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Scope and Method of Study: A search of available literature was made to discover the effects on natural vegetation of as many species of rabbits and rodents as possible. Each genus is treated separately (with the exception of Tamiasciurus and Sciurus), and information is given concerning food habits (qualitative and where possible, quantative) and probable economic value.

Findings and Conclusions: Jack rabbits tend to prefer overgrazed or otherwise open areas and can hold these areas in a preclimax state or practically denude the area of desirable vegetation. Snowshoe hares may destroy many seedlings, but this action can be useful in thinning crowded stands. Cottontails girdle trees at times, but this usually occurs during the winter when other vegetation is unavailable. Other rabbits are generally thought to be of no particular harm to natural vegetation.

Harmful rodents are usually present in reduced numbers on well managed areas and cause no great amount of damage. Some smaller rodents may be present in dense stands of vegetation, but generally they are of no harm due to their size, numbers or their diet which may consist predominately of insects. However, populations of both rodents and rabbits may become great enough to cause localized trouble at times, and some control may be needed.

Although many investigations have been made, it was determined that more work needs to be done in certain geographical areas where effects of some species are uncertain or unknown.

ADVISER'S APPROVAL Jerry J. Proctor

EFFECTS OF RABBITS AND RODENTS ON NATURAL VEGETATION IN THE UNITED STATES

By

GERALD PAT HUTCHINSON

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Report Adviser

Dean of the Graduate School

PREFACE

While there has been a great amount of work done on the effects of rabbits and rodents on natural vegetation, it is clear to me that there remains a great deal left to discover. A rancher in Oklahoma wants to know what is the effect of a certain species of rodent or rabbit on his forage, not what is the case in Arizona or California. In other words, more localized investigations are needed.

I wish to express my gratitude to Doctor J. J. Crockett for his encouragement, suggestions and time spent reading and constructively critizing this report.

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CHAPTER I

INTRODUCTION

> Under original conditions, jack rabbits, rodents, prong-horned antelope, and other game species were in equilibrium with range forage, which they were powerless to injure seriously. (Taylor, Vorhies and Lister, 1935).

When agriculture and livestock were introduced to the prairies and plains of the United States, a balance between endemic animals and vegetation was upset which has not been restored. As it was noticed that range land was deteriorating, those persons directly interested began searching for causes. Rabbits and rodents, probably first noticed for their effects on cultivated lands, were naturally suspected. Ranchers likely found it easier to blame rodents and rabbits for forage depletion and subsequent land deterioration rather than overgrazing brought about by their own mismanagement. Foresters also became interested in what effects rabbits and rodents were having on natural and reseeded timber areas. Recently, on the Southern Great Plains Experimental Range near Woodward, Oklahoma, estimates were made indicating that 45 per cent of the forage which disappeared during the period from 1950 to 1957 was not

eaten by cattle. (McCulloch, 1959). Again, rodents and rabbits were suspected of at least partial destruction of the missing vegetation. With the preceding in mind, an investigation was made into the present status of knowledge of the effects of rodents and rabbits on the natural vegetation of the United States.

CHAPTER II

LAGOMORPHS

Many papers have been written on lagomorphs in general, however some species have received little study. Several studies have been merely qualitative with little attention paid to the quantitative aspect. In these cases, and for those species which have had little study, only the probable economic status of the species is given.

Jack Rabbits

The blacktail jack rabbit (Lepus californicus), according to Burt and Grossenheider (1952), ranges on the grasslands and open areas of western and southwestern United States. Much quantitative data regarding its food habits and the resultant effects of these habits have been obtained, particularly in the southwest.

Vorhies and Taylor (1933) made an investigation of the relationship of the blacktail, and its cousin the antelope jack rabbit (L. alleni), to grazing on the Santa Rita Range in southern Arizona. The antelope jack rabbit occurs in the United States only in a small area of southern Arizona, the rest of its

range being south into Mexico. By feeding caged blacktail jack rabbits pre-weighed amounts of food and weighing that which was left at the end of each feeding period, the amount of food which one rabbit could eat in one day was determined. This amount was calculated at 0.68 pounds per day. Similarly, calculations were made for the antelope jack rabbit which was found to eat 1.28 pounds per day. Translated into more meaningful data, it was found that 15 antelope jack rabbits could eat as much as one 120 pound sheep, and 74 as much as one 750 pound cow in one day. Twice as many blacktail jack rabbits were required to consume the same amounts.

Stomach analyses of rabbits taken from the wild state showed 36 per cent of the food of the antelope jack rabbit to be mesquite (Prosopis sp.) while 45 per cent was grass. Mesquite accounted for 56 per cent of the diet of the blacktail jack rabbit while 24 per cent was grass. These figures show 80 per cent of the food intake of both species to be grass and mesquite leaving 20 per cent for weed consumption. According to the authors, these figures probably underestimate the importance of weeds as jack rabbit food.

While perhaps underestimating weed importance in the diet of jack rabbits, the figures certainly point out the fondness of the two species for grass. However, a study made by Taylor, Vorhies and Lister (1935) showed that the condition of the particular grazing land was a prime factor in jack rabbit populations, and that weed presence was important in jack rabbit pressure. In 1922, the Forest Service set aside three exclosures of grassland

in the following manner. In plot A, grazing was allowed only during the growing season (July, August and September). On October first, and for the rest of the grazing year, all grazing was stopped. On plot B, grasses were grazed from October first to January 31 and protected the rest of the grazing year until 1930 when it was protected year-long. Plot D was exposed to year-long grazing. Pellet counts were used to determine rabbit pressure on each site. It was found that jack rabbits were more than three times as numerous in plot A (grazed during the growing season) as in plot B (protected). Rabbit occurrence on the unprotected area was not as heavy as on the lightly grazed area; however despite the fact that vegetation was much more abundant in the ungrazed plot, rabbit pressure was nearly twice as heavy on the totally unprotected area. The same procedure was followed on other sites on the range with the same results in each case. The rabbits seemed to prefer the finer stemmed, short-lived annual and perennial vegetation to the perennial grasses which were in greater abundance and unprotected from them.

While jack rabbits increased with increased grazing pressure, the authors also point out that there is a limit to this increase, and that when over-grazing severely depletes the available vegetation the rabbit population decreases. Rabbits probably hasten this depleted condition. Parker (1938) found that jack rabbits could consume as much as 99.4 per cent of the perennial grasses on an already deteriorated range.

Damage to vegetation by jack rabbits also occurs in other ways. Costello (1944) found that the rabbits clipped the stems

of certain desirable grasses before the seed heads had had a chance to mature. Vorhies and Taylor (1933) reported that rabbits cut off grass stems and leaves and did not eat them but left them laying. They also indicate that jack rabbits along with rodents are seemingly the causitive agents for holding vegetation in a preclimax state. Johnson (1923) states that jack rabbits are the worst pests to trees in the great plains because they strip bark from older trees and cut off seedlings at ground level. Of course, by destroying desirable vegetation, jack rabbits promote the invasion of less desirable species.

Jack rabbits are also important dissemination agents. Timmons (1942), in an investigation near Hays, Kansas, found prickly pear (Opuntia spp.) seeds in jack rabbit droppings. These seeds were not only viable, but 50 per cent more so than seeds taken from dried fruits. Timmons concluded that jack rabbits were important disseminating agents of prickly pear throughout western Kansas. Brown (1947), in another study near Hays, concluded that:

> ...jack rabbits and cottontails are of considerable assistance in introducing seeds of prairie plants into abandoned cultivated fields and range land denuded by drought and overgrazing.

He also found that seeds of buffalograss (Buchloe dactyloides), cactus (Opuntia spp.) and smooth sumac (Rhus glabra) taken from rabbit pellets were viable and increased in germination potential after passing through the digestive tract of the animal. Seeds of sand dropseed (Sporobolus cryptandrus) seemed to be little affected by the digestive processes, but more importantly, during

a six months period, 12.75 pounds of the seed were deposited on a one acre plot of abandoned crop land. According to Brown this is considerably more seed than is necessary for reseeding formerly cultivated fields. In an anonymous article (1948) it was stated that jack rabbits were partially responsible for the spread of cedar trees (Juniperus spp.) throughout 18 million acres of land in Texas and Oklahoma. Lehrer and Tisdale (1956) found that seeds could remain viable as long as four days in rabbit digestive tracts, and that it was indeed possible that plant species could be spread by rabbits throughout great areas in short periods of time.

Indirectly and perhaps only slightly, rabbits, by destroying desirable forage, affect the numbers of undesirable insects on grazing lands. Treherne and Bucknell (1924) and Weese (1939) have found that on depleted ranges, populations of grasshoppers and other insects are considerably higher than on ranges in good condition.

Despite the potential for damaging vegetation that jack rabbits possess, most authors agree that on properly managed grasslands, rabbits will be no great problem. The real problem, in fact, lies in careful management of range land.

The Snowshoe Hare

The snowshoe hare (Lepus americanus) is an inhabitant of the forests and swamps of the colder regions of North America report Burt and Grossenheider (1952). The hare has been studied as to the effects it has on the forests by authors who take stands

ranging from condemnation to highest praise. The following brief accounts will illustrate this fact.

Baker, Korstian and Fetherolf (1921), who studied the relationship of snowshoe hares to conifers in the Wasatch Mountains of Utah, report that damage to trees results from the rabbits' actions of girdling and eating buds, twigs and tops of the trees. They state, however, that this occurs mainly in the winter when other succulent vegetation is not available. As the snow becomes progressively deeper, the rabbits eat progressively higher and even trees which would be otherwise too high are damaged. In general, the investigators found that damage is greatest to pine trees because young pines have only one leader while spruce and fir trees have more than one or are capable of growing side branches.

Aldous and Aldous (1944) cite several instances of snowshoe hare damage to trees. An especially severe case was one in which rabbits kept a 24-year-old mixed stand of red and white pines (Pinus resinosa and P. albicaulis) at a height of one to two feet. It should be noted that most of the cited cases occurred on plantations rather than natural reproducing areas, however.

Adams (1959) found that rabbits may cut seedlings off near ground level, leaving no trace of them, and that heavily used species in the diet may be actually underestimated.

Hough (1945) reports on a study made in the Kane Experimental Forest in Pennsylvania. The investigation was carried out on an experimental plot consisting of 49-year-old second growth stands on plateau and lower slope sites. The results indicated that tree

reproduction increased as much as 232 per cent to 305 per cent over a five year period when protected from deer and rabbits. This fact became more significant when a similar area showed little increase in reproduction while being protected from deer alone.

Grange (1932) found that from his observations, he had seen no seriously detrimental effects of snowshoe hares on natural vegetation and growths of forest trees in Wisconsin.

Cox (1938) probably has taken the most favorable stand concerning the snowshoe hare when he states that:

> It is an important factor accelerating tree growth and reducing fire and insect damage in the northern forest clear across the continent.

He further states:

> Were it not for the snowshoe hare, it is practically certain that millions of acres of dense thickets would be formed which would suffer increased fire losses and damage from insects as well as from stagnation.

Cox believes that hares are more or less a natural control on themselves in that they move to heavier cover after thinning stands of trees, or they leave themselves open to predation. He concludes that:

> It is manifestly impossible to arrive at any figure representing the saving effected by the snowshoe hare through the reduction of fire and insect losses. But unquestionably the saving is very considerable.

Arctic and Tundra Hares

The arctic and tundra hares (Lepus arcticus and L. othus) probably should be in the same species according to Burt and Grossenheider (1952). Little information is available on either. Howell (1936) describes the arctic hare as being dependent upon the dwarf plants which appear during the short growing season. When food is more scarce they are reported to eat moss and withered grass. They are probably of neutral economic value.

Whitetail Jackrabbit

The whitetail jack rabbit (L. townsendi) inhabits the northern plains and western mountains. (Burt and Grossenheider, 1952). Due to the lack of information available, it is assumed to have habits similar to the blacktail jack rabbit.

Cottontails

At least one species of cottontail (Sylvilagus spp.) occurs in each of the continental United States. (Burt and Grossenheider, 1952). The rabbits are of approximately the same average size, two and one half to three pounds, with the exception of the eastern cottontail which averages slightly larger. Regardless of where found, they have similar habitat and food preferences.

Dalke and Sime (1938) describe the preferred habitat type of the eastern cottontail (S. floridanus mallurus) in Connecticut as being "an interspersion of shrubs, grass and herbs, and an all-aged timber type." Haugen (1942), studying the cottontails in Michigan, agrees that "In general, most individuals were found on areas with a minimum of large-crowned trees, and with generous amounts of shrubby vegetation." Dalke and Hosley (1942) have also placed the New England cottontail (S. transitionalis) in this general habitat type. Fitch (1947) concurs, with the exception of trees, by similarly describing the home range of the desert cottontail (S. auduboni). Borell and Ellis (1934) found the mountain cottontail (S. nuttalli) occupying flats heavily covered with sagebrush and rabbit bush or along stream beds lined with heavy brush and willows.

The cottontail has a large and varied diet. Lantz (1916) states that cottontails will feed on vegetation of all kinds. Sweetman (1949), observing the winter feeding habits of the eastern cottontail in Massachusetts, lists 111 species of woody vegetation in its diet. He reports that the rabbits feed on herbaceous vegetation as long as it is available; at times

digging through soft, shallow snow cover to find it. However, when a snow crust forms, the rabbits turn to the woody species for sustenance. They prefer the succulent sprout and sucker growth to the older, more woody stems. They also have been observed pruning and barking vegetation without feeding. Sweetman lists 64 species in 22 families as being susceptible to extensive injury by cottontails and 44 species as being severely damaged. Nearly all members of the Betulaceae, Fagaceae, Lauraceae, Rosaceae, Cornaceae and Ericaceae families were readily taken by cottontails.

Ingles (1941), studying the desert cottontail in California, fed two rabbits a mixture of native grasses and forbs during a 15 hour period. The rabbits ate 209 and 171 grams of food apiece. Trippensee (1934), according to Ingles, attributes an average of 55.2 grams of food daily to the eastern cottontail. No reason for the greater food consumption by the slightly smaller species is given. No quantitative data could be found for the mountain and New England cottontails.

Fitch (1947) advises that rabbit damage to range land must include not only actual food consumption, but consideration of plant species which are cut down and destroyed or only partially eaten, vegetation which is trampled on the runways and elsewhere, and plants eaten back and stunted in early stages of growth.

Brown (1947) found the cottontail to be slightly less important than the jack rabbit is dissemination of seeds.

Marsh Rabbit

The marsh rabbit (Sylvilagus palustris), found along the east coast from Virginia to Florida, according to Burt and Grossenheider (1952), was found to consume an average of 460 grams of food in 24 hours by Blair (1936). Svihla (1929) found that captive rabbits could consume half their weight in vegetation per day. However, the natural diet in each case consisted of many species of vegetation, and the quantity consumed by a population of marsh rabbits was determined to be small when compared with that which remained.

Swamp Rabbit

The swamp rabbit (S. aquaticus) is found principally along streams and other low, wet areas in the Mississippi valley as far north as southern Ohio. (Burt and Grossenheider, 1952). Toll, Baskett and Conaway (1960) report the rabbit's diet consists of grasses, sedges, forbs, and bark and shoots of trees. No reports of severe damage to vegetation were found. Economic value is probably good due to its value to the hunter.

Brush Rabbit

The brush rabbit (S. bachmani) has been studied by Connell (1954) in the California Chaparral. It was found to prefer brush for cover and an adjoining grassland for food. To the present time, the rabbit has had little effect on the chaparral, which has its greatest value as watershed rather than as grazing land.

Pigmy Rabbit

The pigmy rabbit (Sylvilagus idahoensis) averages one half to one pound in size and ranges over a small portion of the northwestern United States. (Burt and Grossenheider, 1952). Reports of damage to vegetation are lacking. At the present time it is of neutral economic importance.

CHAPTER III

NUTRIA

Nutria (*Myocastor coypus*) were introduced into the United States from Argentina in the late 1930's. At the time, they were popular fur animals and were raised on fur farms in several states. Due to carelessness of the fur raisers and damage to enclosures by storms, several animals escaped into the wild and, in time, established feral populations. Since then, the popularity of the animal has steadily decreased.

There have been scattered reports of nutria in many states, but they are now most abundant in Louisiana. In southern Louisiana, they are occupying areas once populated by muskrats, and are destroying aquatic vegetation formerly used by muskrats and waterfowl. Attwood (1950) found that their food is limited to succulent and soft portions of roots and tubers, with most of the coarse emergents and some floating plants being utilized. A survey of food items in freshwater impoundments of Texas by Swank and Petrides (1954) indicates that nutria readily eat cattail (*Typha latifolia*), giant cutgrass (*Zizaniopsis miliacea*), arrowhead (*Sagittaria spp.*), panic grass (*Panicum sp.*), white water lily (*Nymphaea elegans*), pickerel weed (*Pontederia cordata*)

and others, though to a lesser extent. The animals tended to cut almost all stems in a small area, thereby making openings in an otherwise vegetation choked marsh. Harris (1956) reports that nutria seem to have no effect on submerged vegetation. Once being praised as a control for unwanted aquatic vegetation, their value is now questioned and in many areas, in part due to attacks on crops, they are definitely undesirable. However, Presnall (1958) states:

> Factual data on which to base informed opinions are incomplete and there is great need for investigations of the ecological and economic relationship of nutria to native fauna and agriculture.

CHAPTER IV

SQUIRRELS, PRAIRIE DOGS AND CHIPMUNKS

Tree Squirrels

The genera Sciurus and Tamiasciurus, which were once one genus, are considered here together because of their ecological similarity. These arboreal animals are well known to hunters for the sport they provide; however, they are well known to lumbermen for the damage they cause to trees.

Fritz (1932) describes the action of girdling by which squirrels damage trees:

> The squirrels operate in the early spring when the cambium has been stimulated to action and the region just under the bark is apparently more palatable to them than at other times. They strip the bark from the upper trunk, usually at a point where the diameter is over two inches and under ten inches. The strips are narrow, not over one inch wide, and vary in length from about four inches to over twelve inches. As soon as the bark is removed the squirrel scrapes off the succulent layer from the exposed wood. Stems of small diameters, four inches or less, are often completely girdled. On larger stems the girdling is usually incomplete and the wound eventually heals.

When the wound heals, a scar is left through which decay organisms may enter the wood. These defective areas in the wood reduce the value of the lumber. Reports of squirrel damage have come from

all the timber producing regions of the United States. The one previously mentioned occurred in California and was attributed to the western gray squirrel (Sciurus griseus). Mollenhauer (1939), in Pennsylvania, reports that the red squirrel (Tamiasciurus hudsonicus), due to its preference for the very palatable seeds, has kept the Table Mountain pine (Pinus pungens) from attaining the status of a good timber tree. Pike (1934) reports damage to Ponderosa pine (P. ponderosa) by the red squirrel in the northern Black Hills. McCulloch (1937), in Michigan, advises of damage to Japanese Larch (Larix leptolepis) by the red squirrel. Roe (1948) attributes light crops or crop failure of red pine (P. resinosa) to the red squirrel. Goldman (1928) also indicates that the white-tailed squirrel (S. alberti) gnaws cones of the yellow pine (P. ponderosa), but does not state whether the squirrel is considered a pest.

Squirrels are known to utilize food which is abundant at a given time of year. (Lane, 1954; Bugbee and Reigel, 1945). This is a protective device for the animal. Nichols (1927) states that by knowing what is good to eat and where to find it, they assure themselves of a good supply at all times. He also states that due to their wastefulness, they are in effect good disseminating agents thereby insuring new growths of desirable vegetation.

Brown and Yeager (1945), Allan (1943) and others have indicated the value of the fox squirrel (S. niger) as a game animal. Certainly the fox squirrel, as well as other species, helps establish growths of pecan and other trees, due to its habit of burying pecans, seeds, acorns, etc. in excess of what

they later recover.

Ground Squirrels

Howard, Wagnon and Bentley (1959) state that the ground squirrel (Citellus spp.) is no longer as abundant as in past years; however, those populations which remain still raise questions among interested persons as to their potential destructiveness.

Fitch (1948a) found that confined ground squirrels (C. beecheyi) would consume from 10 to 100 grams of food daily depending upon the kind. Observation of food habits in the field led Fitch to estimate an intake of 27 to 115 grams per day. Squirrels were observed to be highly selective in feeding as they chose only the more nutritious foods. A study of an enclosure, stocked to equal a population of 12 squirrels per acre, showed that the average yield of vegetation was reduced by 1,058 dry weight pounds. This represented 10 times the consumption possible by ground squirrels. Losses, other than by eating, were attributed to stunting of vegetation eaten back during early stages of growth, trampling, and cutting of plants not actually eaten. However, Fitch states that when in competition with stock and other animals, damage by ground squirrels would be somewhat less due to lessened availability of the vegetation.

Howard, Wagnon and Bentley (1959) studied the effects of ground squirrels (C. beecheyi) on two experimental pastures. Results indicated that competition between squirrels and cattle was highly variable from year to year. The most notable

differences occurred during two successive winters when cattle on squirrel-free ranges gained an average of 96 and 46 pounds more per animal unit than did cattle on squirrel-infested ranges. The authors state that cattle weight increases probably represent the main effect of ground squirrels during the entire year, though it was noted that squirrels turned to non-forage vegetation in the summer.

Horn and Fitch (1942) report that vegetation on abandoned ground squirrel mounds "is more luxuriant, of greater density and height, and remains green for from one to two weeks longer than on adjacent undisturbed areas." They attribute this occurrence to better soil conditions due to organic matter being added as a result of squirrel activities. However, they state that in other California areas no increased forage production was evident near old burrows.

McCulloch (1962) found that ground squirrels (Citellus tridecimlineatus and C. spilosoma) in western Oklahoma hibernated approximately four months a year. While taking some grasses and other valuable plant species, they also consumed relatively large numbers of insects. No status for the ground squirrels in Oklahoma was determined by McCulloch.

Prairie Dogs

Prairie dogs once flourished in much of the great plains area of the United States. Today, due to an extensive extermination program, they exist in scattered colonies and remnant numbers.

Koford (1958) provides the background information on the prairie dog. Before the great plains were extensively settled, the prairie dogs lived in colonies or "dog towns" which generally were on gently sloping land, with short grasses and patches of forbs being the dominant vegetation. With the introduction of crops, prairie dogs extended their feeding operations into cultivated lands, destroying much of the yield. The introduction of cattle and the ultimate effect of overgrazing, extended the limits of the dogs onto these newly made favorable areas. Man, for the most part, provided the impetus needed for the prairie dog to become a serious pest. Man also reduced the numbers of dogs to its present level.

Size of the towns varied according to environmental conditions at any given time. Osborn and Allen (1949) describe a town of less than one acre which was evidently dying out. Merriam (1902) reports a town in Texas which was calculated to cover 25,000 square miles. Generally dog towns in the range of 25 to 100 acres are prevalent today. Population per acre is now believed by Koford (1958) to be 12 to 15 animals. Earlier estimates by Merriam (1902) and others had placed the number approximately twice the new one; however, conditions in earlier times undoubtedly were different than now.

Food habits are reported by Kelso (1939) on three species of prairie dogs. Stomach contents of killed animals were analyzed in obtaining data. The blacktail prairie dog (Cynomys ludovicianus) was found to consume 98.6 per cent vegetable matter and 1.4 per cent animal matter. Herbage which was considered to be

of forage value to cattle and sheep accounted for 76.19 per cent of the diet. Of this, 61.55 per cent was green and growing grasses. Wheatgrasses (Agropyron spp.) and fescues (Festuca spp.) were the favorites; however most of the stomachs were from animals killed in Montana, and grass preference undoubtedly would vary from area to area. The whitetail prairie dog (C. leucurus) was found to consume 99.14 per cent vegetable matter and only 0.86 per cent animal matter. Plants considered important forage accounted for 83.97 per cent of the diet. Plants of the goosefoot family (Chenopodiaceae) constituted 50.63 per cent of the total volume, while grasses comprised only 28.09 per cent. Wheatgrasses again predominated. The gunnison prairie dog (C. gunnisoni) ate 94.67 per cent vegetable matter and 5.33 per cent animal matter. Plants considered valuable forage made up 74.80 per cent of the diet. Grasses dominated with 47.26 per cent, and the goosefoot family was second at 13.80 per cent. The latter two prairie dog species were taken mainly from Wyoming (C. lecurus), Colorado and Arizona (C. gunnisoni). On the average, plants of some forage value comprised 78.32 per cent of the diet of the three species. The grasses accounted for 45.63 per cent of the total. Plants of the goosefoot family comprised 25.72 per cent volumetrically. Other important forbs found were saltbush (Atriplex argentea) and Russian thistle (Salsola kali). In passing, it might be noted that cut worms and grasshoppers made up the larger part of the animal matter consumed by the dogs.

Damage to range grasses by the Zuni prairie dog (C. gunnisoni) in two of three experimental areas of Arizona is reported by

Taylor and Loftfield (1924). Results were given in terms of forage destroyed under grazing by prairie dogs alone and by cattle alone (or together with prairie dogs) in comparison with amounts of forage produced under total protection. During the four year experimental period, on area number one, prairie dogs destroyed 69 per cent of the wheatgrass (Agropyron spp.) and 99 per cent of the dropseed (Sporobolus spp.), or 80 per cent of the expected forage production annually. One year's observations on area number two in a different region of the state showed that the dogs destroyed 83 per cent of the blue grama (Bouteloua gracilis) crop, the prevalent grass. In many areas of this region it was noticed that the animals destroyed the grass completely and were forced to move. It was determined that prairie dogs have no beneficial food habits.

Osborn (1942), in Oklahoma, observed the results of prairie dogs (C. ludovicianus) moving into heavily grazed shinnery savannah which he classifies as Andropogon-Quercus scrub. He surmises that the movement is a direct result of overgrazing in colony areas which forced the dogs to move. Once moved, the dogs had no trouble in clearing patches of scrub oak from around their burrows. Soil types apparently were no check on the animals.

Osborn and Allen (1949) have reported on the successional vegetation surrounding an abandoned prairie dog town in the Wichita Mountains of Oklahoma. The area is characterized by a climax of big and little bluestem (Andropogon gerardi and A. scoparius) and Indiangrass (Sorghastrum nutans). As the prairie dog town became smaller, the areas grazed by the dogs gradually

decreased until the last dogs were gone. At this time, the study was undertaken. Starting from the last burrows which were considered to be the center, vegetational stages were noted progressing from the center outward. These changes formed more or less concentric rings. The following zones were observed:

1. Mat forbs, dominated by rushpea (Hoffmanseggia falcaria) and shaggy purslane (Portulaca pilosa).
2. Annual threeawn, dominated by prairie threeawn (Aristida oligantha).
3. Threeawn and forbs, dominated by prairie threeawn and western ragweed (Ambrosia psilostachya).
4. Threeawn and perennial grasses dominated by prairie threeawn, poverty dropseed (Sporobolus vaginiflorus), tumble windmillgrass (Chloris verticillata) and buffalograss (Cynodon dactylon).
5. Short grasses, dominated by blue grama (Bouteloua gracilis) and prairie threeawn.
6. Subclimax mid-grasses, dominated by silver bluestem (Andropogon saccharoides) and sideoats grama (Bouteloua curtipendula).
7. Climax tall grasses, dominated by big bluestem, switchgrass (Panicum virgatum) and Scribner panicum (P. scribnerianum).

Finally, it was noted that a range in good condition was enough to exclude or reduce prairie dog numbers.

Chipmunks

Chipmunks are represented in the East by the genus Tamias and the West by the genus Eutamias. Reports are generally favorable for both genera.

Allen (1938) reports the eastern chipmunk (T. striatus lysteri) is not considered a harmful animal. Its food consists

of nuts, seeds and fruits which are of little value to man. Aldous (1941) agrees on the food items but states that availability generally influences food habits. He states that chipmunks are normally not harmful to tree reproduction, and that they are disseminating agents. Howell (1929) concurs that they "have no harmful effect on forest growth." He states that the western chipmunks are neutral in economic value. The United States Department of Agriculture (1921) has found that chipmunks and mice are aids in establishing new stands of fir trees in Oregon and Washington due to their habit of burying seeds in the forest floor.

CHAPTER V

POCKET GOPHERS

Pocket gophers belong to the genera Thomomys and Geomys. (Burt and Grossenheider, 1952). They are present in the states west of the Mississippi River and in the southeastern states of Florida, Georgia and Alabama. They are important rodents where found.

Moore and Reid (1951) report that a seventeen year study, conducted jointly by the Fish and Wildlife Service and the Forest Service, was made to determine the life history of the Dalles pocket gopher (T. talpoides quadratus) and its influence on plant composition and grazing values on mountain meadows in Oregon. Two meadows, both in poor condition with existing vegetation largely perennial forbs, and both populated with gophers, were chosen for the study. Gophers were excluded from one meadow during a nine year period, while the other was left undisturbed. At the end of the first period, the gophers were reintroduced into the previously unpopulated area and were trapped out of the infested area. During each period, sheep were allowed to graze a part of each area. It was noted during this time that the gophers excavated in open areas, or areas with few

trees. After the first nine years, it was found that conditions on the ungrazed, gopher infested plot were slightly worse than on the grazed, gopher infested one. This was attributed to trampling of sheep which caved in gopher runways and made conditions more favorable for perennial plants, whereas the drying effect of the runways would have favored early maturing annuals. Density of vegetation was approximately 15 per cent on both areas. However, in both plots range condition was still poor. The gopher free sites both improved with grasses being 1.32 per cent more abundant on the grazed one. Density of vegetation was approximately 25 per cent on both areas or 10 per cent more dense than on the gopher infested ones.

With the reverse treatment in effect, at the end of eight years vegetation density on the grazed, formerly gopher infested site was doubled as was the ungrazed, formerly gopher infested one. Conditions where gophers were introduced were little changed though plant species which were favored by gophers decreased somewhat. It was concluded that control must be undertaken to improve already poor range, while gopher infested range in good condition might not need control.

During the study, gophers were found to consume an average of 71.25 grams of vegetation daily. This figure did not take into consideration the amount they destroy by damaging root systems or stunting young plants. The diet consisted of roots and underground stems of broadleaved herbs or vegetation near the mound, but the gophers would feed on grasses, young pines and other trees.

Fitch and Bentley (1949), in California, found that gophers (T. beechyi) destroyed 25 per cent of the herbage crop during the green forage season, but the authors admit that when in competition with other rodents and cattle, the amount destroyed would be less.

The pocket gopher has been blamed by Gabrielson (1938) as a cause of soil erosion which in turn reduces desirable species and vegetation in general. Ellison (1946), however, has found that while the gopher may effect erosion, it is not the primary cause, which he blames on overgrazing. He found that the gopher population per acre on the Wasatch Plateau in Utah was between four and 16, and that they could deposit on the surface as much as five tons of soil per acre. However, gopher digging was confined to areas where, as a direct result of overgrazing, the soil was exposed to the elements. Ellison further states that no evidence had been found which indicates that gophers destroyed enough vegetation to cause accelerated erosion, and that they seem to cause some eroded areas to be revegetated due to their cultivation of the soil. Ellison and Aldous (1952) found that vegetation, particularly grasses, sedges, rhizomatous species and many tall forbs, tended to increase where gophers were present. In addition, gophers loosen and soften soil, which is important in areas exposed to the trampling hooves of grazing animals. Horn and Fitch (1942) state that the animal is an important cultivator of the soil because it does more burrowing than all other rodents together.

Finally, Grinnell (1923), working in the Yellowstone area, attributes the following to gophers:

1. The weathering of the substratum is hastened by the burrow system.
2. The subsoil is brought to the surface where it is further exposed to weathering.
3. Water is conserved for the reason that snow melts more slowly on porous ground that on hard-packed soil.
4. The ground is rendered more fertile through the loosening of the soil.
5. Humus content is increased by the action of storing vegetation in the burrows.

As a result of all these actions, the soil produces a fuller vegetational cover.

CHAPTER VI

KANGAROO RATS

The kangaroo rat (Dipodomys spp.) is distributed throughout the western half of the United States and in parts of Canada and Mexico. They prefer arid or semi-arid country and loose textured soil. (Burt and Grossenheider, 1952).

Fitch and Bentley (1949) studied the effects of the Heermann kangaroo rat (D. heermanni) on forage in a California foothill range. Eight kangaroo rats, representing a maximum population in a good year, were placed in a one-fourth acre exclosure. A similar one-fourth acre exclosure was used as a control. It was found that at the end of the green-forage period, the seven month growing season, the kangaroo rats had eliminated 16 per cent of the potential vegetation as measured against the control. This figure represented forage destroyed by all rat activities. The authors were of the opinion that when in competition with grazing animals and other rodents the amount would be somewhat less. During the dry season losses were relatively small.

Fitch (1948b) studying the effects of the Tulare kangaroo rat (D. heermanni) on the San Joaquin Experimental Range, found that each rat could destroy 11.6 dry weight pounds of forage

during the seven month growing season. He states that numbers of rats fluctuate widely from year to year with reductions resulting from heavy and prolonged rainfall.

Reynolds and Glendening (1949), in southern Arizona, found the kangaroo rat (D. merriami) to be a factor in the dissemination of mesquite seeds. The rats buried more than they used, consequently leaving seeds in shallow soil and favorable conditions for germination. Thus, as the mesquite spread, perennial grasses decreased allowing larger populations of rats to occupy the area. The authors recommend control of kangaroo rats as will as reduced grazing as a possible was to stop the invasion of mesquite.

Reynolds (1950), also in southern Arizona, found that the Merriam kangaroo rat seemed to prefer areas of sparse grass cover though having access to protected areas of higher grass density. It was found that during a dry year, with consequent low seed production, conditions on a rat-infested area deteriorated faster than on a rodent protected area. However, after the return of favorable growing conditions, the rat infested area improved faster than the protected plot. This was attributed to the fact that kangaroo rats harvest large quantities of seed and store them in the surface soil. Usually more seed is stored than is used, therefore with the return of good conditions, seed remaining in stores is in better soil, and conditions for germination are good. Reynolds concludes that:

> The detrimental effect of the Merriam rats will probably be most pronounced on ranges in poor condition where the density of large-seeded perennial grasses is so low that most seed is consumed.

McCulloch (1962) found in a study near Woodward, Oklahoma, that the kangaroo rat (D. ordi) appeared to have the greatest effect of any rodent on vegetation. The rats utilized sand dropseed (Sporobolus cryptandrus), purple sandgrass (Triplasis purpurea), short-lived spring grasses and forbs. Tall grasses seemed to escape use by the rats. McCulloch, as well as Reynolds, observed that the animal preferred heavily grazed to light or moderately grazed tracts. He concluded that his study did not clearly indicate a need for artificial reduction of rodent numbers.

CHAPTER VII

BEAVER

The beaver (Castor canadensis) is now found over most of North America according to Burt and Grossenheider (1952). Although it has caused localized trouble at times, the instances are not of any great significance. Called the premier conservationist of the animal world by Cox (1938), it is most certain that the beaver has a good economic rating.

Bailey (1927) reports that trees utilized for food by beavers are generally of little economic value. He lists aspens (Populus spp.), cottonwoods (Populus spp.), birches (Betula spp.), pin cherries (Prunus sp.), willows (Salix spp.), alders (Alnus spp.), bush maples (Acer sp.), hazels (Corylus spp.) and smaller bushes as being among species used.

Hall (1960), in California, found that beavers utilized aspen most frequently, with willows their second choice. However, while these species dominated, almost every woody plant was used to some extent. When the two preferred species were consumed, the beavers moved their colony. Willow, being more vigorous, then recovered; aspen did not. It was noted that the beaver preferred trees of approximately two inches diameter, primarily as a building material rather than as a food item.

Aldous (1938), working in the Minnesota Superior National Forest, found that aspen is the most utilized food species with birch, alder and willow ranking next. Calculations showed that beavers utilized 36 per cent of the trees and wasted 64 per cent. Trees four to six inches in diameter growing in heavy stands caused cut trees to lodge instead of falling and therefore were wasted more often. Feeding experiments showed that beavers consumed 22 to 33 ounces of aspen bark and twigs daily.

Hammond (1943), in North Dakota, found the winter food preferrences of the beaver to be red-osier dogwood (Cornus stolenifera), green ash (Fraxinus pennsylvanicus) and willow (Salix spp.). Aspen did not occur in the vicinity of the colony; however, beaver were found to have travelled about 200 yards inland to a grove of aspens to feed.

Gese and Shadle (1943), in New York, discovered that beavers were seriously reducing stands of aspen which was considered to be their favorite food. The authors' study showed that an average of eight years were required to regrow aspens one inch in diameter and 32.4 years to produce six inch diameter trees.

Stegeman (1954), also in New York, reports that beavers were found to utilize aspen predominately. As the commercial value of aspen was nothing, the beaver was determined economically valuable for fur. It was also determined that beavers would consume an upper limit of five pounds of food daily, a figure deliberately set high to encompass all situations.

Finley (1937) writes in glowing terms of the beaver's worth as a conservationist, though he probably is not exaggerating:

> The proof today is clear that a beaver's value is in his work and not solely in his hide. The facts have been uncovered in thousands of areas in the West. Beavers were trapped out, ponds and lakes dried up, the water table lowered, and grass-covered valleys reverted to deserts. Soil erosion and dust storms followed.

CHAPTER VIII

RATS, MICE AND VOLES

Muskrat

The muskrat (Ondatra zibethica) is found over most of North America. (Burt and Grossenheider, 1952). It has a high economic rating due to the value of its fur.

Errington (1939) states that muskrats, though adaptable to adverse conditions, prefer quiet water which fluctuates little and heavy growths of herbaceous vegetation as a home site. Muskrat food is largely determined by what is available. Bailey (1937), in Maryland, lists shoots, roots, bulbs and tubers of such plants as sedges, cattails, reeds, and grasses among the preferred food. Overpopulation of muskrats and subsequent destruction of vegetation affects primarily the muskrat itself. When this happens, they may move to a different area or subsist on animal matter such as clams, crayfish, frogs, fish and carcasses of other muskrats. (Errington, 1937). No reports were found on depletion of aquatic plants by muskrats causing irreparable damage.

Woodrats

The wood or pack rat (Neotoma spp.) and its relationship to forage consumption has been studied largely in Arizona and California. Findings can be only presumed true for other species and areas.

Horn and Fitch (1942), in California, describe the habitat preference of the woodrat (N. fuscipes) as being "large rock outcrops, brush thickets, or live oaks, where it may occur in a population of several to the acre, but it tends to avoid open grassland." Food consisted of leaves of shrubs and inner bark of twigs from oak and chaparral. The rat was concluded to be unimportant as a forage destroyer but a possible competitor for browse.

Vorhies and Taylor (1940) studied the woodrat (N. albigula albigula) on the Santa Rita Range in Arizona. Stomach analyses showed cactus (Opuntia spp.) to account for approximately 44 per cent of the diet; mesquite (Prosopis sp.) totaled 29.8 per cent. Grass furnished but 4.79 per cent and was not a principle item at any time. Further, the rat was determined to be important in dissemination of cactus seed and in aeration and fertilization of the soil.

Green and Reynard (1932), studying the burrowing effects of the pack rat and the kangaroo rat in Arizona, found that soil taken from dens contained larger quantities of soluble salts, especially calcium, magnesium, bicarbonate and nitrate ions, than did soil in other areas. They conclude that the two rodents were having measurable non-detrimental effects on the chemical and physical properties of the soil.

Grasshopper Mice

The grasshopper mice are represented by two species, the northern (Onychomys leucogaster) and southern (O. torridus) according to Burt and Grossenheider (1952). They are present west of a line drawn southward bisecting the states from North Dakota to Texas. They also occur in a small area of southern Canada and a rather large area in Mexico. Their ranges tend to overlap somewhat, mainly in New Mexico and Arizona.

McCulloch (1962), in Oklahoma, found the northern grasshopper mouse abundant, but there was no evidence of it doing any harm. Vegetative intake was limited to small amounts of seeds. The mice were found to be no competition to cattle for forage and perhaps even beneficial due to their consumption of various arthropods, mainly insects, which made up the greatest part of their diet.

Bailey and Sperry (1929), writing on grasshopper mice in general, report the mice are known to eat a little grain and seeds at times, but their diet consists mainly of insects; thus they were determined economically beneficial. In addition, the mice were found to destroy other small rodents and thereby to serve as a check on overpopulation of many harmful species.

Meadow Voles

Meadow voles or mice (Microtus spp.) are widely distributed in North America. (Burt and Grossenheider, 1952). They have similar food habits where found. (Martin, 1956).

Martin found that voles fed mostly on grasses in spring and summer. The quantity of grass destroyed was in excess of that eaten, as is the case with so many rodents.

Bailey (1924) found that the Pennsylvania meadow mouse (M. pennsylvanicus) could consume approximately ten per cent of its weight in food every 24 hours. He estimates that an average weight of 30 grams per mouse would encompass both young and old mice in the field.

Reports on density of voles per acre vary greatly, ranging from the nine per acre that Wooster (1939) found in Kansas to the 260 that Hamilton (1937) mentions in New York, indicating that populations tend to be cyclic. Factors of climate, predators, available food and others all affect population numbers.

Hubbard and McKeever (1961) report that meadow mice (M. montanus), due to their girdling activities, killed five per cent and damaged 15 per cent of the bitterbrush plants (Purshia tridentata) on natural and reseeded areas in northeast California and Oregon.

Pocket Mice

Reynolds and Haskell (1949) found that the chief food items of the Price pocket mouse (Perognathus penicillatus pricei) and the Bailey pocket mouse (P. baileyi baileyi) on the Santa Rita Range in southern Arizona were large seeds of unimportant range plants. The largest populations inhabited ungrazed perennial bunchgrass though seeds of these grasses were not eaten in any quantity. Average population of mice on grazed areas was approximately one mouse per three acres. McCulloch (1962) reports that pocket mice (P. flavus bunkeri and P. hispidus paradoxus) were rarely trapped during his work near Woodward, Oklahoma. He states further that the results of studies in the same general area by other investigators have shown pocket mouse occurrence equally infrequent.

Harvest Mice

Johnson (1961) discovered that western harvest mice (Reithrodontomys megalotis) in southern Idaho depended greatly on arthropods for food with some vegetation taken when available. McCulloch (1962) found the harvest mouse (R. Montanus griseus) extremely rare near Woodward, Oklahoma, as did Blair (1954) find R. montanus montanus and R. megalotis dychei rare in the mesquite plains of Texas and Oklahoma.

Deer Mice

Johnson (1961) found grass and grass seeds more often in stomachs of deer mice (Peromyscus maniculatus) trapped in an exclosure which had a more dense stand of grass, than in stomachs from mice trapped outside the exclosure. This indicated to Johnson that availability dictated food choice to the mice. Hamilton (1941) determined that deer mice (P. leucopus noveboracensis and P. maniculatus gracilis) could eat six grams of food daily. Under natural conditions, the food items would be insects, seeds and green vegetation. Dice (1922) found that P. leucopus noveboracensis could consume 2.34 grams of food daily, and that P. m. bairdii could consume 3.34 grams daily. McCulloch (1962) found deer mice P. m. nebrascensis more numerous on ungrazed areas; however, the main dietary item was discovered to be insects.

Cotton Rats

McCulloch (1962) reports that a population outbreak of hispid cotton rats (Sigmodon hispidus) near Woodward, Oklahoma, caused them to become a potentially important competitor of cattle for forage due to their frequent consumption and destruction of range plants. Stickel and Stickel (1949) found S. hispidus common in unburned tall grass prairie which had a mat of dead grass. Ten to 12 rats were present per acre. Mohlenrich (1961) reports that the hispid cotton rat preferred areas of relatively sparse vegetation, and that the least cotton rat (S. minimus) preferred more dense vegetative cover when ranges of the two overlapped in New Mexico.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Conclusions concerning the effects of rodents and rabbits on vegetation should be made for specific rather than general geographic areas. Desirable and undesirable habits must be weighed together before an economic status can be assigned to any species. With the preceding in mind the following summary is given.

The literature revealed that 15 antelope jack rabbits (Lepus alleni) could consume as much forage per day as one 120 pound sheep; 74 rabbits as much as one 850 pound cow. Twice as many blacktail jack rabbits (L. californicus) were required to consume the same amounts. (Food intake per day for jack rabbits and other species of rabbits and rodents, where possible, are given in table I.) Jack rabbits are found predominately on overgrazed or otherwise open areas. On these sites they can hold vegetation in a preclimax state or practically denude the area. Jack rabbits are also important as disseminating agents.

The snowshoe hare (L. americanus) is most detrimental to trees in artificial plantations which can support greater populations of the animal. It is possible that they have some

TABLE I

VEGETATIONAL TYPES AND AMOUNTS CONSUMED BY SEVERAL SPECIES OF RODENTS AND RABBITS

SPECIES	LOCATION	DAILY FOOD INTAKE	GRASS	FORBS	SHRUBS	TREES	OTHER
Lepus alleni	Arizona	581.12 grams	45%	19%		36%	
L. californicus	"	370.72 "	24%	20%		56%	
Sylvilagus floridanus	Michigan	55.20 "	Vegetation; types unknown.				
S. palustris	Florida	460.00 "	"	"	"		
Cynomys ludovicianus	Montana	Not given	61.55%	37.05% (including cactus)			1.40%
C. leucurus	Wyoming	Not given	28.90%	70.24%	"	"	0.86%
C. gunnisoni	Colorado, Wyoming	Not given	47.26%	47.41%	"	"	5.33%
Thomomys talpoides	Oregon	70.25 "	Vegetable matter fed to caged animals.				
Castor canadensis	Minnesota	524-935 "	Aspen bark and twigs fed to caged animals.				
Citellus beechyi	California	27-115 "	Range vegetation.				
Peromyscus leucopus / P. maniculatus	Eastern United States	6 "	Vegetation and animal matter.				
Microtus pennsylvanicus	Throughout range	3 "	Vegetation.				

value as thinning agents in areas of natural forest reproduction. Populations of hares are generally smaller in these areas, and dense stands of seedlings are not as likely to be completely utilized for food.

Due to lack of information, the whitetail jack rabbit (Lepus townsendi) is presumed to have habits similar to the blacktail and antelope species. Arctic hares (L. arcticus) and tundra hares (L. othus) are assumed to be of neutral economic value.

Cottontails (Sylvilagus spp.) are likely to prefer areas with trees and shrubs and dense mats of grass. Occasionally they girdle or otherwise injure trees, but this usually occurs in the winter when other vegetation is unavailable. They are valuable as game animals and are considered to be of neutral to good economic value.

No reports of damage to natural vegetation by the marsh rabbit (S. palustris), brush rabbit (S. bachmani) and pigmy rabbit (S. idahohensis) were found; therefore, they are considered to be of neutral economic value. The swamp rabbit (S. aquaticus) is probably of good economic value as a game animal.

Nutria (Myocastor coypus) has value as a fur animal, but in some areas it is damaging crops and destroying vegetation normally utilized by muskrats and waterfowl. Its economic value is debatable.

Tree squirrels, Sciurus spp. and Tamiasciurus spp., girdle trees to some extent; however, they are good disseminating agents and have importance as game animals.

Prairie dogs (Cynomys spp.) were found to have no beneficial food habits. Dog towns are scattered at the present time, and as long as populations are controlled, the prairie dog will not greatly effect natural vegetation as it once did.

A population of 12 ground squirrels (Citellus spp.) in an exclosure was found to reduce the average vegetation yield by 1,058 dry weight pounds per year. Where large populations of ground squirrels exist, some control measures may be necessary.

Chipmunks (Tamias sp. and Eutamias spp.) utilize little natural vegetation of value to man and are probably of neutral economic worth. In some areas they are important disseminating agents.

Pocket gophers (Geomys spp. and Thomomys spp.) utilize some valuable forage, but they serve as cultivators of the soil. Gopher control may be needed on depleted range land.

Kangaroo rats (Dipodomys spp.) utilize vegetation having large seeds, and occasionally they may be a serious competitor of cattle for forage. However, they aid in reseeding by being disseminating agents, and their burrowing aids in aeration of the soil.

The beaver (Castor canadensis) occasionally causes localized trouble, but its conservation practices far outweigh any damage done. In addition, the beaver is a valuable fur animal.

Wood or pack rats (Neotoma spp.) utilize grass infrequently as food though large populations may compete with cattle for browse. Control is generally not indicated.

Meadow voles (Microtus spp.) feed mostly on grasses in spring and summer. Population density largely determines the potential destructiveness of the vole.

Grasshopper mice (Onychomys spp.) consume arthropods predominately, eleminating insects which deplete vegetation, and are considered probably beneficial for this reason.

Muskrat (Ondatra zibethica) populations may become higher than can be fed by available aquatic vegetation. Animals then either move to new areas or subsist on animal matter. The muskrat is another valuable fur bearer.

Forage depletion by pocket mice (Perognathus spp.), harvest mice (Reithrodontomys spp.), deer mice (Peromyscus spp.) and cotton rats (Sigmodon spp.) is assumed to be directly related to population density and availability of forage species.

In many cases it was noted that population density of rodents and rabbits tends to be cyclic. This probably acts as a natural check on the species' effects on vegetation. Investigators generally agree that proper management of an area, be it forest, range or marsh, is sufficient precaution to take under most conditions to insure against severe damage to natural vegetation by rabbits and rodents.

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VITA

Gerald Pat Hutchinson

Candidate for the Degree of

Master of Science

Report: EFFECTS OF RABBITS AND RODENTS ON NATURAL VEGETATION IN THE UNITED STATES

Major Field: Natural Science

Biographical:

Personal Data: Born in Oklahoma City, Oklahoma, August 12, 1939, the son of Harold I. and Thelma L. Hutchinson.

Education: Attended grade school in Stillwater, Oklahoma; graduated from Stillwater High School in 1957; received the Bachelor of Science degree from the Oklahoma State University, with a major in Zoology, in January, 1962; completed requirements for the Master of Science degree in August, 1963.