rate of gain, if any. In the other case, the animals eat much less and also expend less energy in attempting to harvest a normal amount of forage. In both cases the net result is the same in that regardless of the animal's response to the feed shortage, the rate of gain will be reduced. These findings are verified by White (256). In summary, it is well worth emphasizing that range in good condition provides a well balanced diet. Range in poor condition is deficient in both quality and amount of nutrients.

Experimentation conducted at the Dominion Range Experiment Station, Manyberries, Alberta (226), showed that grazing at the intensive rate of 20 acres produced less gains per head than grazing at 40 acres per head.

The production of wool on overgrazed land is also seriously affected because of the reduction in nutrients available to the grazing sheep. It is common knowledge that the plane of nutrition has a marked effect upon wool production.
Morrison (140) states that adverse conditions such as sickness, undue exposure, or a decided lack of feed will decrease the yield of wool and produce smaller fibres. Wilson (258) found that sheep on a fattening ration grew more wool, longer in staple, superior in crimp, and stronger, than sheep on a submaintenance ration such as may be found on heavily overgrazed rangelands. All experimental evidence (78, 79, 253) points toward greater wool production when sheep are on a high plane of nutrition, a feature which emphasizes the need for proper grazing practices which permit the reproduction of sufficient forage to meet both the maintenance and production needs of the animal.

B. INFLUENCE ON CALF AND LAMB CROPS

Malnutrition, regardless of the cause, results in physiological disturbances, many of which under range conditions escape notice. However, one point is clear regardless of the cause or causes. Decreased lamb and calf crops do not escape the notice of the producer and are of grave concern to him. Friedman and Turner (86) found that under existing deficiencies of protein, vitamin A, and phosphorus have a marked effect on the level of reproduction. Miller, Hart and Cole (137), however, in studying fertility in sheep, found that a serious depletion of vitamin A reserves was necessary before oestrus, ovulation, breeding, fertilization and implantation were affected. Gestation, on the other hand, might become markedly affected with the death of the foetus in utero or
the birth of weak lambs.

When ranges have been overgrazed, poor cows and ewes are not able to provide nourishment for their young (83). The mortality rate of the offspring is resultanty very high after calving or lambing. Frequently, cows with young calves are in such poor condition in the spring and early summer that they do not later conceive and consequently calf only in alternate years. The result is extremely low calf crops. Conversely, Baker and Queensbury (8) found that when animals are gaining in flesh due to good pasturage, a high percentage of calves and lambs is invariably produced. The practical application of these findings has long been used in the process of flushing ewes.

Experiments conducted in Arizona (230) showed that the calf crop on overstocked ranges averaged only 55 percent in contrast with an average of 72.6 percent for the same period on comparable but conservatively grazed ranges. Since the higher the percentage calf crop, the lower the cost per calf, it is further evidence that overgrazing increases the cost of ranching operations.

C. INFLUENCE ON DEATH LOSSES

(1) Poisonous Plants

With few exceptions, the poisonous plants of the range are not species abundant in the climax association but develop large numbers or are introduced as a result of heavy grazing.
With the exception of habit forming species for which livestock acquire a desire, poisonous plants are only grazed as a result of hunger. The main cause of this hunger is poor range conditions.

The principal poisonous plants (227) of the interior of British Columbia were found to be timber milk vetch (Astragalus serotinus A. Gray), larkspur (Delphinium spp.), death camus (Zygodenus venerosus S. Watt.) and water hemlock (Cicuta occidentalis Greene). The order of listing is approximately that of relative importance. The first and last poisonous plants listed are poisonous both to cattle and to sheep, larkspur (Delphinium spp.) mainly to cattle, and death camus (Zygodenus venerosus) to sheep.

Because many ranchers omit to report the losses from poisonous plants, the exact livestock losses from this cause are not available for either British Columbia or Canada, but reports from other experimental areas give an indication. A comparison, however, between privately owned ranges and public domain in Arizona and New Mexico (151) has shown that losses on moderately grazed, privately owned ranges totalled 8.7 percent cows and 2.8 percent other cattle, while on the overgrazed public domain 15 percent cows and 3.5 percent other cattle were lost. When one considers that under good conditions 25 to 27 percent of the herd should be marketed each year, the 18.5 percent loss suffered on the public domain constitutes a terrific economic reduction to the producer's income. Similar situations may be found throughout the
western grazing areas. Forsling (83) found that the mortality from poisonous plants is invariably heaviest when livestock are hungry and/or when the range is closely grazed. His observations are supported by many others (230, 214, 235, 212, 91).

Many poisonous plants are among the earliest species to make their appearance in the spring; and if the supply of forage is short, as in the case of overgrazing, livestock are attracted to these plants to a greater degree than they otherwise would be. Since the stock are in a somewhat weakened condition from the effects of wintering and short feed, consumption of these poisonous plants causes increased emaciation and death. As exemplified by timber milk vetch (Astragalus serotinus), death is not the only ill effect of poisonous plants. Very often affected cattle lose condition and become severely emaciated. In the advanced stages of poisoning, they will stand in a semi-stupor for long periods of time, refusing both to eat and to move. Of even greater concern to the range manager is the difficulty of herding these affected animals. It is the author's belief that affected wet cows continually attempt to leave the subalpine meadows and return to lower levels where it is warmer during the night and the timber milk vetch (Astragalus serotinus) grows because:

(1) The affected cattle feel the cold and dampness more than unaffected cattle; or

(2) The affected cattle become addicted to the timber milk vetch (Astragalus serotinus) poisonous principle; or

(3) Both (1) and (2).
This introduces increased riding and labour since the poisoned cows and their calves must be kept with the herd where they may be protected from predators, swamps, bogs, gullies, etc.

(2) Starvation and Other Factors

Instances of heavy death losses from starvation (235) in the southwest result from misuse of the range and subsequent overgrazing. These losses occur because ranges are stocked on the basis of the forage produced during good years with little or no preparations for severe winters or periods of drought. Griffiths (91) states that the one factor which has contributed more than any other to the depletion of the ranges is the development of hay production in the range area. As long as stock were compelled to subsist the year round on the range, the limited supply of winter feed rendered it impossible to support enough stock to make serious inroads on the more abundant summer growth. While his statements are theoretically correct, it is doubtful if the livestock could survive a winter such as this (1948-49) even if they had not been weakened or poorly conditioned for the winter by feeding on overgrazed land. In the annals of the livestock industry this winter will undoubtedly be compared with the severe winters of the 1880's which forced ranchers to prepare emergency feed on a large scale.

Forsling (83) found that young animals are stunted by the unfavorable conditions and this further reduces the income
from the livestock business. In areas such as interior British Columbia, under good grazing conditions, stock may be sold as gross fattened beef at an age known as long yearlings or coming two (18-24 months of age). Under these conditions, the expense of wintering the animals and grazing them for another year is eliminated and much of the grassland forage may be diverted to producing more young stock. When stock are wintered as long yearlings they are held on a maintenance or submaintenance diet. Under such conditions it may take a good part of the spring and summer grazing seasons to regain the weight lost during the winter. This forage and the hay used during wintering is expensive.

Walker and Lanton (235) found that the major causes of death among range livestock are poisonous plants, predators and disease, although the importance of these varies greatly with the kind of stock and the region concerned. Death losses are related to range conditions. As Figure 12 indicates, the poor or emaciated condition of livestock frequently contributes to losses from other causes. Ordinarily, the number of calves killed by coyotes is small, but these losses increase when the dams are too weak to protect their young. This is especially true where the emaciated animals and their calves have strayed from the rest of the herd (83).

When coyotes kill sheep on the range the procedure differs somewhat. The author has seen the following system used by these animals with great success. The coyote does not attack the band of sheep directly but stampedes them along a
ridge or the side of a hill. As the sheep run, the weaker animals are forced to the sides and back of the flock. The coyote moves in on the downhill side of the flock and as the sheep are running selects his victim, grasps it by the throat, and rolls downhill with it.

Death losses resulting from a lack of forage on overgrazed range may manifest themselves in other ways as well. Losses contributed to factors such as disease are often indirectly the result of overgrazing since stock in an emaciated or poor condition are subject to disease (256) and parasites bearing diseases (230). Emaciation or poor condition may result in death as a result of the inability of the animals to overcome physical obstacles such as bogs and swamps or gullies into which the animals wander and then have not the strength to struggle back to normal rangeland. Almost all these factors contributing to increased death losses on the range can be traced directly or indirectly to overgrazing. These factors contribute directly to economic losses suffered by the producer.

It has been shown that proper grazing has an important bearing on the many factors contributing to the success of a ranching enterprise. Through grazing management, harmful effects of overgrazing on the livestock may be minimized, the calf and lamb crop increased, and more livestock produced and marketed at a higher profit. Continuous and dependable ranch income is contingent upon maintaining the forage production at its maximum. Whereas an immediate maximum meat
yield is not always compatible with range management, it is definitely unwise for the range manager to ignore meat yields as an index to correct range use, for the production of meat is the goal of range management. Since it has no direct application to human nutrition, forage production on the range is not an end in itself.
IV. THE EFFECTS OF OVERGRAZING ON THE SOIL

The results of overgrazing, as previously mentioned, do not end with the reduction or removal of vegetation from the rangeland. Rangeland, when it is in the climax stage or is properly grazed, is in balance with the eroding forces. At this stage, the soil has undergone a series of developments from the original rock or parent material and has become a climax soil. Such a soil may be defined as a soil which has entered a stage of relative stability with the climate. Under these conditions, the downward movement of soluble materials by leaching is balanced by the upward movement of materials by plants. Geological erosion assists the plants in maintaining this balance. In a climax soil the horizontal development is complete and accelerated erosion is negligible. Furthermore, a biological balance is attained in which bacterial and multicellular activities are virtually constant, varying only with the weather (148).

Now since vegetation is the result of the combined factors of soil and climate, it follows that as a soil approaches its climax, so also does the vegetation. Under normal conditions, a climax soil supports a climax vegetation and both are in a state of equilibrium with the climate. As the climate varies, so does the vegetation, the animals living on the vegetation and, to a lesser degree, the soil. A change
in the plant association, whatever the cause, is almost
certain to alter this equilibrium. The change may be brought
about by a long period of abnormal weather, a secular change
in climate, by a parasite, fire, man, or a host of other
causes (119). With the introduction of domestic grazing
animals, a new plant association is produced on western
grazing lands. This change in the vegetation causes a reduc­
tion in soil fertility until equilibrium is again established
under the new vegetative conditions. This change has caused
some alarm among both soil and wildlife conservationists.

The primary problem of western rangelands, then, involves
developing a system of proper range utilization combined with
the prevention of accelerated soil erosion (7). This fact is
borne out in the results of investigations (261) of mismanaged
and excessively overstocked parts of the Palouse Prairie.
Young found that changes in the vegetation do not necessarily
indicate that pronounced changes have also taken place in such
chemical constituents of the soil as organic matter, total
nitrogen, nitrate-nitrogen, and hydrogen ion concentration
unless erosion has been associated with overgrazing. This
particular study (261) has shown that in the Palouse Prairie
region, overgrazed areas which have not suffered from erosion
are not chemically impoverished as heretofore assumed.

Maximum production on rangeland is always congruous with
maximum conservation of soil and moisture. Vegetative control
of erosion on the rangeland then consists of a careful study
of the livestock handling practices and livestock numbers to
determine any source of mismanagement that gives rise to the deterioration of the vegetation. A good cover of vegetation is the most direct and effective means toward soil conservation. It should be emphatically repeated that under overgrazed conditions the problem becomes that of controlling soil erosion regardless of whether it is caused by water or wind. On ranges where erosion is potentially severe, soil stability, not forage production, should be the measure of correct use.

A. WATER EROSION

(1) Factors Influencing Water Erosion

While wind erosion in a serious form is largely confined to regions receiving below 15 inches of precipitation per year, such is not the case with water erosion. However, most of the areas subject to water erosion that do receive more annual precipitation are engaged in some form of agriculture other than rangeland grazing and hence will not be discussed. The question may then be asked: "How can the run-off from such a low annual precipitation become a grave problem when areas receiving considerably more rainfall per year are virtually free of harmful erosion?" Again, the condition and type of vegetation found growing on the land must be considered in presenting the answer to such a question. On more humid areas, the vegetation often tends to be sod-forming in nature. A good cover is thus provided and the soil is well protected by the well-knit sod. On the areas receiving small amounts of precipitation the vegetation tends to be
found in bunches, plant reproduction coming not from rhizomes and creeping root stalks but from seed distribution. Under conditions of climax or proper grazing utilization, these plants are able to withstand the erosive forces of the precipitation. Therefore if water erosion is to be curtailed and controlled the vegetation must be kept in a condition that will permit it to fulfill the demands of soil conservation as well as the requirements of the stock grazing thereon. When overgrazing is permitted, these vegetative controls are reduced, resulting in water erosion.

Slope or topography is a vital factor influencing the degree or rate of erosion. As the slope steepens, not only does the velocity of the run-off water increase, but this erosion factor is also assisted by gravity. The velocity of rainfall is of importance in determining the rate and amount of surface run-off and hence the potential eroding capacity of such run-off. The nature and texture of the soil is also of importance since different textured soils exhibit different susceptibilities to erosion. It is obvious, therefore, that since the alteration of range topography, soil, and precipitation velocity is either expensive or impossible, the only feasible method of controlling water erosion is through the proper management of the rangeland vegetation (7).

(a) Role of the Gross Morphology of the Vegetation in Soil Protection

It has been pointed out that in an established ecosystem the effects of erosion are offset by the activities of
Figure 13. Research enclosure A III. Note the size of the climax grass species within the enclosure.

Figure 14. Research enclosure A III. Note the lower and upper grassland regions in the background.
the plant associations comprising the climax vegetation.

If the exclusion of grazing is permitted, tall stemmy herbage becomes dominant (119), the soil protecting bottom grasses and forbs are choked out with the result that again there is an increase of bare ground. An example of this may be shown in Figures 13 and 14. This enclosure, named A III, was established on Mara Mountain near Kamloops and all grazing was excluded. Indications of reproduction are negligible and large bare spaces between the plants give ample evidence that the water requirements of these plants prevents the more uniform type of cover found on normally utilized areas. There is also a tendency toward excessive drying of the topsoil between the plants during the summer drought period, leaving the soil quite susceptible to erosion. It is therefore evident that complete protection is a detriment to the land, both to the soil as such and economically in that neither game nor commercial meat is being produced.

(b) Influence of the Vegetation on the Soil Microelements

The soil surface under a plant cover may seldom if ever receive the direct rays of the sun, and this markedly reduces evaporation. A further reduction of evaporation is noted since the plant association acts as a windbreak, leaving a blanket of humid air immediately over the soil surface. Reduced sunshine and reduced humidity lower evaporation from the soil surface and prevent the soil from drying. Since the plants draw subsoil moisture for transpiration (214), the
vegetation may be said to make the soil water more evenly distributed, drying the subsoil and keeping the surface soil moister. This is an ideal condition for absorption in the surface soil, moist soil absorbing water more readily than dry soil. The influence of the vegetation on the soil microflora prevents excessive drying of heavy soils and the freezing and thawing of other soils which have been exposed to the direct action of the sun and wind causes cracking or heaving owing to the absence or presence of moisture in abnormal amounts in the soil. This cracking or heaving of the soil which contributes to erosion may also break plant roots or actually destroy them by pushing them out of the soil.
Grassland associations are of great importance in protecting the soil from the eroding effects of rainfall. By intercepting the rainfall, the vegetative canopy may hold the moisture until such time as it can be evaporated. In this way, some of the moisture never reaches the ground and hence erosion is impossible (13). Another effect of the vegetative cover is that when the rainfall strikes the vegetative canopy the impact of the moisture on the soil is reduced to a considerable degree. In some cases a period of one to two hours may elapse while the moisture runs from the point of interception on the foliage to the ground. In general, very little attention has been given to the amount of moisture held by the vegetation, while great publicity is granted moisture evaporation from the soil and transpiration from the plants. The amount of moisture held depends upon a number of factors, such as the kind and density of the plant cover, the duration and intensity of the rainfall, and the temperature, relative humidity and wind movement. When the amount of moisture is expressed in tons per acre, the magnitude of interception by herbaceous vegetation may be more readily appreciated. Sweet cover, it has been noted, is capable of holding 8.0 tons, while prairie sage (Artemisia gnopholodies Nutt.), under comparable conditions, retained 12.5 tons per acre (44).

Since overgrazing leads to a deterioration in botanical composition and an increase in stemmy annual grasses and weeds, as well as to an increase in bare ground, further weight is added to the argument that erosion control and soil conservation
on grasslands of all types are synonymous with good range management.

United States Department of Agriculture Forest Service tests (60) on Idaho rangelands which are similar to those of the southern interior of British Columbia were made on four types of vegetation using artificial rain machines. The four types included (a) awnless wheatgrass (*Agropyron inerme*), representative of the grassland climax; (b) lupines and needle grass (*Lupinus* spp. and *Stipa littermanii*), perennials representing the early stage of depletion from grazing; (c) annual grass (*Bromus tectorum*), a later stage of grazing depletion; and (d) annual weeds (*Gayophylum madia* and *Lactuca*), an inferior range cover brought about by intense misuse. Average observations for each type (vegetational), all other factors having been isolated, are shown in Table IV.

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>Run-off and Erosion from Four Vegetation Types of Southern Idaho (44).</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEGETATION TYPE</td>
<td>WHEAT-GRASS (a)</td>
</tr>
<tr>
<td>Run-off (percent)</td>
<td>0.4</td>
</tr>
<tr>
<td>Soil eroded (tons/A)</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Further evidence of the erosion control of each plant association in shown in California experiments which demonstrated that a soil cover of sagebrush (*Artimesia tridentata*) and grass supplied a reliable source of forage and a stable
year-round protection for the soil (161). When this land is cultivated and permitted to produce unreliable weedy covers such as Russian thistle (*Salsola pestifer*) and mustards (*Brassica* and *Sisymbrium* spp.), erosion is a sure result.

(c) Chemical and Physical Activities of the Vegetation in Soil Protection

The decayed matter or "duff" that covers the soil under vegetation that is allowed a carry-over or is left ungrazed is an important protection against eroding agents and an aid in absorbing water. Experiments (81) have shown that the litter from one square metre of grassland has absorbed as much as 650 gms. of water.

However, the protective activities of the plant do not end with "duff". One of the benefits derived from plant roots is the transfer of organic matter to the subsoil. Over a period of time an organic reserve is built up in the subsoil which results in a higher water holding capacity and increased permeability because of improved structure. Studies conducted in Nebraska by Weaver et al (249) showed that under prairie grasses the pore space in the soil decreases from 60 percent of the volume at 6 inches to 51 percent at 7 feet. Prairie plants are largely grasses and the parts underground consist of roots, rhizomes and bases of stems. As a result of the interlacing and clutching of the particles of earth by the myriads of roots of grasses, the soil is compressed into granules and these are surrounded by colloidal films which maintain their permanence and stability. The living under-
ground parts in the prairie compose approximately one-tenth of the total organic matter by weight. These plant parts slowly deteriorate, die and decay with the passing of years, only to be replaced by new ones (239). The channels which were made by the roots in pressing aside the soil remain for a long period of time, greatly increasing the pore space and consequently the absorption of water (231). The close dependence of this organic material upon the abundance and vigor of the tops cannot be overemphasized. Frequent removal of the tops may cause them to die or the amount of organic matter in the soil to be considerably reduced.

With overgrazing there is also a reduction in the plant root reserves as well as a decrease in root volume which in turn reduces the degree of granulation and porosity present. Flory (81) states that soil structure is materially altered by both cultivation and grazing. He found that 6 years of cultivation reduced the pore space of a climax prairie soil from 50.5 to 44.3 percent and the rate of penetration of water from 0.94 to 0.54 inches per hour. In studying undergrazed, overgrazed and depleted ranges in New Mexico, he found a pore space of 68.1, 51.1 and 46.5 percent respectively. The inches of water penetration per hour were 4.14, 2.16, and 0.28 respectively. This data is shown in Table V.
(d) Mechanical Activities of the Vegetation in Soil Protection

Plant roots, in spite of their apparent tenderness and frailty, are able to exert pressures well over 100 pounds per square inch by osmotic pressure alone. This force enables the roots to open holes and cracks which permit the percolation of water through the soil. This same pressure also assists in preventing erosion by moulding the soil particles into granules, thus improving the soil structure.

Grass swards in particular and other vegetational associations in general obstruct the flow of run-off water, thereby reducing its rate of flow. The reduction in the rate of flow to one-half its original speed will reduce the eroding power of the water to one-fourth and the amount of material it can carry to one thirty-second (6). The reduction in velocity is attributable partly to the vegetation holding some of the water back, partly because it spreads the water out over a greater area of soil surface, thereby reducing its volume and increasing the distance it must flow, and partly because debris such as sticks, dead leaves and stems lodge between the plants.
EFFECT OF OVERGRAZING AND EROSION ON WESTERN GRAZING REGIONS & ITS RAMIFICATIONS

OVERGRAZING

LOSS OF VEGETATIVE COVER

OVERGRAZING

DIMINISHED UNDERGROUND WATER SUPPLY

DROUGHT (INTENSIFIED PERIODS)

INCORRECT SPEED OF RUN-OFF

INCREASED NUMBERS OF INSECTS, SMALL MAMMALS, PREDATORY ANIMALS ETC.

PARASITES, DISEASE

DESTRUCTION OF FOOD & COVER FOR WILDLIFE & FISH

DEPOSITION OF POOR SUBSOIL MATERIAL ON RICH ALLUVIAL SOILS

DEREGONATION OF SOIL FERTILITY

DEPLETED LIVE STOCK PRODUCTION

REDUCED YEILDS

IMPOVERISHMENT

DUSTSTORMS-LOSS OF TOPSOIL & NUTRIENTS

SEDIMENTATION IN NAVIGATION CHANNELS, RESERVOIRS, DAMS AND DITCHES, HARBOURS

LOSSES IN NAVIGATION, CITY WATER SUPPLY, HYDROELECTRIC POWER, IRRIGATION DEVELOPMENT, FARMING & GRAZING

SUFFERING, DISEASE, DEATH

FLOODS

DAMAGE TO ROADS, RAILROADS, FARM BUILDINGS ETC.

Figure 16.
(2) Results of Water Erosion

The results of serious water erosion combined with the
effects of wind erosion, or by itself, present a picture of
destruction and desolation the equal of which would be exceed-
antly difficult to find. Throughout the early literature of
this continent there were countless warnings that erosion
would surely result from the systems of grazing practised.
Many of the publications (89, 108, 127) were written prior
to the turn of the Century. Unfortunately, until the mid-
thirties any mention of the desiccation of the Canadian West
(or of the western United States) almost invariably produced
a counterblast of protest that there is still ample good land
for all and that the pioneering spirit still lives in the
people strong enough to overcome all difficulties. The per-
sistence of opinions such as this resulted in the necessity
of introducing the Prairie Farm Rehabilitation Act (1935) by
which provision is made to remedy the consequences of over-
grazing, drought and soil drifting in western Canada. It is
interesting to note that the money is used not only for
direct assistance and research but also for propaganda and
education; a move toward eliminating all the contributary
causes of poor land utilization. Unfortunately the conditions
brought about by water erosion are not readily rectified.
Dr. W. R. Cahplme has stated (41) that since the West is
dependent on grazing of the range for the existence of its
livestock industry it is imperative that the terrific wastage
exemplified by 80 percent abnormal erosion of western range-
lands be halted. The most valuable erosion control avail-
able, a natural plant cover, must be developed in order to
decrease materially the losses often measured in tons per
acre. Such estimations of excessive soil loss are not
necessarily alarmists' dreams. The literature contains a
wealth of experimental evidence to verify such a statement.
Pickford and Reed (160), while studying subalpine grassland
ranges of eastern Oregon and Washington, found that the
heavy grazing of these areas induced by the high quality of
the summer forage they produce and by the natural shortage of
summer range in the region has reduced their grazing capacity
far below the potential. Their study, which was made in the
Wallawa and Blue Mountains indicates that 927 tons of topsoil
per acre and 96 percent of the grazing capacity was lost when
that range was severely depleted. The study shows that the
green fescue type, which is the most prevalent plant association
in the subalpine zones in the northwest, consists of nearly
pure stands of fescue when in the virgin condition but that
needle grass and ruderal weeds predominate when this type has
become deteriorated. Subalpine ranges in a climax condition
possessed a grazing capacity of 5.35 sheep months per acre.
In a depleted second weed stage when, as previously mentioned,
the vegetation was chiefly needle grass and weeds, the grazing
capacity was but 0.21 sheep months per acre.

Now unfortunately the effects of overgrazing do not end
with the loss of vegetation and topsoil. This soil which was
such an asset to the rangeland and the plants thereon becomes an expense and a menace as it is washed down to lower regions. As indicated in Figure 16, this soil may appear as sediment in stream channels, reservoirs, dams, ditches and harbours. The gravity of the economic and social implications brought about in this manner may be illustrated by the following examples.

The Morena drainage basin is an important drainage basin for water gathering for the city of San Diego, California, and is the site of a dam and reservoir completed in 1910. It was found that by 1935, 10.5 percent of the reservoir storage capacity had been displaced by sedimentary deposits (11). That was over a period of only 25 years. Cattle grazing has been maintained as the principal land use in the area. Overgrazing the valleys and repeated burning of the brushy slopes for the production of sprouts and weed forage have been the chief cause of accelerated erosion.

Mr. W. Talbot has reported (218) that southwestern stock watering reservoirs silt at an average rate of one foot per year. At this rate he considers that most of the reservoirs will be useless in 15 years or less. During the period 1935-36 to 1943-44, the P.F.R.A. spent approximately $450,000.00 on stock watering dams alone (38). If this data is applicable to the Canadian West, it will cost the P.F.R.A. $30,000.00 a year to maintain the present stock watering facilities alone.

The ramifications of the results of sedimentation may be readily seen in a reduction in farming and range utilization
because of a lack of irrigation and stock watering supplies, and a reduction of shipping in river estuaries because of the expense of repeated dredging in an attempt to keep the shipping channel open to navigation.

While every point mentioned in Figure 16 is of great importance undoubtedly one of the most important is the floods which result from overgrazing.

If the proper utilization of rangelands was undertaken immediately, probably in few cases where floods now occur will it be possible to dispense with downstream engineering works such as the dyking projects going on in the Fraser Valley. However, the value of these works in their present state can be greatly enhanced by the adoption of proper soil and moisture conservation practices in the headwaters. The water which accumulates in streams and rivers may arrive at the lower levels or ocean in two ways: either as surface run-off or from the ground water table in the form of seepage water or springs. It is obvious from the references which have been made that excessive run-off can be controlled in spite of the complexity of the hydrologic cycle and hence the amount of run-off water which passes directly into the rivers causing floods may be favorably influenced. Reference has already been made to the action of the grass cover in guiding rainwater safely to the underground storage from which it reappears over a period of time from seepage and springs, thus maintaining a steady supply to the streams and rivers rather than the sudden rush of run-off water that follows a quick thaw or an
intense downpour on a relatively barren watershed. The adoption of a sound grazing policy to reduce run-off, soil washing and the maintenance of a good protective cover of vegetation are the basis of effective flood control. The reduction of the run-off will mean that more water is passing into the soil and to the water table, that streams will have a steadier supply; the vegetation which facilitates this transit generally benefits from the higher water table (in semi arid areas) and thus the vicious cycle of denudation, erosion and floods can gradually be changed to a beneficial cycle of natural re-grassing, soil and water retention and the reduction or elimination of floods.

Unfortunately the process of degeneration in a watershed area, resulting from overgrazing, may result in flood damage in an exceptionally short time, while, as previously mentioned, the processes of soil formation and regeneration are slow.

It is not the objective of this Thesis to discuss in detail all the ramifications of soil erosion caused by overgrazing but to indicate the dire necessity of acknowledging the soil as an essential factor in studying the effects of any change which overgrazing practices may exert on the grazing biome. Therefore, a further discussion of the effects of water erosion will not be pursued.
HYDROLOGICAL CYCLE

ATMOSPHERIC VAPOR → PRECIPITATION

TRANSPARATION

VEGETATION INTERCEPTION

RIVERS

LAKES

OCEANS

RUNOFF

SOIL SURFACE

PLANTS → SUBSOIL

SPRINGS

SUBSOIL
B. WIND EROSION

(1) Factors Influencing Wind Erosion

Wind erosion in a serious form is confined to arid regions usually below 15 inches in precipitation per year. The most important reasons for this are as follows (214):

(a) Vegetation is less dense because of lower precipitation;

(b) Soil organic matter is lower because of lesser amounts of vegetation and higher soil temperature;

(c) The humidity of the atmosphere is lower and hence the surface soil is drier;

(d) Hot, bare soils cause rising air currents which lift soil particles upward into the more swiftly moving atmosphere.

Needless to say, wind velocity is a vital factor influencing the degree of erosion. However, unless the soil and vegetation conditions are conducive to wind erosion, no serious damage will result. Soil texture, just as in areas subject to water erosion, is one of the important factors influencing its susceptibility to blowing (260). The popular conception is that sandy lands blow the most readily, this conception being founded probably upon the fact that the blowing areas are covered by sand. The fact that the sand is merely the material that has not blown away is overlooked. Heavy particles, other things being equal, will blow the least readily, and fine particles the most readily. However, this issue is somewhat confused by the fact that sands are single particles and
are low in organic matter, whereas the fine textured soils cling together to form large granules.

The organic content of soils is an important factor influencing blowing. Though organic matter itself is light and very subject to blowing, it tends to bind soil particles together and make them stable. Likewise, a high organic content means a high water holding capacity, which decreases blowing. Organic content has been called the most important single factor determining the degree of wind erosion (260).

While Wyatt, Smith, Newton and Gillies (260) consider organic matter content the most important single factor determining the degree of wind erosion, Ellis (193) states that vegetation is the most vital single element determining the susceptibility of a soil to blowing. The writer believes the latter statement to be more exacting in that vegetation indirectly influences soil structure, soil organic matter, soil moisture, atmospheric humidity and wind velocity. It is through these mediums, together with mechanical binding of the soil particles, that vegetation protects soil from blowing. The structure of soil is improved by root action, together with increased organic matter and root fibre accumulation. Insufficient root fibre and lack of cohesion between the soil particles are the more important factors determining the readiness with which soil blows, root fibres being much more important than humus.

The action of vegetation in decreasing wind velocity at the soil surface is well known (in the form of tree rows) in
windswept areas. Similar effects can be obtained from the use of smaller plants or even grass swards.

(2) Results of Wind Erosion

Sheet erosion, as previously mentioned, may be expected to affect the activity of the soil flora by changing the nature and number of the organisms present, the amount and quality of the organic matter and the physical environment (148). In some cases soil particles have been known to travel distances of 1,000 to 2,000 miles (85) and actual deposit measurements have shown 10.5 to 85 tons per square mile after a single storm.

The extremely serious soil losses on farm and rangelands are only one of the results of wind erosion. Damage to vegetation by abrasion and smothering caused by deposition are sometimes sufficient to cause death. Exposure of roots by blowing may kill plants (85), especially during the seedling stage when they may be blown from the ground.

The prevention of wind erosion is comparatively simple but when it has progressed to the stage of active soil movement and widespread depletion it becomes one of the most formidable problems facing the land ecologist. Fortunately, soil drifting starts not over a wide area but at a small focal spot from which the spread begins. A partial vacuum is created as wind passes over a small depression of bare soil, causing an upward swirling air current which carries the soil particles and causes an increasingly deep and wide blow-out hole. The material is carried until the air velocity is
decreased, whereupon the larger particles settle out. Thus
dunes are formed along fence lines or any other obstruction.
These dunes are rolled by the wind, material from the wind-
ward side being deposited on the protected or leeward side.

Blow spots may be started because of some local soil
condition such as a sand spot, or they may be cause by some
mechanical disturbance such as is found in a stock rolling
place, a corral, or a roadway. An example of such an area
may be found in the Swift Current - Webb Municipalities
Community Pasture.

During carrying capacity studies in the sand dune portion
of the community pasture it was noted that the blow-out areas
were increasing in size and that cattle tracks gave evidence
of the repeated presence of stock in that area (38). It is
suggested that stock spend parts of the early mornings on
portions of the blow-out sand since these areas warm more
readily than the areas covered with a canopy of vegetation.
It is the author's opinion that the activities of the live-
stock in this area were among the prime factors contributing
to the production and spread of the dune shown in Figures 18,
19 and 20. Wooden pegs and iron stakes have been placed in
the path of the blow-out and a careful study of the activities
of the blow-outs is being conducted by the staff of the Forage
Division of the Dominion Experimental Station, Swift Current,
Saskatchewan. (34).

The soil throughout the area is classified as sand and
undifferentiated dune sands (138) and the vegetation associa-
Views of an active sand dune in the Swift Current-Webb Municipality Community Pasture

Figure 18.

Figure 19.

Figure 20.
tion contains such species as sandgrass (*Calamovilfa longifolia* Hook.), sand dropseed (*Sporobolus cryptandrus*), Indian ricegrass (*Oryzopsis hymenoides* Roem. & Schult), wolf willow (*Elaeognus commutata* Bernh.), choke cherry (*Prunus melanocarpa* A. Nels.), and rose (*Rosa* spp.). The first plant to enter the disturbed soil appears to be the Indian ricegrass (*Oryzopsis hymenoides*).

**Figure 21.** The Result of Uncontrolled Wind Erosion in Southern Saskatchewan. Note the Pole and Wires.
Albertson (1) states that dust blown from cultivated fields probably causes greater damage than overgrazing. An extreme example of this may be seen in Figure 21. This picture, taken in southwestern Saskatchewan, shows Mr. W. A. Hubbard (formerly with the Forage Division of the Dominion Experimental Station, Swift Current, Saskatchewan), holding telephone wires. The top of the telephone pole may be seen to the left of Mr. Hubbard. The soil (sand) drifts in the foreground have covered the road allowance. The land behind Mr. Hubbard was formerly grassland. These dunes are the result of soil drifting, not from overgrazing but from the cultivation of soils that were too light to hold. When the early pioneers first settled southern Saskatchewan they homesteaded the lighter lands because of the comparative ease of plowing. With repeated cereal cropping the organic matter of the soil decreased and soil drifting began. When the soil drifted to the uncultivated or grazing lands the soil was held by the foliage until with successive storms the plant cover was finally inundated. Scenes such as the one pictured in Figure 21 lend added weight to Albertson's (1) statement.

As in the case of water erosion, the effects of wind erosion are both devastating and extensive. Since the object of this Thesis is to deal mainly with the role played by the vegetation under conditions of overgrazing, it is suggested that if further examples of the ramifications of wind erosion are desired, Figure 16 should be studied.
C. SUMMARY OF THE EFFECTS OF OVERGRAZING ON THE SOIL

A grass sward well managed is an efficient cover for preventing erosion and reducing run-off; a grass sward badly managed is a dangerous thing, with the poor vegetation incapable of guiding the rainfall into the soil, the bare ground favouring soil packing from several causes, and the beginning of gully erosion by water or the wholesale removal of topsoil by wind.

A good sward has numerous merits from a conservation point of view. It covers the surface of the ground, protecting it from the direct impact of the falling raindrops, thus keeping the pores of the soil open and capable of receiving excessive amounts of water. The leaves of the herbage assist in guiding the falling raindrops to the soil. The humus layer below the herbage is capable of storing many times its volume of water. In this way a good grass sward favours a high degree of infiltration and ensures that any water which does flow away as run-off is clear and has little eroding power. The root system of the grass is of value in protecting the soil against erosion, particularly the action of wind.

Overgrazing removes the protective vegetative cover for the soil resulting in the conditions mentioned throughout this Section. Some of the consequences of soil erosion on western rangelands in the form of soil blowing and soil washing are:

(1) the silting and sedimentation of stream channels, reservoirs, dams, ditches, and harbours;
(2) the loss of fertile soil material in dust storms;

(3) the piling up of soil on lower slopes and its deposit over alluvial plains; the reduction in productivity or outright ruin of rich bottom lands by the overwash of poor subsoil material such as sand and gravel swept out of the hills by streams of varying intensity;

(4) deterioration of soil and its fertility and the associated deterioration of crop yields per acre and the vegetation grown thereon;

(5) loss of soil and water which causes the destruction of food and cover for wildlife, including a blowing and washing of soil into streams which silt over spawning beds as well as destroying water plants -- a food supply of fish;

(6) a diminishing of the underground water supply which intensifies periods of drought;

(7) an increase in the speed and volume of rainfall run-off, causing severe and increasing floods which bring suffering, disease and death;

(8) impoverishment of families attempting to utilize eroding and eroded lands;

(9) damage to roads, railroads and highways, farm buildings, fences, and other property;

(10) losses in navigation, hydroelectric power, municipal water supply, irrigation developments, farming and grazing;

(11) increases in insect, rodent, and other small animal populations which may be carriers of diseases and parasites, thus endangering the domestic grazing herds already weakened by scarcity of good forage.
V. OVERGRAZING AND WILDLIFE POPULATIONS

The size of domestic livestock populations, it has been shown, are governed by the forage and water available on a range area. So also it must be for wildlife populations. Large amounts of forage may be lost to commercial herds through the activities of wild animals. However, due to the varying degree of motility and the decided wariness of human activity, it is difficult to establish the fact that wildlife competes with the domesticated livestock for the available forage and water. The destruction of plant life by insects such as grasshoppers and locusts has been recorded and mourned since biblical days and has had a profound influence on the development of the West. When the forage demands of wildlife are placed on a range already carrying its full capacity of domestic livestock, overgrazing often results.

While at times grave losses of forage are suffered by commercial herds, the presence of wildlife species is not always considered totally objectionable. The question may then be asked: If wildlife species compete with domestic livestock of commercial value, how and when may they be considered unobjectionable and harmless? Stoddart and Smith (214) have classified native herbivorous range animals according to size and economic value. They classify the fauna into two
groups:

(a) large mammals which are economically valuable 
and hence their value must be weighed against 
the value of the forage they consume;

(b) small mammals, essentially rodents, whose 
effects on range are popularly considered 
to be solely destructive.

A. LARGE RANGE WILDLIFE SPECIES

The large herbivores found on rangelands include deer, 
elk, moose, antelope, bighorn, mountain goats and bison. 
Today, for the most part, only the deer and elk compete 
seriously with domestic animals for range forage. Large 
animals, other than elk and deer, usually exist either in 
areas relatively inaccessible to domestic livestock, or in 
numbers so small that they do not seriously compete for the 
available forage. They may also exist in areas lacking ade­
quate watering facilities or a vegetation palatable to 
domestic livestock.

Elk (cervus canadiensis), like cattle, are fundamentally 
grass eaters (172, 201), although browse and forbs may at 
times constitute a portion of the diet. For this reason it 
may be seen that elk do compete with domesticated livestock. 
Recent studies by Pickford (157), of the United States Pacific 
Northwest Forest and Range Experiment Station, have revealed 
that a band of 300 elk consumed two-thirds as much range for­
age as a band of 900 ewes and lambs during a three-month 
grazing season on a summer range allotment of the Whitman 
"ational Forest. These studies also revealed that the ten
range plants which made up 80 percent of the sheep diet also made up 80 percent of the elk diet. These striking data add much weight to the stockmen's arguments that the reduction of domestic livestock numbers is only a partial control of over-grazing in areas where elk are numerous. Individually, the competition from deer for available forage does not appear to be as critical as that from elk; however, the deer population is much greater than that of the elk in British Columbia and most other range areas. In Arizona, Rasmussen (166) found that browse plants were completely grazed out by deer while grass species were maintained. However, Dixon (73) found that Mule Deer consume larger amounts of grass when forbs and browse are scarce and when the grass is green and succulent. Lack of spring grazing, accelerated by premature grazing by deer, is one of the factors contributing to the increasing cost of ranging domestic grazing animals.

In spite of the fact that antelope are natives of the prairies and intermountain plains, grass does not seem to constitute much of their diet. Coney (51), in studying antelope foods during the fall grazing period, found that grasses comprised only 6.0 percent of the diet. The other constituents included mainly browse (87.4 percent) and weeds (5.7 percent).

The economic and social problems associated with the competition between game and livestock are not based solely on the amount of available forage. Steepness and lack of water (213) cause many ranges to be little used by livestock and on these areas, competition is not serious. On limited spring
range, such as is the case in most of the western range areas and British Columbia in particular, the problem may be acute. In the case of deer, because of the dietary differences (except during spring grazing) and the differences in the ranges, they graze it would be necessary to remove 10 to 50 deer to make room for one more steer (213). (Competition is much intensified by excessive numbers of either game or livestock.) The removal of such high numbers of game would cause considerable alarm among the sportsmen. Table VI shows the revenue in British Columbia derived from hunting licences and fees alone (25). The amounts spent on equipment, guides, and accommodation for the hunters is many times greater.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fines</th>
<th>Revenue from Licences and Fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1943</td>
<td>$5,554.50</td>
<td>$207,661.72</td>
</tr>
<tr>
<td>1944</td>
<td>5,570.50</td>
<td>238,902.36</td>
</tr>
<tr>
<td>1945</td>
<td>8,381.50</td>
<td>352,228.85</td>
</tr>
<tr>
<td>1946</td>
<td>10,921.00</td>
<td>502,555.25</td>
</tr>
<tr>
<td>Total 1943-46</td>
<td>$199,387.07</td>
<td>$5,390,972.23</td>
</tr>
</tbody>
</table>

In reviewing the history of game in British Columbia, Brooks (26) states that in the early days there were relatively small numbers of deer. Subsequently, large numbers of deer migrated to the Kootenays and the Okanagan. With them came the mountain lion. These mountain lions have been known to attack herds of wintering cattle causing considerable damage.
Because the game are owned by the federal and provincial
governments they have a tendency to reach large numbers in
such protected places as the Jasper, Banff, and other large
national and provincial parks. However, when winter closes in,
the tendency is for the game to migrate to valley bottoms
such as the Rocky Mountain Trench. Here they concentrate in
large numbers, compete seriously with the winter domestic
livestock and often are responsible for serious damage to
stored emergency feed such as hay and unthrashed grain. This
situation is a constant worry to the stockmen of the Elco-
Waldo and Windermere areas, where winter feed and spring range
is not abundant.

Many diseases and parasites common to deer also occur in
domestic range animals (106). In California, for example, the
intestinal round-worms found in deer have a direct life cycle.
On ranges intensively grazed by deer and sheep and cattle, the
domestic species often ingest larval worms. While the domestic
livestock are treated with drugs, their relief can only be
considered temporary since little can be done to control the
infestations in deer. In the control of deer parasites two
methods can be employed:

(a) The game animals can be attracted away from the
domestic livestock ranges.

(b) Both the deer and domestic livestock numbers
must be reduced.

The problems of interrelationships between domestic and
native grazing animals cannot be readily solved because of
the diversity of interests and values involved. Domestic
INTERRELATIONS IN A NATURAL BIOME

Figure 22.
livestock cannot be eliminated from crown or public grazing lands without drastic economic changes. Nor can the game be eliminated without upsetting the public in general and the hunters in particular. Only through the co-operation of the stockmen, conservationists and sportsmen can problems of this type be solved. They must study livestock numbers, game numbers, range conditions, hunting conditions and economic conditions, and then only after carefully integrating all these factors will they be able to make scientifically sound decisions.

B. SMALL RANGE WILDLIFE SPECIES

In countless instances the deterioration of the grazing areas of the West is depicted by desolation, dust, bleached skeletons and almost invariably a gopher sitting on its haunches beside its burrow. The artist in portraying his scene may not have been aware of the actual part played by these small mammals. No range area is free of the presence of these animals which are today the subject of some of the most important discussions concerning proper range management. Since many of them consume principally the same forage species as the domestic grazing animals and since their burrows have contributed to numerous broken legs for all classes of stock, these small animals are usually considered with great disfavour by stockmen. Nor are they accepted by farmers and grain growers who lose much of their crop each year. A bibliography published in 1936 (171) contains 8,274 important
books, articles and other publications dealing with the management of western ranges, livestock and wildlife. It is interesting to note that of these, 216 come under the title of "Control of Range-destroying Rodents". It is obvious that the majority of the authors prior to about 1939 regarded rodents and other small mammals in a very baleful light. It is surprising to discover that until that time very few investigators seemed to realize that an animal, even though a rodent, may possibly do more than one thing; in other words, that a cause may have more than one effect and an effect more than one cause.

(1) Detrimental Effects of Small Grazing Mammals

Jack rabbits appear to prefer plants in the order of weeds, grasses and browse, with the first two making up a major and about equal part of the diet (5). The equal portion of weeds and grass in the diet offers the explanation as to why rabbits are more abundant on overgrazed than on normal ranges. Arnold suggests that once deterioration is well under way, rabbits may be a partial cause of overgrazing, while in the final stages of deterioration they may be the primary cause of depletion. Under normal conditions (28) the rabbit population of mixed grass prairie is one jack rabbit and one cottontail per acre. The jack rabbits grazing in terms of cows (5) is:

\[
\begin{align*}
62 \div 7 & \text{ Arizona rabbits } = \text{ one 1000 lb. cow} \\
48 \div 2 & \text{ Antelope rabbits } = \text{ one 1000 lb. cow.}
\end{align*}
\]
Taylor, Vorhies and Lister (225) found that only 15 antelope jack rabbits would be required to eat as much valuable range forage as one sheep, or 74 as much as one cow; that 30 Arizona jack rabbits would eat as much as one sheep and 148 as much as one cow. It may be noted that the apparent discrepancy in the equivalents is explained that Taylor et al. made their calculations on valuable forage amounts, while Arnold's calculations were based on total forage consumption by the rabbits. It was also noted (225) that grass made up 45 percent of the diet of the antelope jack rabbit and 24.1 percent of that of the Arizona jack rabbit.

It would not appear that the amount of valuable forage consumed by these rabbits should constitute such an alarming amount when under normal conditions the rabbit population is only 2 per acre. Unfortunately, under conditions of overgrazing the population increases (Table VII) and the amounts of valuable forage available to domestic livestock decrease. The reasons for these increased numbers of rabbits may be (225):

(a) They prefer annual shoots and weeds to old grass
(b) The added visibility in the overgrazed areas is an advantage to the rabbits.

In overgrazed areas where so many domestic animal equivalents may appear in the form of rabbits, the question may arise: "Can the range be rehabilitated if jack rabbits are present?" There can be no one answer to this question, for local conditions will govern the answer to a considerable
degree. Where livestock pressure is moderate and the vegetation close to a balance between improvement and deterioration, the rabbit population might tip the scale downward. Where the livestock pressure is heavy, its effects will be preponderant and jack rabbit effects may increase the seriousness of the situation. Some investigators go as far as to state that an attempt at artificial reseeding without rabbit control is inadvisable, while some believe that rabbits may be able to keep a range in a constant state of deterioration. The writer has not been able to find verification or instances in the literature to support these latter views, although it is theoretically feasible that such may be the case.

Ever present in areas with large numbers of rabbits and rodents is the possibility of contraction and spread of tularemia (caused by the organism *Pasteurella tularensis*) among the rabbit population, thus endangering the lives and health of the residents of such a grazing area; a further ramification of the effects of overgrazing.

To the writer's knowledge, the only prairie dog "town" in Canada is found near Val Marie, Saskatchewan, and therefore does not constitute much of a problem. In the United States, however, the prairie dog is one of the most destructive rodents in the western grazing regions. Taylor and Loftfield (224) claim they destroy as high as 80 percent of the available grasses and are of no benefit to the biome whatsoever. They found that a total production of approximately 2,250 pounds

*See Appendix A*
per acre of the important forage grasses, over 1800 pounds were consumed by the prairie dogs. The investigation showed that the prairie dogs and cattle eat the same plant species and in the same order of preference. It may therefore be seen that the prairie dog does nothing to assist in overcoming the effects of overgrazing, while it does contribute to such a situation. It does not seem probable that there would be any increase in the numbers of prairie dogs under overgrazing because of the shortage of palatable species under such conditions.

Supervisor Simpson (168) of the Cochetopa National Forest has reported that the elimination of prairie dogs from that forest has resulted in:

(a) checking extensive erosion;
(b) reclothing denuded areas;
(c) eliminating forage losses;
(d) increasing forage enough to carry an additional 2,000 head of sheep and 500 cattle;
(e) eliminating losses in lambing through broken legs.

Shaw, in studying the Columbia ground squirrel, found that it was destructive to both pasture and haylands. Experiments (185) conducted in the summer of 1913 showed that a ground squirrel ate one-seventh of a pound or 17.2 percent of its body weight daily. At this rate 385 squirrels would consume the pasture of one cow or 96 squirrels would devour the pasture of one sheep in the same time. In a complete eradication experiment conducted in a ravine pasture it was found
that the population was 10 squirrels per acre. In other areas it was noted to be as high as 75 per acre. With populations as high as 25 per acre, the squirrels in an area of four acres would be able to consume the forage that would normally satisfy one sheep. Like jack rabbits, ground squirrels are especially favored when the taller grasses are eliminated leaving a dense mat of short grasses and clumps of forbs (Table VIII). It is agreed (115, 163) that the ground squirrels increase in numbers under conditions of moderate but tend to decrease under conditions of severe overgrazing accompanied by erosion. The cause of the decrease at this stage in the plant succession is probably due to the lack of palatable forage.

The Richardson ground squirrel, which is commonly found in Alberta, is harmful in addition to the amount of forage it consumes. Studies by Brown and Roy (29) have shown that both the squirrels themselves and the ecoparasites living on them are carriers of the Sylvatic or Bubonic Plague (*Pasteurella pestis*), Rocky Mountain Spotted Fever (*Dermacentorxenus tickettisi*), and Tularaemia (*Pasteurella tularensis*). Gwatkin (96) has also demonstrated that there were evidences of the Sleeping Sickness virus (*Equine Encephalomyelitis*) in the brain of some Richardson ground squirrels.

Increases in the concentration of these rodents as a result of overgrazing could readily enhance the rapid spread and outbreak of any of these serious diseases.
A further danger to livestock is afforded in that each squirrel has its own burrow and each burrow averages 8 openings in an area of 10 to 15 feet in diameter. Unless the livestock are wary, many broken legs may result in such areas.

In studying the mixed grass prairie of Oklahoma, and the effects of overgrazing upon it, Smith (200) found that the total number of species of small animals is greatest in undisturbed prairie and least in overgrazed and eroded areas. The smallest populations of all small mammals is reached in the severely overgrazed but uneroded areas and again increasing when erosion begins and new plants invade the community. Animals favoured by a sparse, weedy vegetation show their greatest abundance on the eroded areas. In this group are found the deer mice, picket mice and cottontail rabbits.

Table VIII shows the relative abundance of the various small mammals considered in Smith's study. Abundance is indicated by a scale of 1 to 5. One indicates an infrequent or rare species, while 5 indicates great abundance. This method is frequently used to put such data on a comparative basis.

**TABLE VII**
Concentration of Richardson Ground Squirrels in Southern Alberta (231).

<table>
<thead>
<tr>
<th>LAND</th>
<th>ANIMALS/A</th>
<th>BURROWS/A</th>
<th>ANIMALS/SECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prairie</td>
<td>8</td>
<td>64</td>
<td>5,120</td>
</tr>
<tr>
<td>Abandoned</td>
<td>6</td>
<td>48</td>
<td>3,840</td>
</tr>
<tr>
<td>Grassland</td>
<td>5</td>
<td>40</td>
<td>3,200</td>
</tr>
<tr>
<td>Cultivated</td>
<td>3</td>
<td>24</td>
<td>1,920</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>5</strong></td>
<td><strong>40</strong></td>
<td><strong>3,200</strong></td>
</tr>
<tr>
<td>Animal</td>
<td>Normal Prairie</td>
<td>Properly Grazed</td>
<td>Somewhat Overgrazed Not Eroded</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
<td>----------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Deer mouse</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Harvest mouse</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pocket mouse</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>House mouse</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cotton rat</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shrew</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cottontail</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Jack rabbit</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ground squirrel</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mole</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gopher</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
(2) Beneficial Effects of Small Grazing Animals

As indicated, range rodents prefer as food plants which are early in the succession. Under some circumstances (20), the rodent may assist in overcoming the effects of overgrazing by speeding up the plant succession. This is done by lessening the competition between the climax perennial grasses and the forbs which some rodents find more palatable. Thus, while these rodents may prevent the recovery of a badly deteriorated range, they may also speed up the recovery rate of ranges that are not in as poor condition.

The main beneficial functions performed by the small mammals appear to be those of soil improvement. Indeed, it would seem also that the only other beneficial function carried on by these animals is to divert predators away from valuable game and livestock. Although the importance of animals in soil formation is recognized and briefly mentioned under the title of "biological forces", little data has been presented to show just how important these factors might be. Grinnell (95) believes that the presence of these small mammals brings to the native plants associated with them quite the same sorts of effects as the farmer produces by his "artificial" cultivation of the crop he raises. And the rodents and other small animals, be it noted, likewise take pay, in the form of seeds, fruit, leaves, stems, and roots.

It is believed by many investigators that the native small mammal burrowers contribute to the optimum welfare of
the plant associations in the following ways:

(a) Weathering of the substratum is promoted by burrow systems which carry air and water with contained solvents to the subsoil and parent masses below (95). By their presence the deepening of the soil is hastened.

(b) Subsoil is brought to the surface, where it is spread out by the action of the animals, the wind and rain, subjected to further weathering and finally incorporated with the topsoil. Bond and Borell (21) state that gophers in Yosemite National Park annually move an average of 3.6 tons of earth per square mile from underground to the surface.

(c) The activities of burrowing animals on ground that is not overgrazed tends to prevent erosion. During storms or rapid thaws, the burrows form entry ways for the water leading it into the porous ground for further slow distribution there (21). Unfortunately, in some instances, rodents accompanied by overgrazing have been shown to be the primary causes of erosion.

(d) Plant material is carried by the rodents into their burrows where it contributes to form organic matter in the dry western soils that are generally deficient in organic matter (222).

(e) The activities of rodents increase the supply of available nitrogen and other soil nutrients. Greene and Reynard (90) believe that the average nitrogen value of the Kangaroo rat burrow is 31.5 cents, while that of the wood rat is 10 cents. The rodent population of the Santa Rita Range Reserve is estimated at 2,000,000, of which about 500,000 are wood rats and 100,000 are Kangaroo rats (223). The value of the nitrogen from these two rodents in that area alone would then be 81,500 dollars.

(f) The mechanical loosening of the ground through the activities of burrowing animals makes for thrifty plant growth. This helps to combat the compacting effect of livestock feet, especially when the soil is wet (94).
If the effects of these small mammals are important to the rangeland biome as these investigators (90, 95, 94, 222, 25, 155) would lead us to believe it may well prove that their increase in numbers under conditions of overgrazing is beneficial rather than detrimental. Only the preponderantly beneficial effects of these animals has been discussed in this sub-section. It is very difficult to form any opinion as to whether, in the final analysis, these animals are economically beneficial or detrimental under conditions of overgrazing. When rangeland forages are properly handled, there is a slight excess of forage above all needs for livestock or for watershed protection except in abnormally dry seasons. Consequently, the consumption of forage by these animals is probably of little economic importance except on overgrazed ranges or in extremely dry seasons. A part of this forage is stored by the animals in their burrows, and a small part of the food consumed is returned to the soil in the excreta of the animals. This adds to the fertility of the soil and in addition there are also the physical effects mentioned that are produced by the burrowing of the animals and the probable increase of phosphorus available for plant use (90). Under present conditions, except where the situation becomes acute, it will probably be best to await the results of further studies before initiating any widespread recommendations. Until then the economic status cannot be verified under overgrazed or even normal conditions although it does not seem impossible that the beneficial effects may
equal the injurious effects of these small range mammals.

C. HARMFUL RANGE INSECTS

The destructive activities of grasshoppers are considered among the four chief causes of rangeland deterioration. The others are: severe long continued drought, overgrazing, and burial by dust or erosion. Dibble (71) found that severe grasshopper infestations, particularly on the lighter soils, have been a major contributing factor in soil erosion. Unfortunately, because of its size and the more spectacular effects that grasshopper infestations have on cereal crops, many ranchers ignore or do not appreciate the widespread damage caused by these insects. Allred (4) noted that the collaboration of heavy grasshopper infestations with the severe droughts of 1934 and 1936 brought about a 50 percent loss in sagebrush foliage (Artemisia tridentata). He found only a 15 percent loss of the same plant a short distance away where the drought was the same but the grasshopper infestation was much lighter.

The question might be asked: "How can grasshopper damage be related to overgrazing?" Branson (22) has shown that there is a correlation between insect population and certain moisture-temperature relations. There is an increase in grasshoppers in the areas that are grazed most heavily. The belief (71) that overgrazing alone by cattle would not have resulted in the complete denudation of grasslands and the subsequent loss of soil from wind and water erosion is
repudiated by Dibble. Further experiments (254) on normal and
overgrazed land showed that the total population in the over-
grazed grassland is on the average four times as great as in
the normal prairie, resulting in some cases in permanent dam-
age to the grasslands and great injury to food and shelter for
wildlife and cattle as well as to soil improvement and erosion
programmes (76).

While studying heavily grazed and overgrazed areas in
British Columbia (1947, 1947) as well as in Alberta (1946)
and Saskatchewan (1946, 1947), the writer found that the
numbers of grasshoppers present in those areas far exceeded
the numbers present on properly or undergrazed areas. Some
of the areas considered were immediately adjacent.

It may also be shown that while the initial break in the
habitat is due to rash overgrazing resulting in partial de-
 nudation and erosion, these factors in turn exert an influence
on the grasshopper population which contributes to further
denudation and erosion. Where this erosion is caused by wind
the grasshopper (Agencotettix deorum) has found a very
favorable environment.

Ball's study (10) of the grasshoppers of Colorado and
Arizona indicates that out of about 130 species of true grass-
hoppers occurring in each state, only about 5 or 6 should be
cased as injurious to crops and scarcely more than a dozen
more should be listed as of serious injury to the grasses of
the range. This leaves well over 100 species that are either
beneficial or of little importance one way or the other. He
states further that many grasshoppers are strikingly beneficial in that they help to check the weeds that would overrun the ranges. He fails to mention, however, that the "scarcely more than a dozen species of grasshoppers injurious to the range" readily multiply under favorable conditions to cause damages of the proportions shown in Table IX as well as cause considerable expense for control measures. Ball also fails to mention that under proper range management, i.e., when overgrazing is not present, the weed populations are controlled by the other species of the plant associations without the aid of the beneficial grasshoppers.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CULTIVATED CROPS</th>
<th>RANGELAND</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934</td>
<td>5,513,000</td>
<td>500,000</td>
<td>6,013,000</td>
</tr>
<tr>
<td>1935</td>
<td>2,434,000</td>
<td>600,000</td>
<td>3,034,000</td>
</tr>
<tr>
<td>1936</td>
<td>1,900,000</td>
<td>650,000</td>
<td>2,255,000</td>
</tr>
<tr>
<td></td>
<td>9,847,000</td>
<td>1,750,000</td>
<td>11,597,000</td>
</tr>
</tbody>
</table>

These figures are probably too low for the rangelands since they are based on an estimated damage of approximately 16 to 20 percent of the range in central and eastern Montana and a value of 10 cents per acre of the grass destroyed. There is also the cost of poison and control measures to be considered.

The Mormon cricket (Anabrus simplex), contrary to the
grasshopper species, is a general feeder which in plague proportions often ingests all the vegetation present in the path of its migration. Swain (216) has found that it has an affinity for the inflorescences causing great losses in the reproductive powers of the plants. His observations of one-tenth acre plots showed a loss in forage production varying from less than one percent to 100 percent, while one plot lost 56 percent of the total dry weight of the herbage, which is equivalent to 483 pounds of forage. This amount is more forage than much of the shortgrass prairie produces per year in its present general condition.

Smith (200) in studying insect populations on undergrazed, overgrazed, and eroded lands, found that habitat conditions in severely overgrazed areas appear to be very unfavorable to Chrysomelids (leaf beetles) but favorable to the Meloidae (blister beetles). In general the Hemiptera (bugs and lice) increase both in number of species and specimens under conditions produced by overgrazing but are not favored by changes brought about by erosion following severe overgrazing. The Hemoptera (cicades, treehoppers, etc.) showed behaviour similar to that of the Hemiptera in their reaction to overgrazing but showed their greatest abundance in somewhat eroded areas.

It is evident that again the results of overgrazing do not terminate with the simple loss of vegetation to the grazing domesticated animals, but some of the possibly available forage is also consumed by insects and other invertebrates, causing heavy losses to graziers and crop producers both through losses
D. PREDATORS OF DOMESTIC GRAZING LIVESTOCK AND WILDLIFE

Although predators cause only 1.5 to 2 percent of the annual livestock losses in the western rangelands of the United States (164), the spectacular nature of the loss has resulted in many predatory animal control programs. The establishment of rewards and bounties by many provinces, states, and stockmen's associations has resulted in considerable hunting and trapping by experienced hunters. The cost of these bounties is by no means a small financial matter (Table X). The following table shows the bounties paid by the British Columbia Game Commission alone (25):

<table>
<thead>
<tr>
<th>PREDATOR</th>
<th>RATE</th>
<th>BOUNTIES CLAIMED</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolves</td>
<td>$10/head</td>
<td>932</td>
<td>9,320.00</td>
</tr>
<tr>
<td>Cougars</td>
<td>$15/head</td>
<td>461</td>
<td>6,915.00</td>
</tr>
<tr>
<td>Coyotes</td>
<td>$5/head</td>
<td>239</td>
<td>1,195.00</td>
</tr>
<tr>
<td>Coyotes</td>
<td>$2/head</td>
<td>2,481</td>
<td>4,962.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1946</td>
<td>4,113</td>
<td>22,392.00</td>
</tr>
<tr>
<td></td>
<td>1922-46</td>
<td></td>
<td>673,658.80</td>
</tr>
</tbody>
</table>

(1) Coyotes

The coyote, a symbol of the rangelands of the North American West, is confined in its Canadian habitat to the three Prairie Provinces and British Columbia, where its range is restricted to the typically open or semi-wooded country.
Contrary to most predatory animals, the coyote populations have decreased only in isolated areas where vigorous coyote extermination has been undertaken. The greatest losses inflicted by coyotes are to the livestock industry, the stock affected being mainly sheep and poultry. Next to the losses inflicted upon domestic grazing animals come those upon game such as grouse, pheasants, and ducks, as well as deer. Although there are no records of outbreaks in Canada, considerable losses have been inflicted on domestic animals such as cattle, horses, and dogs, through the spread of rabies from coyotes (63). The introduction of domesticated grazing animals has provided a new source of food supply for the coyote which may enable it to survive when its normal diet falls short. Criddle (63) considers that the sheep-killing habit is by no means a usual one; being more the work of one or two old coyotes it is also probable that most of the damage is done by the large common coyote (*Canis latrans*) east of the Rocky Mountains and the almost equally large mountain coyote (*Canis listis*) west of them. In British Columbia, the mountain coyote shows a greater liking for sheep than the common coyote, resulting in articles by such men as Major Allan Brooks, the noted naturalist, and T.P. MacKenzie, former Provincial Commissioner of Grazing, each condemning the coyote.

On the other hand, not all the activities of the coyote are detrimental. It is useful both as a destroyer of noxious rodents and small range animals and as a fur producer. Attention has been drawn to the damage that may result from
the activities of the animals and insects that comprise the coyote diet. These items of diet may include rabbits, gophers, mice, birds, frogs, grasshoppers, white grubs, as well as the more publicized species such as calves, sheep and deer. Coyotes (80) on a 4,600 acre foothill range in California were found to feed mainly on cottontail rabbits and ground squirrels. They comprise 45.4 and 31.2 percent of the diet respectively. These facts indicate how difficult it is to arrive at an accurate conclusion as to the coyote's standing. At one time it does infinite harm, at another its benefits probably outweigh its harmful activities.

The evidence against the coyote relates to its destruction of sheep, occasional calves, and poultry. There are, however, years when due to rabbit scarcity the losses to livestock will be great. This problem can be overcome in most areas by studying the prevalence of wild rabbits and rodents and the necessary precautions taken accordingly. It is evident in areas of overgrazing where the rodent and rabbit population normally increases that the presence of the coyote is an aid toward protecting the grasslands from rabbit and rodent infestation, thus aiding the regrassing processes. In these areas the presence of a conscientious herder, especially just at dawn, will have a marked influence in reducing sheep losses from coyotes. Another expensive but useful protection is the coyote-proof fence.

The craving for lamb and mutton as well as venison, however, has made the continued existence of the mountain coyote
of British Columbia much less desirable if sheep production is to become a permanent success. In general, the administration and supervision of rodent and predatory animal control should be of the most rigorous kind so as to restrict the killing of detrimental species to the particular areas where they are clearly destructive, and even in such areas to reduce them to the requisite point. The control should be local and specific, not general and universal, and should be decided upon only after careful investigation.

(2) Wolves

It is well known that wolves destroy large numbers of deer and similar animals which are part of their natural diet. As in the case of coyotes, the introduction of domestic grazing animals has provided other prey which wolves take advantage of. Sheep probably suffer most, but young horses and cattle are often destroyed by them (63). The value of wolves lies chiefly in their pelts and as destroyers of noxious rodents and small mammals. Dr. Cowan (58) in studying timber wolves in the Rocky Mountain National Park of Canada found that 18 percent of the annual diet of wolves is rodents. They also play a useful part in eliminating sickly game animals due to the fact that the weakly are more apt to fall prey to them than are healthy animals. Men of the Waldo Stockmen's Association have stated that wolves and coyotes are among the stockmen's best friends. The reason for this is that they help keep down the numbers of deer and game
that migrate from the National Parks to the ranch haystacks during times of feed shortages. These stockmen, however, are engaged in cattle, not sheep, production.

Considering the information concerning the wolf, it would appear that in spite of its limited benefits it is far more detrimental and far too dangerous to tolerate in grazing districts.

(3) Other Predators

Among the other predators known to contribute to livestock losses are the mountain lion or cougar, the grizzly, black and cinamon bears, and the bobcat or lynx. However, there is no evidence in the literature that these species increase in abundance as a result of overgrazing, and hence they will not be discussed.

Much has been written concerning the effect that predatory mammals have on the rise and fall in abundance of various rodent species. It has been contended (57) that the persistent warfare on coyotes, bobcats, wolves, weasels and other predatory fur bearing animals is responsible for the excessive abundance at times of jack rabbits, field mice, ground squirrels, marmots, pocket gophers and other small mammals reputed to be agents of overgrazing.

Couch states that while there is no doubt that predatory mammals are a factor in controlling rodents, yet they play a small part in maintaining the balance. Large factors are involved and these include seasonal conditions, fecundity of
the species, the acts of man in providing abundant food, and the presence of natural and other shelter. On the other hand, rodents the size of ground squirrels or smaller are more effectively decreased in numbers by raptorial birds than by predatory animals. Couch believes that the value of predatory animals in controlling injurious rodents has been overestimated. Presnall's work (164) adds weight to this argument since he found that heavy rodent population cycles are unrelated to predator fluctuations. If these reports are verified it may result that the complete biological control of rodents (187) on overgrazed land can be carried out by raptorial birds and hence the stockmen will be free to eliminate the detrimental effects of the fur bearing predators while these birds assume the beneficial work formerly carried on by these animals.
VI. DISCUSSION

For over half a century periodic complaints have been made regarding overgrazing in the West and its abuses. These complaints and demands for corrective measures resulted in the establishment of the P.F.R.A. in Canada and the Conservation services in the United States. Through these bodies a concerted effort has been made to stem the destruction and economic loss caused by overgrazing. The question arises: "Why and how did overgrazing become such a problem that the legislatures of Canada and the United States were forced to appropriate large sums of money in an attempt to restore the productive and protective values of the rangelands of the West?"

The text indicates that one of the reasons necessitating such expenditures has been the lack of knowledge and understanding of the principles of range management. In the past many ranchers knew nothing of how to maintain semi-arid ranges, to restore depleted ranges, to plan grazing systems and to prepare for or prevent periods of drought and feed shortage.

The depletion of range forage, as indicated in the introduction, became of considerable concern prior to the turn of the century. The addition of sheep to ranges already stocked to capacity with cattle, coupled with the fact that
settlement and cultivation was eliminating much of the highly productive portions of the range, resulted in an intensified use of the remaining rangelands. This intensified use had but one result -- overgrazing.

While the effects of climate on grazing procedures have not been discussed, droughts do play a part in encouraging overgrazing. Ranchers have continually attempted to graze ranges without relating livestock numbers to carrying capacity or on the basis of the forage produced during periods of good growth. Again overgrazing is the inevitable result during periods of drought such as the mid 1930's.

Fluctuations in livestock prices have also played an important role in causing overgrazing. Stockmen who bought breeding herds at high prices during the peak of a boom period invariably graze more intensely in an attempt to realize a profit on a declining market.

The lack of a constructive national land policy (in both the United States and Canada) applicable to the semi-arid and mountain grazing lands of the West has been another major factor in overgrazing. The failure to classify grazing areas according to their actual long-term productive capacity -- as indicated in Section II -- has also played an important role in forage depletion.

Today, as previously discussed in the body of this Thesis, the western range areas constitute regions which are commercially suited only for grazing livestock because of one or more adverse agricultural conditions such as:
(a) rough topography;
(b) low precipitation, or the lack of facilities to develop irrigation, or adverse climatic conditions.

As indicated in Section IV, the demands made on native vegetation in range areas surpass that of supplying feed for grazing livestock. The preservation of a satisfactory watershed condition on rangelands is vital to the well being of the West. Irrigation, hydroelectric and municipal water supply enterprises depend on a stable flow from water yielding ranges. Water power is maintained by stream flow from range watersheds. It is of great importance to maintain an unbroken vegetation and a productive soil on all rangelands and the optimum yield of water from range watersheds. Depletion of the vegetation, as previously shown, has resulted in floods and erosion, menacing the social and economic security of the entire continent. The destruction of soil and the impairment of watershed values is without doubt one of the gravest results from misuse of the range.

In British Columbia, as elsewhere, factors such as wildlife, forestry and recreation are of value and interest to much of the population. As indicated in the text, these factors must also be considered in determining a range policy or management program.

How can the productivity and value of the western grazing regions be maintained? The answer lies in the application and strict adherence to the principles of sound range management. Management of western ranges with their intri-
cate and variable pattern of conditions and their interlocking private and public values is not an easy job. It has to do with determining the proper grazing system, grazing capacity, season of use, class of livestock, reseeding practices, game management program, and all related activities necessary to attain the highest use consistent with the protective and sustained yield of all the resources.

Conservation and protection of the grazing resources of British Columbia and elsewhere may be achieved with little skill or efficiency simply by restricting use. To do so, however, would result in unemployment for a considerable portion of the population. The most efficient method is to apply the knowledge and skill which will result in the highest yield of resources consistent with their perpetuation.

An appraisal of either the resource of its depletion is possible only in terms of their social and economic significance. The production of livestock, the water yield, and the income, pleasure, and diversion from the wildlife and recreational opportunities dependent on grazing lands mean nothing unless they add to a nation's welfare. On the other hand, a reduced grazing capacity, erosion, floods, dust storms, depletion of wildlife populations, and the inhibition of recreation carry no import unless they detract from the nation's welfare.

The question arises: "Are the effects of overgrazing in interior British Columbia as drastic as those found in other areas throughout the western grazing regions?" In answering
such a question, many factors must be weighed and considered. Areas such as Indian reserves, roadsides, cattle trails and holding grounds have been as seriously abused as any other grazing areas in the west. However, British Columbian rangelands, in general, have suffered to a lesser degree than average for one or more of the following reasons.

(1) Because greater returns could be made on investments in lumbering, mining and other more intensive forms of agriculture, the early competition for grazing lands was not as intense as it was in other areas throughout the West.

(2) The topography of the rangeland and the natural vertical zonation of the vegetation permits a natural form of rotational grazing. The stock winter in the valley bottoms and as plant growth advances, they gradually graze up and onto the higher grazing regions.

(3) The nature of the topography and the vegetation tends to divide the rangelands into natural grazing units, many of which are individually owned and controlled.

(4) Long winter feeding periods, rough topography, shipping and trailing difficulties, predatory animals, and other environmental factors masked the true value of the interior rangelands and discouraged intensive livestock production for many years.

(5) There was and is now a shortage of haylands and winter feeding grounds.

(6) The climate of British Columbia is not subject to the periodic fluctuations found in many of the grazing regions.

(7) Rainfall intensity is considerably less than that found in most grazing regions.

While grazing has not been as severe in British Columbia as in many other areas, it has certainly not been negligible
or absent, nor has the interior been spared the disturbances in the biotic community which are associated with overgrazing. The deterioration and abuse of spring-fall range is almost universal throughout the West, and British Columbia is no exception. Nor is there any indication that the extent or carrying capacity of this type of range will be markedly increased. The major expense in producing range livestock is wintering and emergency feeding. It is only natural, then, for the producer to attempt to turn out his herd as soon as new growth begins in the spring. Granted, he saves on the cost of wintering under this system, but he does not give the vegetation a chance to become established, to replenish root reserves, or the ground a chance to dry. Under such conditions, the vigor of the plants on spring range is weakened. These ranges receive further abuse in that when ranchers round up fat stock for the late June market and find that the market is poor or the shipping date delayed, they leave these animals on the lower grasslands (spring-fall range) until they can be shipped. During this period the fat stock are able to graze a high percentage of the seed culms or again reduce the vigor of the plants to such a degree that plant reproduction is hindered or delayed. With the further expansion of irrigation, more of the spring-fall range will be lost, resulting in a further intensification of its use.

Lower grasslands are not the only vegetational zone to suffer overgrazing, but as extremities of the range, such as the forest zones, are approached, the deleterious effects
lessen. The use of forested ranges for summer grazing has removed some of the grazing pressure. Until recent years, many ranchers could not be convinced that livestock are able to make economical gains from open coniferous forest range during the summer and early fall. The adverse ratio of spring-fall range to summer forest range is one of the basic causes for the lack of full utilization of forest range.

Many other factors may be introduced to increase the productivity of British Columbia rangelands. Reseeding depleted ranges to species such as crested wheatgrass can do much toward increasing the carrying capacity of these ranges. Management practices such as fencing and riding, salting and water development, to control livestock movements will assure optimum utilization of the range forage. The control of parasites such as flies and ticks and the use of well bred stock that can make economical gains will also do much toward deriving the maximum returns from a range.

With the exception of the Chilcotin and upper Windermere Valleys, the vegetation of range areas throughout British Columbia is improving. This is due to the combined effects of improved management, livestock, and grazing practices, the increased use of forest range, better growth conditions, increased activities and efficiency of the Grazing Division of the B.C. Forest Service, high livestock prices and freedom from grasshopper outbreaks. The causes of overgrazing in the Chilcotin Valley are being removed, by the activities of the Forest Service, while the Dominion Experimental Farm Service
is conducting reseeding experiments. The situation in the Windermere Valley has arisen largely through the neglect of the ranchers. They have permitted horses to run wild, and consequently the horse population has increased tremendously. The Forest Service is planning to restrict the number of horses in this area during 1949.

While other areas throughout the West have suffered excessive water and sheet erosion, there is very little evidence of harmful soil loss throughout the ranges of interior British Columbia. There are some indications of erosion along roadsides and on knolls, especially in the Thompson and Nicola Valleys, but these are not considered serious. In this respect, much credit is due to the annual grass downy brome or cheatgrass. This plant invades overgrazed regions, leaving the soil well covered and closely bound. Other reasons for the lack of soil erosion have been discussed. To what degree overgrazing has increased the speed of run-off and reduced the water holding capacity of the rangelands of this province has not yet been determined.

During the 1930's and early 1940's, outbreaks of grasshoppers caused some alarm among the ranches of the Nicola, Chilcotin, Similkameen, Thompson and Okanagan Valleys. However, the combined effects of good growing conditions, good livestock prices, and sound management practices has reduced the extent of many of the grasshopper breeding grounds. At one time, some of the Douglas Lake Cattle Company ranges were notoriously overgrazed and noted to be some of the most
prominent breeding grounds of grasshoppers in the Nicola Valley. Under the astute management of Mr. B.K.DeP. Chance, the depletion of these ranges has ceased and a marked improvement in the vegetation may be seen. At present the Nicola Indian Reserve is one of the few grasshopper areas in the Nicola that has not shown improvement. Mr. Buckell, Dominion Entomologist, Kamloops, B.C., now considers that the greatest grasshopper danger areas are in the Chilcotin Valley.

Small mammals have never been as great a problem in British Columbia as in other areas of the West. This is probably due to the prevalence of predators. The only area that has suffered to any great extent has been that portion of the Nicola Valley near Stump Lake. At one time there was a fairly high concentration of ground squirrels in this area, but today they are virtually absent. In fact, many of the signs of rodent habitation, such as burrows and earthen hummocks, have disappeared. Many of the ranchers in this area claim that the removal of the coyote bounty and the subsequent return of this predator caused this reduction in ground squirrel numbers.

Dr. Cowan believes that reports of the control of hibernating animals such as ground squirrels by predators must be carefully weighed and considered. Undoubtedly, the improvement in native vegetation played some part since this animal, as previously indicated, prefers associations lower in the vegetational succession.

The effects of predatory animals such as wolves, bears, and cougars, are more strongly felt in British Columbia than
in most range areas. However, it is the writer's belief that this predation is not the result of overgrazing but rather that large expanses of uninhabited land are prevalent throughout the province.

In the United States, conservationists are gravely concerned with the wildlife situation, especially that of the deer, elk and other big game species. Throughout much of the range regions of the United States there are few areas that are unsuited for domestic livestock production, and consequently there is little range left for wildlife. If the ranges are overgrazed, there is not enough feed left for wildlife, and starvation is the inevitable result. In British Columbia, on the other hand, the situation is reversed. There is relatively little range suitable for domestic livestock production while with the possible exception of winter feeding grounds the wildlife species have virtually the same range they always had.

Unfortunately, overgrazing has caused considerable hardships for game birds, especially ducks. Many of the lakes, swamps, and ponds on interior rangelands serve as resting places and breeding grounds for migratory ducks. Many of the swamps have been drained and used for the production of wild or swamp hay which is a source of winter feed for livestock. Under conditions of overgrazing, livestock crop the vegetation around the shores and edges of many of these lakes and ponds to such a degree that no vegetation and hence no protective cover is left for the nesting birds. Dr. Cowan suggests that
a portion of the shore line of these ponds and lakes should be fenced off to allow the ducks an opportunity to nest.

In summary, it is clear that the rangelands of British Columbia are improving and many of the deleterious practices that have contributed to overgrazing in the past are being eliminated. However, care must be taken so that the conditions of overgrazing that became so prevalent throughout the entire West are never permitted to occur again in British Columbia.
VII. SUMMARY AND CONCLUSIONS

(1) Present range regions, in British Columbia and the West, have resulted from interactions of edaphic and biotic factors.

(2) Rangelands of British Columbia comprise a small portion of the area of this province; the grazing regions represented are the bunchgrass and coniferous forest regions.

(3) An appraisal of the grazing history of the West leads to an understanding of present range conditions.

(4) A vegetative cover is of prime importance in the maintenance of the West. Realization of this was generally late in coming. Extension and range surveys have done much toward obviating the protective and productive value of such cover.

(5) Classification of vegetation provides a basis for determining the intensity of range use and future range management practices.

(6) In British Columbia, as elsewhere, range enterprises are dependent upon livestock products production per acre rather than livestock numbers.
With overgrazing, calf and lamb crops, wool production, and meat production decrease, while death and forage wastages increase.

Removal of the vegetative cover by overgrazing causes serious losses through wind and water erosion. Although in British Columbia less attention to erosion is required because ranges are protected from high velocity winds by topography and because rainfall intensity is low, erosion cannot be totally ignored.

Rangelands, including those of British Columbia, are the home of wildlife as well as domestic livestock. Because part of the population is interested in wildlife from an economic, moral or recreational viewpoint, the claims of wildlife to ranges used for domestic livestock production must be considered. Foresight and planning solves this problem to mutual advantage.

Overgrazing results in increased numbers of small mammals and insects, many of which cause considerable damage.

The broad concepts presented in this Thesis are intended to integrate overgrazing and its effects in such a manner that this work may serve as a basis for future research on the rangelands of British Columbia.
APPENDIX A

Doubt has been expressed regarding the legitimacy of including domesticated grazing animals among the components of an ecosystem or "biotic community". Professor Phillips (154) makes a point of separating the effect of grazing herbivorous animals naturally occurring in the "biotic community", viz., the bison and antelope from the effect of grazing animals introduced by man. The bison and antelope are said to have co-operated in the production of the short-grass vegetation of the Great Plains (129) and to have assisted in preventing the invasion of grasslands by the forest. Domesticated grazing animals are supposed to be destructive in their efforts and to play no part in the successional or developmental process (220). It is obvious that modern civilized man upsets the "natural" ecosystems or "biotic community" to a considerable degree. However, it would be exceptionally difficult if not impossible to draw a natural line between the activities of the human tribes, which presumably fitted into and formed part of these "biotic communities" and the destructive human activities of man and the modern world. The question then becomes: "Is man part of 'nature', or not?" Man is regarded as an exceptionally powerful biotic factor which increasingly upsets the equilibrium of formerly existing ecosystems, even to the extent of destroying some of them. At the same time, human activity often forms new ecosystems sometimes of exceedingly different nature.

As an ecological factor acting on vegetation, the effect of grazing heavily enough to prevent the development of the previously mentioned forest growth is basically the same effect regardless of how and when it occurs. If such is the result of grazing, the grazing animals are a very important factor in the biome actually present regardless of how they got there, whether they migrated to that place by themselves or whether they were introduced by modern man.

The substitution of one type of vegetation for another, be it a grassland or a forest vegetation, involves destruction to some degree; but it also involves the gradual establishment of a new vegetation culminating in a climax that is well defined under the influence of the factors present. Needless to say, when man introduces grazing animals such as cattle, sheep and horses, restricting them with fences and protecting them by destroying predators, he sets up an ecosystem whose essential feature is the equilibrium between the grassland and the grazing animals. In such a way the "biotic communities" may be altered from one developed independently of man.
but the essential formative processes of the vegetation are the same, however the factors initiating them are directed.

It is therefore essential that we have a system of ecological concepts which will allow the inclusion of all forms of biological expression and activity. We must not confine ourselves to the so-called "natural" entities and ignore the processes provided as the result of the activities of man.
### Appendix B

**Scientific and Common Names of Plants Discussed**

<table>
<thead>
<tr>
<th>SCIENTIFIC NAME</th>
<th>COMMON NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. GRASSES</strong></td>
<td></td>
</tr>
<tr>
<td>Agropyron inerme (Rybd.)</td>
<td>Awnless wheatgrass</td>
</tr>
<tr>
<td>Agropyron Smithii (Rybd.)</td>
<td>Bluestem wheatgrass</td>
</tr>
<tr>
<td>Agropyron spicatum (Pursh.)</td>
<td>Bluebunch wheatgrass</td>
</tr>
<tr>
<td>Bromus tectorum (L.)</td>
<td>Downy brome (Cheatgrass)</td>
</tr>
<tr>
<td>Calmargrostis longifolia (Hook.)</td>
<td>Sand grass</td>
</tr>
<tr>
<td>Calmargrostis rubescens (Buckl.)</td>
<td>Pine grass</td>
</tr>
<tr>
<td>Elymus condensatus (Presl.)</td>
<td>Giant wild rye</td>
</tr>
<tr>
<td>Festuca arizonica (Vasey.)</td>
<td>Arizone fescue</td>
</tr>
<tr>
<td>Festuca idahoensis (Elmer.)</td>
<td>Bluebunch fescue</td>
</tr>
<tr>
<td>Festuca scabrella (Torr.)</td>
<td>Rough fescue</td>
</tr>
<tr>
<td>Hordeum jubatum (L.)</td>
<td>Wild barley</td>
</tr>
<tr>
<td>Koeleria cristata (L.)</td>
<td>June grass</td>
</tr>
<tr>
<td>Muhlenbergia montana (Nutt.)</td>
<td>Mountain muhley</td>
</tr>
<tr>
<td>Oryzopsis humenoides (Roem. &amp; Schult.)</td>
<td>Indian rice grass</td>
</tr>
<tr>
<td>Poa pratensis (L.)</td>
<td>Kentucky bluegrass</td>
</tr>
<tr>
<td>Poa secunda (Presl.)</td>
<td>Sandberg's bluegrass</td>
</tr>
<tr>
<td>Stipa comata (Trin.)</td>
<td>Common spear grass</td>
</tr>
<tr>
<td>Stipa columbiana (Macoun.)</td>
<td>Columbia spear grass</td>
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<td></td>
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<tr>
<td><strong>B. FORBS, SHRUBS, and TREES</strong></td>
<td></td>
</tr>
<tr>
<td>Abies spp.</td>
<td>Fir species</td>
</tr>
<tr>
<td>Artemisia frigida (Willd.)</td>
<td>Pasture sage</td>
</tr>
<tr>
<td>Artemisia snaphalodes (Nutt.)</td>
<td>Prairie sage</td>
</tr>
<tr>
<td>Artemisia tridentata (Nutt.)</td>
<td>Sagebrush</td>
</tr>
<tr>
<td>Astragalus serotinus (A.Gray)</td>
<td>Timber milk vetch</td>
</tr>
<tr>
<td>Balsalmorhiza sagittata (Nutt.)</td>
<td>Balsam root</td>
</tr>
<tr>
<td>Brassica spp.</td>
<td>Mustard species</td>
</tr>
<tr>
<td>Cicuta occidentalis (Greene)</td>
<td>Water hemlock</td>
</tr>
<tr>
<td>Crysothamnus nauseosus (Pall.)</td>
<td>Rabbit brush</td>
</tr>
<tr>
<td>Delphinium bicolor (Nutt.)</td>
<td>Two-coloured larkspur</td>
</tr>
<tr>
<td>Elaeognus commutata (Bernh.)</td>
<td>Wolf willow (Silverberry)</td>
</tr>
<tr>
<td>Gutierrezia sarothrae (Britt. &amp; Rusby)</td>
<td>Broom weed</td>
</tr>
<tr>
<td>Lactuca spp.</td>
<td>Lettuce species</td>
</tr>
<tr>
<td>Lappula occidentalis (Greene)</td>
<td>Little bluebur</td>
</tr>
<tr>
<td>Lathyrus orcholeucus (Hook.)</td>
<td>Creamy peavine</td>
</tr>
<tr>
<td>Lupinus arcticus (S.Wats.)</td>
<td>Arctic lupine</td>
</tr>
<tr>
<td>Madia spp.</td>
<td>Madia species</td>
</tr>
<tr>
<td>Norta altissima (L.)</td>
<td>Tumble mustard</td>
</tr>
</tbody>
</table>
Picea spp.
Pinus contorta (Dougl.)
Pinus ponderosa (Dougl.)
Prunus melanocarpa (A. Nels.)
Pseudotsuga taxifolia (Britt.)
Rosa spp.
Salsola pestifer (A. Nells.)
Sisymbrium spp.
Tragopogon pratensis (L.)
Zygaenus venenosus (S. Wats.)

Spruce species
Lodgepole pine
Western yellow pine
Black-fruited choke cherry
Douglas fir
Rose species (wild)
Russian thistle
Mustard species
Ghost's beard
Death camus
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