AN EVALUATION OF SOME RABBIT MANAGEMENT PROCEDURES AS APPLIED IN SOUTHEASTERN VIRGINIA

by

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INTRODUCTION

Perhaps no game animal or bird is so universally sought as the cottontail rabbit. Certainly, throughout the state of Virginia, the rabbit is one of our most important game species. Sprunt (1957:42) found the rabbit to be the fourth most popular game animal in Virginia, but this does not indicate the hunting pressure, only its popularity. Thornton (1954:1) estimated that 30 per cent of all shotgun shells bought in Virginia were intended for rabbits and, with the possible exception of the squirrel, that the cottontail was the most important game animal in Virginia. The importance of the cottontail as a game animal is pointed out by the many beagle clubs throughout the state, as well as the beagle's number one rating with the American Kennel Club. In recent years the farm game habitat improvement program has included measures designed to encourage the cottontail. The effectiveness of many of these management activities has not been tested. Therefore, the present investigation had as one of its primary objectives the evaluation of certain rabbit management procedures.

This study is phase "C" of a multiple phase project designed to study the biology and management of the cottontail rabbit in Virginia. Phase "A," completed by J. B. Redd (1956) dealt with the abundance and distribution of the cottontail as affected by land use. Phase "B," completed by B. S. McGinnes (1958) considered some factors influencing cottontail rabbit populations. The present study, "An Evaluation of Some Rabbit Management Procedures as Applied in Southeastern Virginia" had the following objectives:

1. To evaluate the response of the rabbit population to certain land cultural treatments by comparing the rabbit population density on various areas receiving different management techniques.

2. To evaluate the various rabbit management techniques based on cost and rabbit response.

3. To determine the vegetative changes resulting from cultural treatments such as mowing and burning.

4. To test various methods of estimating the rabbit population present on a defined area.

5. To maintain records on tularemia in rabbits in Virginia during the period of investigation.

The field work was conducted from June 1958 through May 1959 on the Camp Pickett Military Reservation in Nottoway, Brunswick and Dinwiddie Counties, Virginia. Here the rabbit involved, according to Llewellyn and Handley (1945:381), is Sylvilagus floridanus mallurus (Thomas). The habitat manipulation techniques evaluated in this study included only those land management practices undertaken on this Reservation under the cooperative agreement between the Virginia Commission of Game and Inland Fisheries and the United States Second Army.

LITERATURE REVIEW

Much has been written about the cottontail rabbit. This situation aids and hinders study of the species. Assuredly, the voluminous material is advantageous, yet it requires a careful and diligent search if the literature review is to be adequate.

This section merely reviews some of the most important papers from which the investigator extracted data. It does not purport to compile a complete bibliography of writings on the cottontail; Makepiece (1956) has already accomplished this admirably.

The life history of the rabbit has been well investigated by Bruna (1952) in Kentucky and Majors (1955) in Alabama; Llewellyn and Handley (1945), Redd (1956) and McGinnes (1958) in Virginia and Dalke (1937 and 1942) in Connecticutt also made life history studies.

Elder and Sowls (1942) in Wisconsin published material on body weights and sex ratios of rabbits. Cooley (1946) in Michigan published a short paper entitled "Cottontails Breeding in Their First Summer." Hale (1949) studied age determination in cottontails by bone growth as did Thomsen and Mortensen (1946). Petrides (1951) in Michigan used this aging method, as did Bruna (1952) in Kentucky and Dell (1955) in New York.

A host of writers have presented data and recommendations on cottontail management including Linder and Hendrickson (1956) in Iowa, Bowers (1956) in Pennsylvania and Dell (undated) in New York. Pirnie (1949) discussed hunting as a means of cottontail control and Studholme (1951) in Pennvylvania was concerned with plant succession and cottontails as was Byrd (1956) in Virginia. Others concerned primarily with management

recommendations were Latham (1952) in Pennsylvania, Bruna (1952) in Kentucky, Thornton (1954) in Virginia and Harper (1952) in Ohio.

Dusi (1949) discussed a method of determining food habits by plant micro-techniques and histology. Dalke (1942) made food studies in Connecticut by gross analysis.

Cover and rabbit relationships were studied by Linduska (1947) in Michigan. This same author also used ferrets as aids to winter den studies (1947). Fay and Chandler (1955) reported on cover preferences of Massachusetts cottontails. McGinnes (1958) in Virginia made cover manipulation studies.

Stocking studies were reported on by Dell (1953) in New York, McDowell (1955), Bowers (1954) and Latham (1952) in Pennsylvania.

Census methods were studied and partially evaluated by Redd (1956) in Virginia, Crunden and Hendrickson (1955) in Iowa and Peterle and Eberhardt (1959) in Michigan along with many others.

Kirkpatrick (1950) published a very interesting paper on "Crow Predation Upon Nestling Cottontails." Beule (1940) kept records of cottontail predation and most writers on the cottontail have had something to say about the important subject of predation.

Most of the literature that has been written on rabbit disease has been concerned with domestic species, for example Lund (1956) in California. Although Woodbury and Parker (1953) in Utah did extensive studies on tularemia they were not primarily concerned with cottontail rabbits. Yeatter and Thompson (1952) discussed the subject of tularemia, weather, and rabbit populations in Illinois and McGinnes (1958) studied tularemia

in an enclosed rabbit population in Virginia. A comprehensive study of Shope's rabbit fibroma in cottontails was conducted at the Patuxent Research Refuge by Herman, Kilham and Warback (1956).

Cottontail rabbits are heavily parasitized and much has been written on these parasites. Ecke and Yeatter (1956) in Illinois and Herman and Jankiewicz (1943) in California did parasite studies on cottontails. Stannard and Pietsch (1958) made an excellent study of rabbit ectoparasites in Lee County, Illinois. Dalke (1937) also reported on rabbit parasites. Vail and McKinney (1943) dealt with the Cuterebra fly, a common cottontail ectoparasite. In Michigan Gies (1957) studied the incidence and effects of warbles while McGinnes (1958) gave the life history of Cuterebra indirectly quoted from Cheatum. McGinnes (1958) is also the only investigator who found blood trypanosomes in eastern cottontails, according to the literature searched.

PROCEDURE AND TECHNIQUES

SELECTION AND DESCRIPTION OF STUDY AREA

Locating a suitable study area for this investigation proved to be somewhat of a problem. The V.P.I. college farm, due to its intensive land use practices (expansion and space limitations) was not compatable with this type of investigation. After inspecting a number of areas, Camp Pickett, a deactivated military reservation located in southeastern Virginia near Blackstone, was selected. This area best met the project requirements as it had a high rabbit population, a series of rabbit management techniques applied to the land and it was possible to obtain hunting kill data as all hunting on the Reservation was by check in - check out permit.

The United States Army Garrison at Camp Pickett has a minimum of permanent personnel, and the area is largely utilized for training purposes by military personnel from other installations. The Reservation contains approximately 46,000 acres and is located in parts of three counties: Nottoway, Brunswick, and Dinwiddie. Five thousand acres are contained within the cantonement area and airfield; this area is closed to public hunting. Approximately 2,000 acres of agricultural land is leased to private individuals. There are four lakes and one water filled rock quarry located on the Reservation, encompassing about 1,400 surface acres of water. An old artillary impact area contains approximately 15,500 acres. The remaining 23,000 acres are comprised of woodland and abandoned agricultural land. Pulpwood and some saw timber are harvested each year from the forested land.

Ackerman (1954) describes the general weather, topography, soils and vegetative conditions on Camp Pickett. The following descriptions of the area are taken from this source.

The mean annual temperature in this section of Virginia is 58 degrees F. The minimum annual temperature rarely falls below 15 degrees and the maximum rarely goes above 100 degrees. The average first killing frost occurs on October 7 and the last on April 8.

Mean annual rainfall is 47 inches, the greatest amount customarily falls in the summer, but normally there are no prolonged periods of drought.

The topography of the study area is gently rolling; elevation ranges from 200 feet along the Nottoway River, in the south, to 430 feet along the northern boundary.

The soils are of the Cecil, Appling, Dinwiddie and Durham series and are whitish sandy loams over red, brown and yellow sandy clay loam subsoils. On many sites the top layer of soil has eroded completely, leaving only the subsoil. In a few places the granite parent rock is exposed.

The woodland region is primarily of three vegetative types. Pines comprise approximately one third of the Reservation; the most common species being loblolly (Pinus taeda) with a considerable scattering of shortleaf (Pinus echinata) and a scant number of Virginia pine (Pinus virginiana). Throughout the pine stands are scatterings of white oak (Quercus alba), sweet gum (Liquidambar styraciflua), red maple (Acer rubrum), black oak (Quercus velutina), pin oak (Quercus palustris) and several species of hickories (Carya spp.).

Pure hardwood stands occur mostly on bottom land and consist of red oak (Quercus rubra), American elm (Ulmus americana), post oak (Quercus stellata), sycamore (Platanus occidentalis), river birch (Betula nigra), white ash (Fraxinus americana), and beech (Fagus grandifolia) (Ackerman, 1954:3-4). The primary shrubby material is young trees of winged elm (Ulmus alata) and sweet gum (Liquidambar styraciflua) together with sumac (Rhus spp.) and trumpet vine (Campsis radicans).

The cover over most of the Reservation is broken into pine and mixed-pine-hardwood stands, interspersed with large open areas of abandoned agricultural land. Cutting across these are winding streams that eventually flow into the Nottoway River which separates the southern tip of the reservation from the remainder of the area. Along these creeks are numerous swamps and low wet areas which support good hardwood timber.

The fauna of the area is somewhat diversified and includes along with other forms white-tailed deer, turkeys, gray squirrels, bobwhite, snipe, rabbits and doves. A few ducks and geese utilize the lakes and swamps for resting purposes on a seasonal basis. Some wood ducks and mallards nest on the area each year.

There are, in addition to the indigenous avian and mammalian predators, feral cats, and free ranging dogs. Fur bearers are relatively numerous and include skunk, raccoon, muskrat, beaver and otter. Other mammals known to exist on the area are woodchuck, shrew, meadow mice, meadow jumping mice and chipmunks. Both the turkey vulture and the black vulture are numerous. Great blue herons have been observed occasionally near the lakes and swamps.

TRAPPING

Location of Traps

For this investigation wooden box traps were used of the type described by Redd (1956:10).

The Virginia Commission of Game and Inland Fisheries sowed randomly 127 annual mix wildlife food plots throughout Camp Pickett. These annual plots consist of eight species in the following percentages: soybeans (Glycine max) 20 per cent, cow peas (Vigna sinensis) 18 per cent, buckwheat (Fagopyrum sagittatum) 10 per cent, rape (Brassica rapa) 2 per cent, German millet (Setaria italica) 5 per cent, brown top millet (Panicum ramosum) 5 per cent, milo or grain sorghum (Sorgum vulgare) 19 per cent, and Korean lespedeza (Lespedeza stipulacea) 19 per cent. Also dispersed over the area are 27 winter grain-clover combination patches, consisting of either red clover (Trifolium pratence) or white clover (Trifolium repens) combined with a winter grain which was either rye (Secale cereale) or oats (Avena sativa). Both the annual mixture and winter grain-clover plantings were approximately one-half acre in size and generally were long narrow strips, 20 to 30 yards wide. Four study plots were randomly selected from each of these two food plot types. These investigational areas were plotted on a work map and assigned a number (Figure 1).

A square area containing five acres was laid out by compass and pacing around each of these selected study plots. The cultural treatment was located in the approximate center of the five-acre area but in most cases extended beyond the five-acre boundary on two sides.

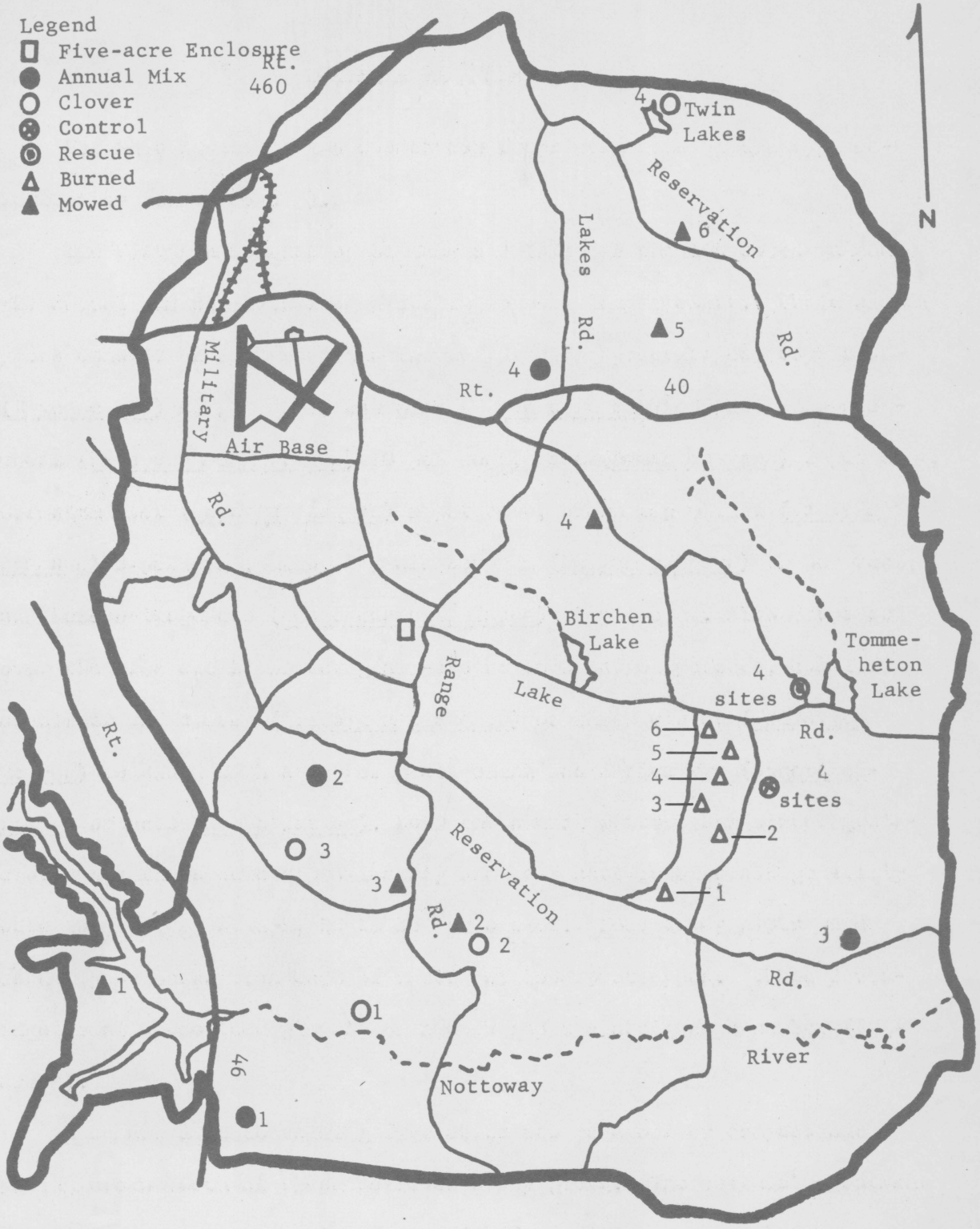


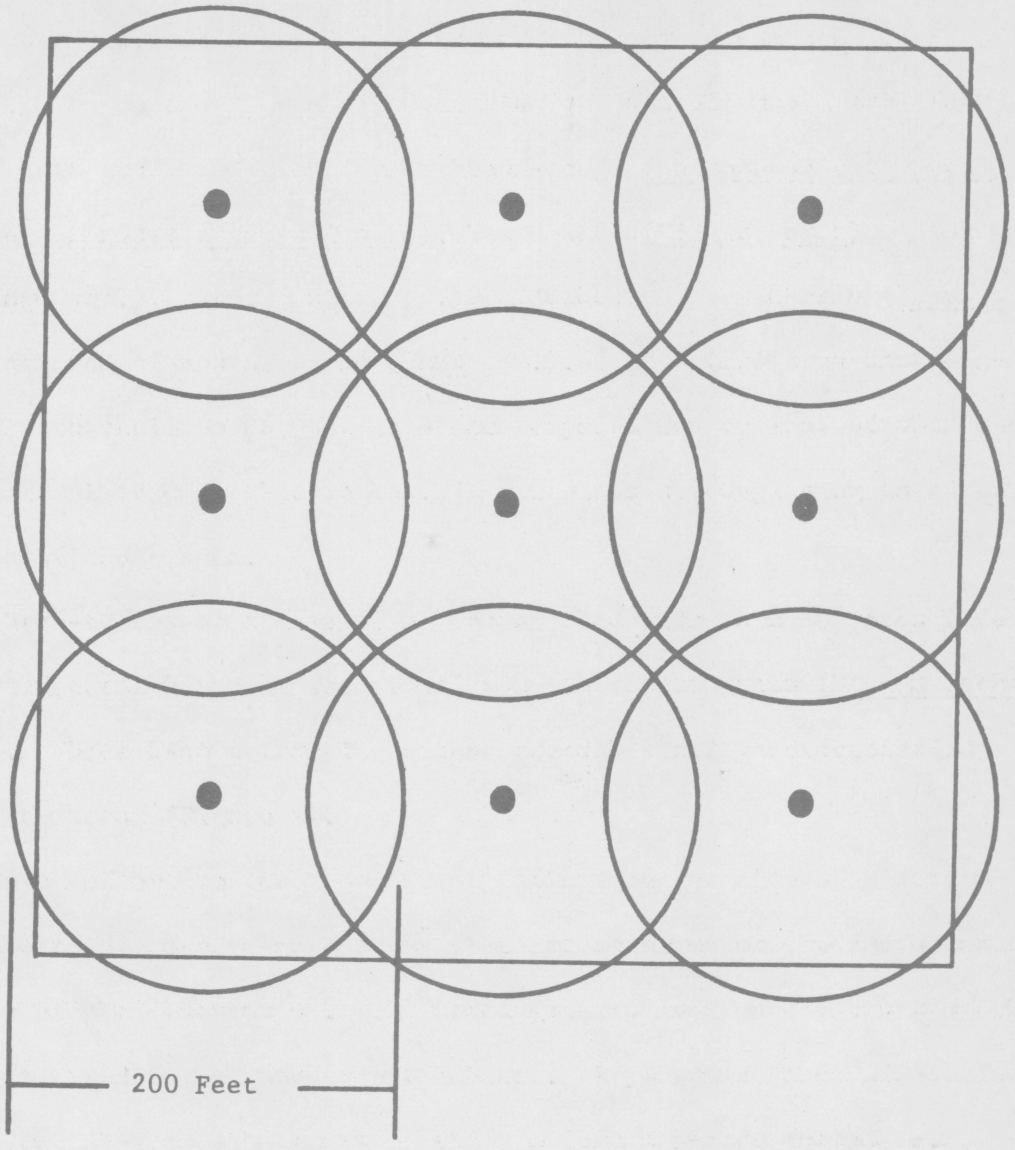
Figure 1. Camp Pickett, Virginia, showing trapping and vegetative inventory sites. Scale: 1 Mile

By gridding the work map into numbered blocks, then making a random selection, four 5-acre sites were selected on a 100-acre area chosen as a control area. These 5-acre plots were then marked on the ground (Figure 1). The control plots were situated on part of an old artillary impact area grown up primarily to broom-sedge (Andropogon virginicus), ragweed (Ambrosia artemisiifolia), buttonweed (Diodia teres), goldenrod (Solidago spp.), aster (Aster spp.), blackberry and dewberry (Rubus spp.) and scattered clumps of sumac (Rhus spp.). The entire area was pock-marked with shell holes; but in other respects was typical of abandoned agricultural land in this region. A few pines are beginning to appear on some of the ridges.

Three-tenths of a mile of an established fire lane 30 yards wide and extending through a pine forest was sown to rescue grass (Bromus catharticus). Three 5-acre trapping sites were arbitrarily selected along this fire break (Figure 1).

In an effort to test population estimation formulae on a static rabbit population, a five-acre study plot was selected on the cantonement portion of the Reservation. The selection was made on the basis of what was considered to be good rabbit habitat. A portable fence of one-inch mesh wire, 30-inches high was erected to form a 5-acre enclosure.

On each trapping site, nine traps were placed to cover the entire five acres. The trap spacing was predicated on a 100-foot radius of influence for each trap (Figure 2), an assumption made by Redd (1956:10) which also proved satisfactory for McGinnes (1958:15).



Location of traps on five-acre site

Figure 2. Effective trapping radii and overlap of gridded traps on five-acre study plots.

Handling and Marking Trapped Rabbits

Two methods of handling captured rabbits were used; the wire funnel method described by Redd (1956:11) and the feed sack method described by McGinnes (1958:15). Types of tags and tagging methods used for all rabbits were those described by McGinnes (1958:15). Two different colored washers were used for identification of sex; aluminum washers with red Scotchlite reflective tape for males and aluminum washers without tape for females. All other animals captured except rabbits were marked with fish tags of the type described by Redd (1956:11). In most cases these animals were tagged in only one ear. Figure 3 shows a tagged rabbit in the holding funnel.

Field data were kept on 4 by 6 inch cards. Field observations such as predation, parasite observations, nesting and disease, were kept on consecutively numbered observation cards and were filed under appropriate subject headings. Trapping records were kept on cards identical in format to field observation cards. These cards were used to record trapping site, trap number, sex, age, parasites and other pertinent data. A third record card was filled out for each marked rabbit, listing date and location of original capture and all recaptures; observations of parasites, disease, tag numbers, tag colors, abnormalities, injury and general condition.

Baits

Baits were not used in this investigation. Redd (1956:32) found that "leaving the traps unbaited did not appear to have any effect upon

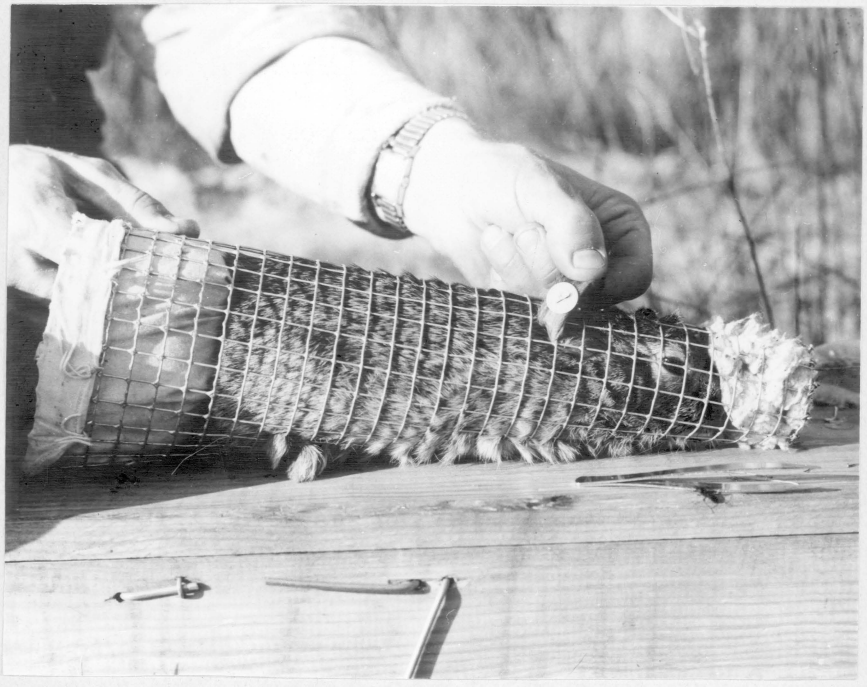


Figure 3. Marked rabbit in holding funnel.

the catch of rabbits." McGinnes (1958:104) used shelled corn for bait but observed that unbaited traps appeared as successful as did baited ones. In Kentucky it was reported that apples were the best bait; corn was second (Bruna, 1952:6). Dalke in Connecticut listed carrots, apples and parsnips as satisfactory bait (Dalke, 1937:545). The decision to not use a bait in the present investigation was based on the assumption that rabbits use traps primarily as cover or shelter. By not employing bait, all traps were considered to be equally effective.

FENCING OPERATION

In an endeavor to evaluate the results of the trapping procedures, a portable fence was erected around three 5-acre trap sites which encompassed one winter grain and two annual-mix plots. Due to terrain difficulties, the fence was not erected around a control area. This fence was constructed of one-inch mesh poultry galvanized netting, 30 inches high, fastened to steel posts 12 feet apart. The bottom of the wire was burried four to six inches in a plow furrow. The wire was fastened by wire clips to the posts at top and bottom only. Two men were able to erect this fence in one day, except for plowing and filling in the furrow to bury the wire. Figure 4 shows the furrow being plowed and Figure 5 shows the fence in the furrow.

After erection of the fence, the 5-acre enclosed area was mowed using a rotary mower pulled by a farm tractor. A flush count of all rabbits inside the enclosure was made. The flushed rabbits were captured in a large landing net (21 inches in diameter, 30 inches deep and fitted with a three-foot handle) and released outside the fence. After the mow-

Figure 4. Plowing furrow for the erection of the portable fence.

Figure 5. The wire was burried in the furrow for several inches to prevent rabbits escaping by burrowing.

ing approximately 20 traps were operated inside the fence for several nights in an effort to capture any rabbits which had escaped mowing and flushing operations. Approximately eight traps were operated outside the fence for one or two nights after mowing; this was done to capture and identify any rabbits which had been marked on the area prior to fencing and excluded by the fence.

In one instance smoke grenades procured from the Army were used in an unsuccessful attempt to drive rabbits from woodchuck burrows. However, when the burrows could be located before mowing, they were plugged with burlap bags. After mowing, the burrows were opened to permit any rabbits to emerge which might have been in them at the time of plugging. By tramping the area a day later, with the holes again plugged, these rabbits were captured by the traps or landing net. This process was repeated until it was believed there were no rabbits remaining within the enclosure. The fence was then taken down and moved to the next location. Two men disassembled the fence, removed the posts and wire in one day.

SEX DETERMINATION

The method for sexing rabbits described by Petrides (1951:315-316) was used in this investigation. Rabbits less than six weeks of age are difficult to sex accurately due to similarity of the sex organs. Other criteria for sex determination used by the investigator were the presence of descended testes in the male and mammae in the female.

AGE DETERMINATION

Each individual rabbit was aged as adult or immature, based upon overall body size and development of sex organs. The nipples of females were a good indicator of age; if the nipples were apparent upon passing the hand over the belly fur, the investigator considered the animal to be adult; if the mammae were not evident, the animal was considered to be immature. Penis length was beneficial in determining age in males. If the penis was 18 mm. in length or over, the rabbit was considered an adult, if 14 mm. or less, an immature (adapted from Petrides, 1951:327-333).

PARASITE EXAMINATION

A count of fleas or ticks was not made during this investigation; the incidence of occurance of these parasites was not high.

Most of the bot fly larvae (Cuterebra sp.) were removed and destroyed. Removal was accomplished, in most cases, by inserting the point of a sharp knife into the breathing hole and splitting the rabbit's skin, thus enlarging the hole. The larva was then extracted with a pair of tweezers.

PELLET COUNTS

Pellet counts were made on each of the 15 five-acre trapping sites. A one-foot square wire frame was used to delineate the count quadrat and 12 counts were made at each trapping site. Six counts were taken within the cultural treatment itself and six were made outside the treatment,

but within the five-acre area. To locate the count quadrats within the cultural plot, the investigator stood in the approximate center of the plot and tossed the sampling frame lengthwise of the plot but slightly to the left. The point of landing located the first quadrat. Standing at this quadrat the frame was again tossed in the same direction, but slightly to the right; the point of landing located the second quadrat. Standing at this point, the investigator once more tossed the frame lengthwise and slightly to the right of the plot; again, point of landing located the quadrat. Returning to the center of the plot, the process was repeated in the opposite direction.

To locate the six quadrats outside the cultural treatment, the investigator merely stood at each of the three trap sites opposite the two long sides of the treatment and tossed the sampling frame over his shoulder. These same patterns of selection were used for the control area.

All pellets within the frame were counted.

ROAD COUNTS

Road counts were conducted by driving a prescribed route and counting the rabbits observed. Six such counts were made. The first three consisted of a 48 mile route and consumed two and one-half hours. It was decided that this course was too long, as it started before and ended after optimum rabbit activity. The next three counts were reduced to a 19.7 mile course which required about one hour to complete. With the exception of the first, all counts were made in the afternoon; one half of the run before official sundown and the other half after sundown. All rabbits were classified as juvenile or adult.

VEGETATIVE SAMPLING

On Camp Pickett two techniques have been employed which retarded vegetative succession; namely, mowing and burning. Therefore an investigation was made to determine what species of plants were coming in following the burning and mowing which might be suitable to rabbits and to evaluate the two procedures for their desirability as rabbit management techniques.

The mowed areas, about two to ten acres in size, were distributed throughout the Reservation. These tracts were not laid out in any design, but were located where open areas were being invaded by pines and hardwoods. Mowing, using a rotary mower pulled by a farm tractor, was done in 1957, approximately one year before vegetative sampling in this investigation.

The mowed patches were plotted on the work map and given a number from which six were randomly selected for detailed vegetative investigation (Figure 1). Selection of the quadrat for investigation was made as follows: The investigator approached the approximate center of the plot and tossed a two-foot right-angle frame over his shoulder. The landing point located one corner of a mil-acre quadrat. Substantial stakes were driven to mark each corner. Each mil-acre quadrat was divided into three equal parts to facilitate counting. A total count by species of all vegetation was then made. Verification of doubtful species identification was made by Dr. A. B. Massey, botanist, V.P.I. Biology Department.

In March 1957 an area of approximately 680 acres was controlled

burned by a slow fire. This area embraced a section of the old artillary impact area. The purpose of this burning was to expose any unexploded shells. About two-thirds of the burned section was wooded, predominently loblolly pines with some mixed hardwoods mainly in the low swampy area along a creek. The remaining one-third was open land.

This entire burned area was gridded on a work map into two and one-half acre plots. Six of these plots were randomly selected for study (Figure 1). These six squares were located on the ground by compass bearing and pacing and each of the four corners was blazed on a tree. A record card was made for each plot giving the starting point, azimuth and number of yards from starting point. This was done to enable subsequent workers to locate the plots. A mil-acre quadrat was located in each of the six plots and counting was conducted in the same manner as for the mowed area.

RESULTS

VEGETATIVE INVENTORY

Mowing and burning are game management tools used to modify habitat. The merits of these techniques have been discussed at length by various investigators.

Stoddard (1931:408-410) is of the opinion that on southern quail lands a light burn applied in the winter causes a heavy production of perennial legumes; but summer and spring burning produces an opposite effect. He also states that burning should be done in patches so that a great area is not without winter berries at one time. He believes that fire on southern quail preserves is a convenient tool for cover control and serves as a sterilizing agent to reduce the danger of disease.

Leopold (1933:305) says "Cover (and often food) can be controlled by either speeding up or setting back the plant succession. Cover is controlled by controlling the plant succession in the right direction at the right time and place." This writer lists fire and mowing as "tools" for setting back plant succession (Leopold, 1933:322).

Allen (1954:69) relates that Ben C. Jenkins, in a three year study of the history and plant cover of northern Michigan burns, reached several significant conclusions. Jenkins reported that to maintain desirable openings for deer and grouse, areas should be burned over every five to ten years, either in late fall or early spring. Light burns in woody cover increased not only sprout growth, but legumes and shrub fruit production. Fires also eliminated debris that rendered logged areas prac-

tically inaccessible to hunters, and served to open up the undesirable, nearly solid, stands of second-growth hardwoods.

Odum's opinion on the value and use of fire is summed up in this statement: "Properly used fire can be an ecological tool of great value. Fire is thus an extremely important limiting factor if for no other reason than that mankind is able to control it to a far greater extent than he can many other limiting factors" (Odum, 1953:60-61).

Mowing is a relatively simple way to set back vegetative succession; however, it may be much more expensive than burning. Both burning and mowing are valuable game management tools when properly used. The beneficial effect to wildlife of establishing or maintaining early ecological succession stages is summed up by Allen (1954:69-70) as follows: "Whatever the means of attaining the condition, it is evident that early successional stages support the greatest amount and variety of wildlife, and a perpetual program of maintenance will be necessary to preserve the age pattern of vegetation that will mean satisfactory game yields."

This investigation attempted to determine the species of plants which occurred after a slow burn and after mowing. One hundred per cent counts were made of all vegetation appearing within six randomly selected mil-acre quadrats on each of the two treated areas. Many of the plants were collected and sent to Virginia Polytechnic Institute, for identification and verification. Table 1 shows the results of this study.

After the data were assembled, it was found that due to an error one of the mowed plots was located on an area that had previously been sown to Korean lespedeza (Lespedeza stipulacea). This explains the excessively high number of Korean lespedeza plants (1,545) and the percentage

Table 1. Vegetative inventory from six mil-acre quadrats on burned area and six from mowed area, Camp Pickett, Virginia, fall, 1958

Species	Burned		Mowed	
	Total no. plants	Per cent of total veg.	Total no. plants	Per cent of total veg.
Aster (*Aster* spp.)#	2	.1	100	1.5
Bedstraw (*Galium* spp.)	3	.2		
Beggar weed (*Desmodium* spp.)	23	1.2		
Black haw (*Viburnum prunifolium*)	1	.1		
Bramble (*Rubus* spp.)	16	.9	47	.7
Broad leaf plantain (*Plantago major*)	11	.6	25	.4
Brome grass (*Bromus* spp.)#			15	.2
Broom sedge (*Andropogon* spp.)*	201	10.6	101	1.5
Buttonweed (*Diodea teres*)	136	7.3		
Chickweed (*Stellaria* spp.)#			6	.1
Chickory (*Cichorium intybus*)	2	.1	2	.1
Cinquifoil (*Potentilla recta*)	213	11.6		
Croton (*Croton* spp.)			166	2.5
Dogwood (*Cornus* sp.)	3	.2		
Ebony-spleenwort (*Asplenium platyneuron*)	1	.1	8	.1
Evening primrose (*Oenothera* sp.)			6	.1
Fleabane (*Erigeron* spp.)#	9	.5	174	2.6
Foxtail (*Setaria leutescens*)			41	.6
Golden aster (*Chrysopsis* sp.)#	9	.5		
Goldenrod (*Solidago* spp.)#	30	1.6	95	1.4

Table 1. Vegetative inventory from six mil-acre quadrats on burned area and six from mowed area, Camp Pickett, Virginia, fall, 1958 (Continued)

Species	Burned		Mowed	
	Total no. plants	Per cent of total veg.	Total no. plants	Per cent of total veg.
Ground cedar (Lycopodium tristachyum)	12	.7		
Groundsel (Senecio spp.)#	70	3.7	7	.1
Hawkweed (Hieracium sp.)	18	1.0		
Hazelnut (Corylus americana)	2	.1		
Hickory (Carya sp.)	1	.1		
Hog peanut (Amphicarpa bracteata)	1	.1		
Honeysuckle (Lonicera spp.)			78	1.2
Horse nettle (Solanum carolinense)	6	.3	21	.3
Korean lespedeza (Lespedeza stipulacea)	40	2.2	1545	23.1
Large spotted spurge (Euphorbia preslii)	1	.1	16	.2
Lespedeza (Lespedeza hirta)*			6	.1
Lespedeza (Lespedeza repens)*	134	7.4		
Maypop (Passiflora incarnata)			1	.02
Milkweed (Lactuca sp.)			10	.2
Morning glory (Ipomoea sp.)			17	.3
Mountain mint (Pycnanthemum flexuosum)	16	.9		
Mouse ear hawkweed (Hieracium pilosella)	22	1.2		
Narrow leaf plantain (Plantago lanceolata)*	17	.9	84	1.3
Oak (Quercus spp.)	2	.1		
Panic grass (Panicum sp.)	82	4.3	51	.8

Table 1. Vegetative inventory from six mil-acre quadrats on burned area and six from mowed area, Camp Pickett, Virginia, fall, 1958 (Continued)

Species	Burned		Mowed	
	Total no. plants	Per cent of total veg.	Total no. plants	Per cent of total veg.
Partridge pea (*Cassia* spp.)	40	2.2	46	.7
Paspalum (*Paspalum* sp.)*			6	.1
Pearly everlasting (*Anaphalis margaretacea*)			1	.02
Pine (*Pinus taeda*)	10	.5	6	.1
Plum (*Prunus* sp.)	31	1.7		
Poison ivy (*Rhus radicans*)	1	.1		
Pussy's toes (*Antennaria* sp.)	153	8.3	8	.1
Queen Ann's Lace (*Daucus carota*)			671	10.2
Ragweed (*Ambrosia artemisiifolia*)	242	13.0	175	2.6
Red clover (*Trifolium pratense*)			1	.02
Red maple (*Acer rubrum*)	3	.2		
Red top (*Agrostis alba*)			106	1.6
Sedge (*Cyperaceae*) (Fam.)*	56	3.2		
Serecia lespedeza (*Lespedeza cuniata*)			7	.1
Smilax (*Smilax* spp.)	4	.2		
St. John's-wort (*Hyperecum* sp.)#	10	.5		
Strawberry (*Fragaria* sp.)	19	1.0		
Sumac (*Rhus* sp.)	7	.4	6	.1
Sweetgum (*Liquidambar styraciflua*)	10	.5		
Thouroghwort (*Eupatorium hyssopifolium*)	31	1.7		

Table 1. Vegetative inventory from six mil-acre quadrats on burned area and six from mowed area, Camp Pickett, Virginia, fall, 1958 (Continued)

Species	Burned		Mowed	
	Total no. plants	Per cent of total veg.	Total no. plants	Per cent of total veg.
Trumpet creeper (*Campsis radicans*)	7	.4	1147	17.3
Umbrella-sedge (*Cyperus* sp.)			1	.02
Vervain (*Verbena* spp.)#			1515	22.8
Vetch (*Vicia* sp.)			13	.2
White clover (*Trifolium repens*)*			2	.03
Wild onion (*Allium* sp.)			24	.4
Winged elm (*Ulmus alata*)	3	.2		
Wood sorrel (*Oxalis* spp.)	1	.1	62	.9
Yarrow (*Achillea* sp.)	19	1.0	27	.4
Unidentified	128	6.9	190	2.9
Total	1859		6636	

*Listed by clumps
#Probably; Plant material not complete

of total vegetation (23.05 per cent) appearing in Table 1. A total of 1,428 of these lespedeza plants appeared in this one plot, leaving only 121 distributed among the other five plots; an average of 44.2 stems per plot. By extending this number (44.2) into the sixth plot and discounting the other 1,424 stems, a total of 165.2 stems for the six plots results, with a percentage of 3.16 per cent of the total number of plants instead of 23.05 per cent. Of course, to do this would alter slightly all of the other percentages for the mowed area, in that it would change the total number of stems of all plants.

In a few instances, where plants were too numerous for practical counting, the percentage was estimated; that is, the per cent of the area within the quadrat which that particular species occupied. This percentage was then reduced to figures by application of the percentage formula P•RB where P = number of other stems present, R = estimated percentage of area covered and B = total number of stems resulting after calculations. This method, while not completely accurate, was deemed sufficiently reliable for purposes of this investigation.

TRAPPING FOR CULTURAL TREATMENT EVALUATION

The 135 traps were opened September 16, 1958, on the four study areas which were comprised of annual mix, winter grain and clover combination, rescue and control plots. These traps were operated until October 31, 1958, a total of 45 nights of trapping or 6,075 trap-nights. One hundred and thirty-five rabbits were marked and of these, 76 were recaptured. A total of 211 rabbits were handled in this phase of study. Each rabbit captured required 28.8 trap-nights. One individual was captured

10 times. An immature to adult female ratio of 2.3:1 and a sex ratio of 130 males to 100 females was found.

Too few rabbits were handled to get a reliable population estimate by the trap-retrap method on most of the areas, so the number of individual rabbits marked was used as an index of abundance. Redd (1956:94) believes that reliable monthly population estimates cannot be made by live trapping due to variability of trap response, especially during summer and early fall. He stated that 40 per cent of the estimated population must be handled before a reliable estimate can be made.

This investigator believes that the relatively high number of trap-nights per capture was due in part to the mild fall weather and the absence of a killing frost until the trapping was terminated. This study tends to indicate a relationship between trapping success and temperature. A coefficient of correlation of -0.273 indicates a possible correlation between a high rate of rabbit captures and low temperature. A correlation coefficient of nearly 1 (or -1) would seem to indicate a definite relationship between two given sets of values; a coefficient near zero would seem to indicate practically no such relationship (Mode 1951:245). Figure 6 shows the number of rabbits captured in relation to minimum daily temperature. A correlation seems to exist, except for the highest temperature range of 65-69 degrees. This may be explained by the fact that only two trapping days fell within this range, resulting in an uneven sample. A correlation may exist between rainy or cloudy days and poor trapping success. Although no correlation coefficient was calculated for this set of conditions, an average of five rabbits per day were

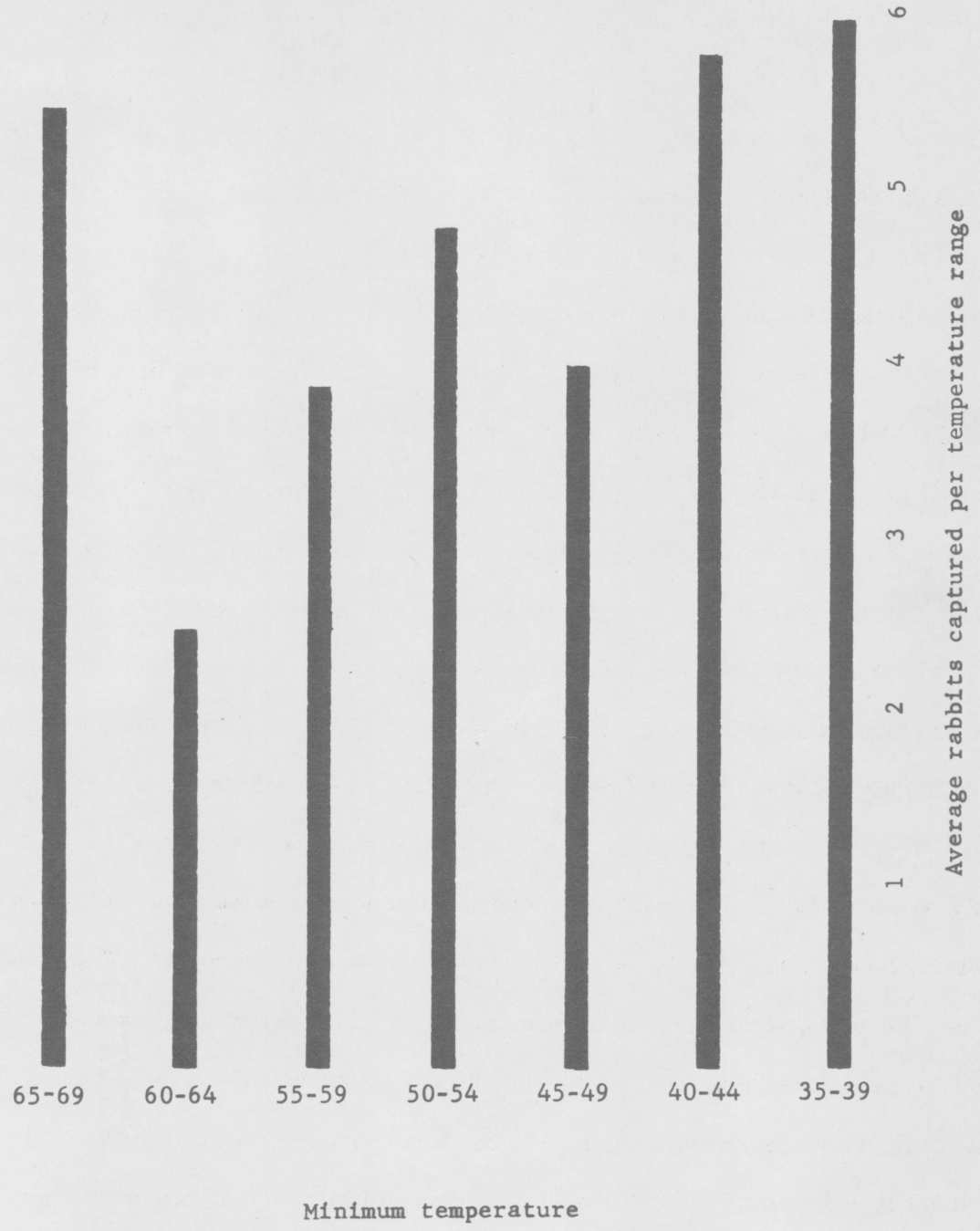


Figure 6. Comparison of minimum daily temperature and number of rabbits captured.

captured on clear days as against 3.5 for rainy or cloudy days.

Since it is assumed that rabbits enter the traps primarily for cover or shelter, it follows that as long as the weather is mild and the fall vegetation luxurient, the traps will be little used. It may be further assumed that when the temperature drops and killing frosts appear, rabbits will enter more readily these handy forms of cover.

This investigator is of the opinion that if trapping had been carried on uninterruptedly into November or December, a higher coefficient of correlation would have been evident.

Annual Mix Trapping Results

On the four annual mix plot trapping sites, 55 rabbits were marked and 25 were recaptured; a total of 80 rabbits were handled. This catch represented 37.9 per cent of all rabbits handled during the first trapping period and 40.8 per cent of all rabbits tagged were captured on the annual mix plots. The annual mix plots had 19.6 per cent more rabbit usage than the clover plantings; 157 per cent more use than the rescue plantings; and 205.5 per cent more than the control area.

Winter Grain - Clover Trapping Results

There were 46 rabbits marked on the winter grain-clover combination plots, 21 of which were recaptured for a total of 67 rabbits handled. A total of 34.1 per cent of all rabbits marked were captured on these plantings and 21.8 per cent of all animals handled during the study were handled in this type plot. This type had 155.5 per cent more rabbit usage than the control area.

Rescue Grass Trapping Results

On a strip of rescue grass, 16 rabbits were marked; this number representing 11.9 per cent of all marked animals. There were 20 recaptures for a total of 36 animals handled; 17.1 per cent of all rabbits handled during this phase of trapping were in this cultural type.

This treatment comprised only 15 acres, compared to 20 acres each for the other two treatments and control; therefore, the best basis for comparison was deemed to be the number of rabbits captured per acre. This study type yielded 1.07 rabbits per acre, the annual mix 2.75, the clover 2.30 and the control 0.90 rabbits per acre. It should be emphasized that these are not the population figures but the average number of rabbits captured per acre of trapped area. This method of comparison of rabbit density was not a valid test of the rescue grass as there was little cover adjacent to the plots. The grass was sown in a firelane which had been bulldozed through a loblolly pine forest.

Control Area Trapping Results

On the control area, 18 rabbits were marked; 10 were recaptured, giving a total of 28 rabbits handled. A total of 13.3 per cent of all rabbits marked during this phase of the study were captured on the control area and 8.6 per cent of all those handled were taken here.

The trapping data for the three cultural types and for the control area are summarized in Table 2.

Table 2. Comparison of rabbit use of various cultural treatments as determined by the number of individuals taken by live trapping, Camp Pickett, Virginia, 1958

	Control				Annual Mix				Clover				Rescue		
	Location No.				Location No.				Location No.				Location No.		
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
Total rabbits tagged	7	2	3	6	4	33	8	10	10	12	16	8	6	8	2
	18				55				46				16		
Recaptures	8	1	0	1	5	8	4	8	11	4	5	1	11	9	0
Per cent of total original captures	13.3				40.8				34.1				11.9		
Number rabbits captured per acre	0.90				2.75				2.30				1.07		

FENCING OPERATION

Flushing Counts

In an effort to evaluate the trapping operation, a portable wire fence was erected around three of the five-acre trapping sites. The enclosure was then mowed and a count made of all rabbits which could be flushed and captured. The rabbits were captured in a large fish dip net. In order to catch any rabbits in burrows, traps were operated for the next few successive nights.

In area I, a winter grain-clover planting, five rabbits were captured during and after mowing but 12 animals had been marked on this area during 45 nights of trapping. This gives an average of 0.26 rabbits per night of trapping. From this it may be assumed that at least 12 rabbits include all or a part of this area in their cruising radius but that probably no more than five are to be found here at any one time. About 20 woodchuck burrows were discovered on this area after the mowing operation. Smoke grenades were used in an attempt to smoke out rabbits that may have entered the burrows; none were smoked out. These facts give interesting background for speculation. In all probability 12 rabbits were using the five acres (2.4 rabbits per acre), yet when the fence was suddenly erected, five rabbits were inhabiting this same five acres (1.0 rabbits per acre). This would lead to the conclusion that during daylight the number of rabbits occupying an area will be less than half the number which utilize the area at night or over a month's time. These ideas are purely speculative.

In area II, an annual mix, six rabbits were captured during and after mowing as compared to 33 marked on this site during the 45 nights of trapping. This is an average of 0.73 rabbits captured per night. From this data it follows that as many as 33 individual cruising ranges may touch upon the five acres but it remains that only five or six rabbits are to be found here at any one time. It is interesting to note that the number of rabbits captured inside the pen is nearly the same as it was on the previous site, yet this latter site produced nearly three times as many rabbits by trapping.

On this area the woodchuck burrows were plugged with burlap bags before mowing then unplugged after mowing to allow any rabbits to emerge which may have taken refuge in the burrows.

Area III, another annual mix plot, when fenced and mowed yielded no rabbits, although 10 had been marked by trapping (an average of 0.22 rabbits per night). The only conclusion would seem to be that 10 animals used this area to some extent but few or none used it intensively.

In opposition to this, however, is the fact that a higher percentage of rabbits were recaptured on this latter site than on either of the other two. On this area one-half were recaptured at least once as opposed to one-third being recaptured for area I and slightly over one-fourth for area II.

It appears that when a given area was fenced, mowed and the rabbits counted by flushing, a reliable index to abundance was not obtained. One area on which 33 rabbits had been marked produced six after fencing; another on which 12 had been marked yielded five and a third on which 10

had been marked produced none. Admittedly, these cases are too few in number to draw conclusions; more investigation needs to be conducted on this problem.

Testing of Population Estimation Formulae

In an effort to test population estimation formulae, the fence was again erected on an area which appeared to be good rabbit habitat. In order to conduct this experiment with a known population, trapping was conducted inside the pen and 10 rabbits were captured, marked and released. Nine of these traps were gridded at 200 foot intervals, as for all other trapping operations, and 12 additional traps were placed along the fence. Three rabbits in addition to the 10 were captured within the enclosure but were released outside the pen. There were then a total of 13 rabbits captured within five acres.

This area was left idle for about two weeks then the traps were again opened in an effort to get a population estimate. It soon became apparent however, that some of the rabbits had disappeared. The fence had been knocked down by deer and at least one rabbit had burrowed under the fence. The pen was intensively trapped for 19 days and only five individuals were captured.

Working on the assumption that five rabbits had been removed by unknown causes, five additional rabbits were tagged and stocked into the pen. Traps were again opened and an attempt to measure the population was made. The area was trapped from January 25 until February 17, which was termed the first trapping period. It was discovered that rabbits were again being lost to predation so four more rabbits were marked and added

to the population.

The second trapping period started February 26 and continued until March 19 at which time it was decided that the population was again declining markedly. As a result of the lower numbers, 13 more cottontails were added to the pen, a total of 32 animals had been released into the pen. As it was impossible to know how many rabbits were present after this last release, it was decided to conduct the estimate for a reasonable time and then mow the pen and flush-count the rabbits. Since it was believed that predation was the major cause in removing rabbits from the pen, three pole traps and three fox sets were made. The pole traps were put inside the pen and the fox sets were placed just outside the wire. A total of one song bird, two barn owls, two sparrow hawks, one opossum, one skunk and one female red fox were caught. All species considered to be beneficial were released.

The third trapping period started on April 2 and the area was mowed on April 16. No predation was observed during this period but six rabbits were found dead in the trap and three more on the ground. Four of these rabbits were frozen and shipped to the Virginia Polytechnic Institute Animal Pathology Laboratory for autopsy. No evidence of disease was found and the animals apparently died from shock, stress, and reduced food supply.

Population estimates for these trapping periods were made by three formulae; the Krumholz formula, the Lincoln index and the Shumacher and Eschmeyer formula. The Krumholz formula states that $P = \frac{\Sigma AB}{\Sigma C}$, in which P is the population, A is the number of animals captured in any one day,

B is the number of marked animals in the area and C is the number of returns or recaptures.

The Lincoln formula says $\frac{N}{n} = \frac{T}{t}$, where N is the population (unknown), n is the number of animals marked in the precensus period, T is the total number of animals handled in the census period, and t is the number of marked animals captured during the census period, Redd (1956:15-16).

The Shumacher and Eshmeyer formula, $N = \frac{\Sigma\left[n^2 (m + u)\right]}{\Sigma (nm)}$, where N is the total population, n is the number of marked animals in the area, m is the number of recaptured animals in each sample and u is the number of unmarked animals in each sample. The sampling variance for this method can be calculated by the following formula in which K equals the number of samples taken and the other symbols are as given above: $S^2 = \frac{1}{K-1}\left[\sum\left(\frac{m^2}{m+u}\right) - \frac{\left[\Sigma(nm)\right]^2}{\Sigma n^2 (m+u)}\right]$. The standard error of the estimate was calculated by the following formula: $S.E. = N\sqrt{\frac{S^2}{(\Sigma nm)^2}}$, Schumacher and Eschmeyer (1943).

Results of Censusing

Table 3 shows a comparison of estimates made by the three formulae for each of three census periods. The first period ran from January 25 until February 17 with six rabbits in the pen at the start and four at termination of the census. The second period ran from February 26 until March 19. There were seven rabbits in the pen at the beginning and four at the end of the census period. Census period number three started April 2 and extended until April 16. There was an unknown number of rabbits in the pen on April 2 and on April 16 the pen was mowed and eight rabbits were recovered.

It may be seen from Table 3 that the three formulae produced very similar results. The Krumholz formula estimate for the first trapping period was 5.3 rabbits higher than the Shumacher-Eschmeyer estimate and 6.6 rabbits higher than the Lincoln formula. It is a characteristic of the Krumholz formula, that as daily estimates are made they are erratic in the beginning, however, after approximately 40 per cent of the estimated population is handled the estimated population figure begins to level off and fluctuate closely around a mean (Redd, 1956:94).

For purposes of this investigation, an estimate was considered valid when the fluctuations did not vary over approximately 10 per cent for a five-day period. The arithmetical mean of the last five days was then taken as the population estimate. In the case of the Krumholz formula, this static situation never existed for the first trapping period. At the termination of trapping the daily population estimates were still highly erratic which probably accounted for the above-mentioned discrepancy.

In trapping period two, all three formulae produced very similar results.

In trapping period three, the Lincoln Index differed from the other two by nearly two rabbits, but all three differed from the actual number present (determined by mowing and flush counting) by approximately one rabbit. When the area was mowed and counted, eight rabbits were recovered. At this time the population estimate was 9.0 by the Lincoln formula, 7.1 by the Krumholz formula, and 7.0 by the Schumacher-Eschmeyer formula.

Table 3. Comparison of population estimates by three formulae for three census periods within a five-acre enclosure, Camp Pickett, Virginia, January - April, 1959

Trapping Period	Lincoln Formula	Krumholz Formula	Schumacher-Eschmeyer Formula	S.E.	Trap Nights
1	5.3	11.9	6.6	.60	589
2	5.0	5.1	5.3	.47	441
3	9.0	7.1	7.0	.53	277

Population Estimation on Rescue Grass

The only area in the original trapping for comparison of cultural treatments on which reasonable population estimates could be based was the rescue grass on an established firelane. Twenty-seven traps were opened on fifteen acres of this type (three 5-acre trapping sites) on September 16. When the traps were closed on October 31, a total of 16 rabbits had been marked and 20 recaptures made. Eight, or one-half of the marked rabbits had been recaptured at least one time. Population estimates were prepared for this area by the three previously mentioned formulae.

The Krumholz formula yielded a population of 16.8 rabbits during this period, while the Shumacher-Eschmeyer formula gave 17.9 with a standard error of .48 and the Lincoln Index a population of 14.9 rabbits for these 45 days of trapping.

PELLET COUNTS

Pellet counts were made at each trapping site. The results of these studies substantiate the findings indicated by live trapping. Percentages of total pellets found in the various treatments agree quite favorably with the percents of total rabbits tagged in the same respective treatments. These data are summarized in Table 4.

The pellet counts were made during March 1959, after some of the areas had been mowed. One of the clover areas and two of the annual mix areas were mowed. On the clover area which had been mowed, 10 pellets were counted; the average for each of the four clover plots was 30.5.

Table 4. Comparison of rabbit use of cultural treatments as indicated by pellet counts and live trapping, Camp Pickett, Virginia, 1958

	Control				Annual Mix				Clover				Rescue		
	Trapping sites														
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3
By pellet counts															
Total number pellets	24	5	11	14	40	32	74	1	63	25	10	24	21	6	6
	54				147				122				33		
Per cent of total pellets	15.2				41.4				34.2				9.2		
By live trapping															
Total rabbits tagged	7	2	3	6	4	33	8	10	10	12	16	8	6	8	2
	18				55				46				16		
Per cent of total tagged	13.3				40.8				34.1				11.9		

The two annual mix plots, which had been mowed, averaged 16.5 pellets each while the average for all the annual plots was 36.8 pellets each. The mowing operation apparently reduced rabbit usage of these three sites. This reduction in rabbit usage is further indicated by the fact that prior to mowing rabbit usage was 43.8 per cent (determined by trapping), whereas, after mowing rabbit usage was reduced to 12.1 per cent (determined by pellet counts). This reduction in usage, probably due to mowing, was obviously temporary. Where mowing was done, the entire five acres, with the cultural treatment in the center, was mowed. This operation eliminated the cover adjacent to the food supply. It would seem logical to assume that as the succulent new growth appears in the spring, usage around the periphery will increase. Also, when the plant material is high enough to provide cover, the rabbits will probably be back in the cultural treatments in normal abundance for the time of year.

ROAD COUNTS

Road counts were conducted in an effort to obtain young to adult ratio data, as well as an index of abundance. Petrides (1951:334-335) says that during normal years young rabbits are all important in determining the size of the rabbit crop available to hunters. It also seems evident that by early July the majority of young cottontails have been born. Yet, at that time few immature rabbits normally would be large enough to be confused with adults. It would seem that roadside tallies made in late June and July of the total number seen per mile and the

ratio of young per adult cottontail could be easily correlated with later hunting success. Conceivably, this system could provide a simple basis for predicting potential hunting success and for adjusting open season regulations where necessary.

In Kentucky, Bruna (1952:51) found a rabbit road count conducted by conservation officers from March through October to be the most feasible means of sampling cottontails over large areas. By recording rabbits into relative size classes, data on the adult:juvenile ratio were obtained. One practical method of categorizing rabbits is the scheme of one-fourth grown, one-half, three-fourths grown and adult.

In the present study, roadside counts were conducted from August 23, 1958, through October 10, 1958, at an average of two per month.

During the six counts, only 23 rabbits were seen on 209 miles traveled; an average of 0.1 rabbit per mile.

This study indicated a young to adult ratio of 3.6:1. Assuming the sexes to be even, a young to adult female ratio of 1.9:1 is calculated. These data appear in Table 5.

It is difficult to explain the relatively poor success of this road count. In all probability few rabbits were seen because of the density and abundance of cover along the roads, a situation which may not exist extensively in agricultural areas.

HUNTING SEASON HARVEST

A complete record of the game killed on Camp Pickett was collected by the Game Commission for the 1958-1959 hunting season. Included was a

Table 5. Results of road counts conducted at Camp Pickett, Virginia, August 23, 1958 - October 20, 1958

Rabbits observed		Date	Miles traveled	Rabbits observed per mile
Adult	Juvenile			
1	1	8/23/58	48	.04
3	3	8/23/58	48	.13
0	6	8/30/58	48	.13
0	2	9/24/58	19.8	.11
0	6	9/30/58	19.7	.32
1	0	10/20/58	19.7	.05

record of the harvest of all rabbits which had been marked during this study. The total number of hunters using the area per day was recorded, but these data were not broken down as to type of game hunted.

There was a total of 6,625 man-days of hunting and a total of 5,455 head of game killed. Of this, 2,863 head (52.5 per cent) were rabbits. By assuming an equal percentage of success for all types of game and using 52.5 per cent of the total hunter man days, it is calculated that 3,478 man days were spent in the pursuit of cottontails. If this be the case, 1.21 rabbits were killed per hunter-day. This kill figure appears to be low which indicates that a higher percentage of success existed for rabbit hunters than for some other types of hunters.

Of the 2,863 rabbits killed, 34 were tagged. By applying the Lincoln index, $\frac{N}{n} = \frac{T}{t}$, (where N is the unknown population, n is the number of animals marked in the precensus period, T is the total number of animals handled in the census period and t is the total number of marked animals captured during the census period [Redd 1956:15-16]) a population of 11,367 rabbits for entire Camp Pickett was calculated; this calculation indicates a population density of one rabbit per 4.1 acres. Of course the confidence level of this estimate is very low, due mainly to the fact that too few rabbits were tagged during the census period. When it is considered that much of Camp Pickett is totally unsuitable as rabbit habitat, this figure of one rabbit per 4.1 acres does not seem unreasonable.

The hunting kill records for Camp Pickett date back to 1956-1957 season. It was at this time the intensive management of this area was

undertaken. This management effort consisted mostly of the food plots previously mentioned, winter grain and clover sown along firelanes and some predator control in the form of fox trapping. These management techniques seem to have resulted in higher kill of game. In the 1956-1957 season, 1,972 head of game were harvested. In the 1957-1958 season 3,247 head were killed, an increase of 69.7 per cent. During the same period, hunting pressure increased from 4,579 man-days to 4,959 man-days, an increase in pressure of only 8.3 per cent. During the 1958-1959 season 5,455 head of game were killed for a 68 per cent increase over the preceding season. The hunting pressure for the same period shows an increase of 33 per cent.

The increase of rabbits killed from the 1956-1957 season to the 1958-1959 season was 70.2 per cent. Table 6 shows the number of rabbits killed by months at Camp Pickett for the 1956-1957, 1957-1958, 1958-1959 seasons. Appendix Table 1 shows the hunting take for all species.

If it is assumed that 11,000 was the approximate rabbit population on Camp Pickett before the 1958-1959 hunting season, then about 26 per cent of the population was harvested during this season. Most investigators would agree that cottontail rabbits can stand a much higher per cent removal without danger to the population. Hendrickson (1947:474) in Iowa found that three-fourths of the rabbit population can be harvested and the remaining seed stock may be expected to reproduce as well the next year if food, cover, weather and other general conditions are normal. Bruna (1952:72) says, "As long as there is proper cover it is nigh impossible to overhunt an area. It appears that habitat, weather,

Table 6. Rabbits killed at Camp Pickett by season and month during the hunting season 1956-57 through 1958-59

Season	November	December	January	Total
1956-57	195	401	256	852
1957-58	503	745	656	1904
1958-59	1102	1085	676	2863
Total	1800	2231	1588	5619

disease, and predation are the factors that determine whether the brood stock will provide a scarce or bountiful harvest season."

In Michigan, Pirnie (1949:305-307) found that through hard hunting about 60 per cent of the rabbits were being removed from a 500 acre tract during 1935 and 1937. The same hunting pressure was applied for 16 consecutive years (1932-1947) without any apparent detrimental effects on the population. The average yield over the 500 acres was about one rabbit per five acres.

DISEASE

Evidence of rabbit disease was very limited on Camp Pickett. Three dead rabbits were autopsied in the field but negative results were found. One of these rabbits, No. 845-46, a mature female, died in the investigator's hands while being tagged. Death was apparently due to shock or perhaps a coronary occlusion. Rabbit 986-87, an immature female, was suffering from shock upon removal from the trap on October 28, 1958. She was in a debilitated condition, but was placed near the trap in the sun in the hope that she would recover. On October 29 this rabbit was found dead about 18 inches from where she had been left. Upon autopsy, the small intestine was found to be packed with tapeworms, the lungs were bright red and no manifestations of a diseased condition were evident. Death was apparently caused by shock, aggrevated by the poor general condition. Rabbit No. 1158-59, an immature female, was found dead in the trap February 26, 1959; death apparently attributable to shock. Six rabbits were found dead in the five-acre enclosure, four in the trap and two on the ground. Four of these six were frozen and shipped to the Virginia

Polytechnic Institute Animal Pathology Section for autopsy. No evidence of disease was found and death was apparently due to a combination of stress, shock and low food supply.

Tularemia

Since 1955 the Virginia Cooperative Wildlife Research Unit has received bi-monthly Morbidity Reports from the Bureau of Communicable Disease Control of the Virginia Department of Health. In addition to these reports, records on tularemia back to 1945 were received from the Department of Health. For the past three and one-half years a follow up by mail has been made on 102 human cases of tularemia by writing to the respective county health officer. Information relative to the source of infection was sought. These data then gave the number of human cases, distribution of tularemia throughout the state, seasonal occurance and sources of infection. This data is summarized in Table 7.

Human Tularemia in Virginia

From 1945 through April 1959, there were 642 tularemia cases in Virginia. During this time the largest number of cases occurred during 1946 when 77 cases were reported. The next peak was reached in 1953 with 55 cases. The least number of human cases was in 1956 when only 23 Virginians were reported as having had tularemia. The following two years, 1957 and 1958, had 35 and 32 cases respectively. The fact that tularemia can be easily mistaken for some other malady and the causitive organism destroyed by antibiotics without a correct diagnosis having ever been made may account, in part, for the decline in frequency since 1946.

Table 7. Sources of tularemia infections in humans, Virginia, October, 1955 - April, 1959

Source	Oct. 1955	1956	1957	1958	Apr. 1959	Total
Cottontail Rabbit	4	8	20	23	9	64
Tick bite	2	4	5	5		16
Squirrel bite		1				1
Cat scratch	1					1
Dog bite		1				1
Opossum bite		1				1
Laboratory infection			1			1
Unknown		2	3	3		8
No reply		1	6	1	1	9
Total	7	18	35	32	10	102

Distribution Throughout the State

Although tularemia is widespread in Virginia there are two areas of greatest incidence. The most notable concentration area for the disease is south-central Virginia. Halifax County had the greatest number of cases, 42 (6.5 per cent) for the period in question. The surrounding counties of Mecklenburg, Pittsylvania, Charlotte and Campbell also experienced a comparatively heavy incidence. The second concentration area was in northern Virginia which included the counties of Augusta, Rockingham, Shenandoah, Culpeper, Fauquer and Loudon.

In the Camp Pickett area (Nottoway, Dinwiddie and Brunswick counties) the trend has followed closely that of the rest of Virginia; with a high of four cases in the three counties in 1946, then another high of six cases in 1952 and the last case reported from this area in 1954 when two occurred. During the entire period from 1945 through April 1959 a total of 18 human cases of tularemia were reported from these three counties. This is 2.8 per cent of all cases reported throughout the state of Virginia for the same period.

Sources of Infection

From the replies received from the county health officers, on the 102 cases followed up by mail, it would appear that the common name for tularemia, "rabbit fever," is well chosen because 64, or 62.7 per cent, of the infections were attributable to the handling of cottontail rabbits. Next in importance were tick bites which were 16 in number for 15.7 per cent of the total cases. In eight cases the cause or source of infection

could not be determined and in nine instances a reply was not received from the county health authorities. The remaining five infection sources with one case each were: squirrel, cat scratch, dog bite, opossum bite and laboratory infection.

It would seem logical to anticipate a definite increase in tularemia incidence during and just after the rabbit hunting season; this is borne out by the morbidity reports. The peak period of occurrence is January, but the months of November, December, January and February are notably high. Another peak is evident during the months of June, July and August which coincide with the height of tick activity. The period of quiesence is from March through May, a time of little tick activity. This points up the fact that ticks are one of the primary vectors of tularemia.

Fibroma

"Shope's fibroma is a virus disease which attacks cottontails and is spread through the bites of mosquitos and perhaps fleas" (McGinnes 1958:48). It seems to have no particular ill-effects on the rabbit and is probably not communicable to man. The disease is manifested by a pink, fleshy wart or tumor found primarily on the feet and head.

"According to present knowledge, hunters need have no fear concerning the handling or eating of rabbits with fibroma. The tumors are confined to the skin and are automatically removed when the animal is pelted. There is no evidence of transfer of the infection to man either through handling or eating rabbits which have been infected with these tumors" (Herman et. al., 1956:86).

Throughout this investigation, all rabbits handled were inspected for gross lesions of Shope's fibroma. From 179 individual rabbits handled, four animals or 2.2 per cent, were found to have fibroma tumors. In all cases they were on the rear legs and feet. Rabbit No. 1022-23 when first captured on October 14, 1958, had no evident tumors; recaptured eight days later, a tumor was observed on a hind leg. McGinnes (1958:71) at Blacksburg, Virginia, found fibroma in only one rabbit out of 973 handled.

PARASITES

A detailed record of parasites was not kept during this study except for Cuterebra larvae; however, several parasite species were observed.

Endoparasites

Rabbit No. 986-87, which was one of three autopsied, was found to contain tapeworm. This tapeworm was not identified, but was presumed to be the rabbit tapeworm (Cittotaenia sp.). The small intestine was completely blocked with numerous individuals. Examination was not made for other endoparasites.

Ectoparasites

Fleas and ticks were not numerous on the cottontails except during the spring and were noticeably scarce during the winter months.

Records were kept on the incidence of occurance of bot fly (Cuterebra) in the rabbits handled. Cheatum (1952:20, original not seen) says

"This bot fly larva or grub is found under the skin and is most commonly located in the neck region. A breathing hole is made in the skin and the larva grows to maturity. When fully grown these grubs may be over one inch long and half an inch in diameter, dark in appearance, and covered by short, stout spines. During the latter part of summer and in the fall they force their way through the breathing aperature and fall to the ground where they burrow and enter the pupal state for the winter. In the spring the adult bot fly emerges from the pupa, mates and searches for a rabbit on which to deposit her larvae, and the cycle is repeated." Figure 7 is a Cuterebra fly larva which was removed from a cottontail.

One hundred fifty-five infestations of Cuterebra parasitism in the cottontails were observed; 115 living larvae and 40 scars. Bot fly larvae apparently do not display preference to sex of the host; 75 infestations were made on males, 65 on females and 15 on rabbits of undetermined sex. There was, however, heavier parasitism in young rabbits; 111 larvae were observed on immatures, 39 on adults and 5 on individuals of undetermined age.

One immature male had been host, at different times, to eight bot larvae. Rabbit No. 857-58, an immature female, was host to six larvae at one time. Twenty-two adult rabbits were parasitized with an average of 1.8 larvae per rabbit, 41 immature cottontails had an average infestation of 2.7 larvae per rabbit. Larvae were found on 35.1 per cent of all individuals handled. McGinnes (1958:50) found an average infestation for two years at Blacksburg, Virginia, of 15 per cent. Bruna (1952: 38) in Kentucky, observed bot larvae on 12.6 per cent, while Geis (1957: 94) observed 26 per cent infestation in the summer of 1956 and only 11

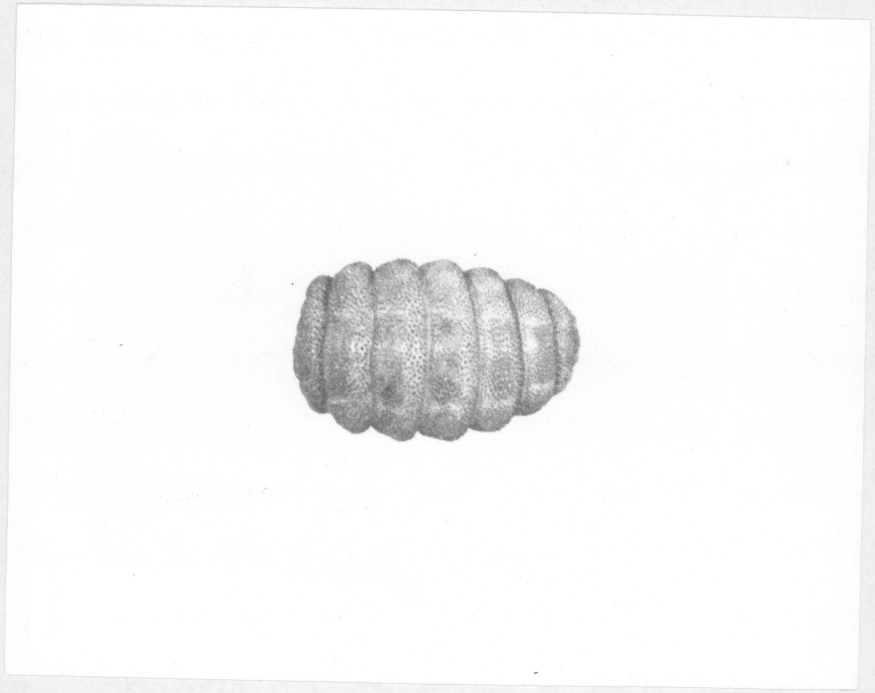


Figure 7. Bot fly larva.

per cent in the summer of 1957 in Michigan. Geis also discovered a heavier infestation in immature than in adult rabbits as did McGinnes (1958: 50). Geis (1957:94) reported that most rabbits contained one larvae, a few had two or three and as many as eight were observed in a single rabbit. This latter worker found most of these parasites located beneath the skin of the throat and chest region. McGinnes (1958:50) found practically all parts of the body attacked.

In the present investigation it was found that all parts of the body were infested, but the larvae were more frequently observed in the rabbit's genital region where 48 of the 155 "grubs" and scars were found. The next preferred site was in the shoulder region where 31 infestations were observed and 29 were found in the side of parasitized rabbits. Only 15 bot fly larvae were found to attack the neck region, and most of these were on the back and sides of the neck. The parasites were located in other places as above and under the tail, in the back, the flanks, the belly and foreleg. It is of interest to note that only one larva was found near the genitals on adult rabbits. The preferred area of attack on adults seemed to be the side and shoulder regions respectively.

RABBIT MANAGEMENT DISCUSSION

Game management, says Leopold (1933:391-392), is a way to maintain a supply of game and other wildlife, in the face of an expanding population. This game supply must have quality as well as quantity. Trippensee (1948:v) states, "The field of wildlife management has many sides and many angles. Fundamentally it is the process of making land and water produce sustained crops of wild animals... Wildlife management has a sound economic basis. Crops of wildlife can be grown on land not suited to other crops."

Fortunately, wildlife management often fits admirably into a plan of multiple land use. This is not only true in conjunction with the practice of forestry, but applies also in the science of agriculture. That wildlife management in one form or another may be adapted to nearly all programs of land use is a fact deserving major emphasis (Trippensee, 1953: vii).

Although this investigation was conducted on an area not primarily devoted to forestry or to agriculture, many of the rabbit management recommendations here set forth are applicable to both types of land use as both are practiced here to a limited degree.

Thornton (1954:5) reported that food is not normally a major problem for the rabbits on agricultural lands in Virginia. On most farms, enough food and cover are available to produce a huntable surplus of rabbits.

On Camp Pickett, this is obviously not the case. As shown by results of trapping, over 200 per cent more rabbits were found on areas where food alone was provided than on unimproved areas. This does not

refute Thornton's opinion as he was referring to agricultural regions where good rabbit food usually results as a by-product of farming operations. Since very little or no farming is practiced on Camp Pickett, and since it is an area of comparatively fertile soil, it seems logical to assume that rabbit cover would be more naturally abundant than food. If this be the case, and if Bruna (1952:72) was correct in stating that habitat, weather, disease and predation are the factors that determine whether the brood stock will provide a scarce or bountiful harvest season, then management of large non-agricultural blocks of land should be concerned with supplying food and breaking up available cover.

It has been said that the greatest boon to quail and rabbits was the split rail fence with a strip on both sides that could not be cultivated. These fences were usually allowed to grow into a tangle of ragweeds, briars and plants which offered good wildlife food and cover conditions. Our modern methods of clean farming have eliminated these swaths of food and cover to the detriment of the farm game population in many instances. It is not feasible to recommend a return to the split rail fence, but if fence rows, ditch banks, roadsides, railway rights-of-way, and other such areas were planted or even allowed to grow naturally to preferred food and cover plants for rabbits, quail and small game species, we would undoubtedly experience an increase in game abundance. Nearly all farms have some waste acres that are suitable to produce food and cover for the cottontail and other game species (Thornton 1954:5).

COVER

There are basically two kinds of cover required by cottontails; nesting cover and escape cover. Nesting cover is usually less dense vegetation than escape cover. In Iowa cottontails were found to nest chiefly in bluegrass, timothy, oats and alfalfa; partially in open fields and partially in orchards (Hendrickson 1940:31). Dalke (1937: 544) in Connecticutt found 43 per cent of 12 nests examined in brush, 25 per cent in woods, 16 per cent in hayfields and 16 per cent in grass lands other than hayfields. In Kentucky, Bruna (1952:15) found broomsedge to be the preferred nesting cover early in the season and shorter grass later in the season.

The best nesting cover consists of open grassy fields near good brushy escape cover. Unmowed hayfields, broomsedge fields and even pasture fields that have not been grazed too closely make good nesting sites. Ditch banks with a good grassy sod and other cover nearby, are also suitable nesting sites (Thornton 1954:5).

Brushy fence rows, briar patches, honeysuckle thickets, brush piles and rock piles are good examples of escape cover. It is the opinion of Bruna (1952:70) that multiflora rose, pines and brambles are good cottontail cover; this worker believes that the lack of cover isn't as important in Kentucky as its distribution. In West Virginia (Survey of Pittman-Robertson Activities, 1957) it was found that 5.7 miles of multiflora rose borders contained an average of 32.1 rabbits per mile while 3.8 miles of natural borders contained an average of 51.0 rabbits per mile. Also, in 1954 they found twice as many rabbits in natural as in rose planted borders.

After heavy frost the brush pile becomes most valuable. It has been said that good cottontail management in Virginia is as simple as building plenty of brush piles in the right places. Brush should be placed in or near durable escape cover and should be piled closely on top of long logs or large rocks in order to provide head room. The brush piles should be four or five feet high and 12 to 15 feet in diameter to provide maximum shelter after settling. Brush from recent lumbering or logging operations or pruned from fruit trees or shrubs are suggested sources. Wind rows from bulldozer operations provide excellent cover (Thornton, 1954:6).

Growing conifers often make good cover, especially when widely enough spaced that low growing branches form a dense ground cover. Discarded Christmas trees are very satisfactory in brush piles.

The position or location of cover seems to be at least as important as any plant species (Bruna, 1952:41). In Iowa, Linder and Hendrickson (1956:733) found the mean distance between escape cover and nest sites to be 64.7 feet with a range from zero to 262 feet. Dell (n.d.:1) says that in New York cottontails may be found in almost all types of cover except extensive woodlands. Ideal rabbit habitat consists of about equal quantities of cropped land, grass land, brush land and cut over wood land interspersed as small units. The location of food in relation to cover is of extreme importance in determining rabbit survival from season to season.

The emphasis in cottontail management might logically be placed on small nesting areas that will attract the females, as they use a small area for a breeding territory and will use the same nest for successive litters and nest in close proximity to other females. These areas should

be well stocked with preferred food and cover, fenced from livestock and protected from man and free ranging dogs and cats (Dalke 1942:77).

In Kentucky it was found that broomsedge and woods were intensively used for cover at all times of the year. Large solid blocks of broomsedge were not as heavily used as small areas adjacent to other types of cover. "It appears that the utility of cover probably is determined by what cover is present at a certain time, and its position in relation to the daily and seasonal requirements of a rabbit, rather than any individual preference" (Bruna, 1952-41).

FOOD

Webster defines food as, "Nutritive material taken into an organism for growth, work or repair and for maintaining the vital processes." Food may also be defined as any substance taken into the body which can be utilized for the release of energy, for the building and repair of tissue, or for the regulation of body processes (Villee, 1957:298). For the cottontail, food consists primarily of vegetative material. Bruna (1952: 71) says that food is not too important except during very severe weather, but Stuber (1938:652) in Ohio believes both summer and winter food to be just as important as cover. In a Connecticut study it was found that grasses and clovers comprised 56 per cent of all the food consumed. The rest, which could be identified, was found to be a wide variety of herbaceous and shrubby plant material, including seeds and fruits. A relatively large percentage of the stomachs examined showed traces of rabbit fur (Dalke, 1937:546-547).

Seton (1929:789) says that to make a complete list of the plants that are cottontail foods would be to catalog 99 per cent of the flora of the United States. Nevertheless, some foods are preferred over others. Appendix Table 2 lists a number of plants used by rabbits for food and cover. This list was compiled from the literature and the writer's observations. Undoubtedly many other species could be added.

It has been said that cottontail management consists primarily of providing adequate food and cover within the cruising radius of the rabbit. This cruising radius varies greatly and seems to be inversely proportional to the quality of the range, that is, the food and cover present. Stuber (1938:652-653) found the cruising radius to be from one-fourth to one-half mile, providing the habitat is satisfactory. Hamilton (1939: 305) says that cottontail rabbits are relatively sedentary creatures; the females having a yearly range of about three acres and the more active males about eight acres. "On an area of 200 acres or more, it is wise to have at least two food patches of an acre each." (Stuber, 1938:652). Bruna (1952:71) recommends a one-fourth acre plot to every 25 acres.

The present investigation found a much higher usage (205 per cent by trapping and 172 per cent by pellet counts) of areas supplied with food plots over natural untreated areas. These plots consisted of eight annuals, sown in the fall after an application of 2:12:12 fertilizer. These annual areas showed higher usage than plots sown to clover and winter grains (Table 2). It must be pointed out, however, that the trapping period was in the fall, from September 16 to October 31, at a time when rabbit usage of the annual mix was probably at its highest. Notwithstanding the fact that spring-conducted pellet counts supplied data very simi-

lar to the fall trapping (Table 3), it seems logical to assume that the clover received a higher year-around usage than the data indicate. Old pellets as well as new ones were counted and the counts were made in February when rabbits had probably just begun to use the clover. These clover patches consisted of red clover or Ladino clover and a winter grain, rye or oats, which served as a nurse crop. Each plot was treated with lime, as well as 2:12:12 fertilizer.

Based on these findings, as well as the literature, it appears logical to make the assumption that food is the chief limiting factor for cottontails on large non-agricultural blocks of land. However, cover may well be the chief limiting factor on farming areas.

On areas such as Camp Pickett, management should be directed toward food plots consisting of a mixture of annuals plus clover or fescue for spring greens interspersed with the available cover. These food patches could be used to break up large blocks of cover; which would provide approximately one to one and one-half acres of food per 200 acres of land. Planting food patches in a long narrow shape or even serpentine form, will provide desired maximum edge effect.

Where it is not feasible to plant food to this extent, mowing or burning can be used to break up large blocks of cover to allow tender succulent growth to become established. Burning should be conducted with great caution. Only small areas should be burned at a time and burning should be done early in the spring, before wildlife begins nesting. In Virginia, January and February are probably the best times for early burning.

On areas primarily devoted to agriculture, most of the preceding recommendations hold true; except, that in most instances management should be directed more toward cover restoration than toward establishment of food.

There are many ways to improve cottontail cover on most farms. Brush piles strategically located, ditch banks, fence rows and odd field corners which are allowed to grow up to briars, sumac and evergreens provide excellent cover conditions. These cover plants supplemented with food such as ladino clover, rape, fescue and honeysuckle constitute good rabbit habitat. After harvesting corn with a mechanical picker, stalks left in the field till spring provide some rabbit cover. If the land owner or game manager is willing to sow a strip of clover or fescue along the margin of the corn field after harvest, this practice will provide rabbits and other wildlife forms with a winter source of green food. Fencing of woodlots and areas of low pasture value and felling occasional undesirable trees for cover along woodlot edges and letting the tops lay in the adjoining fields improves the habitat which may result in an increase in the rabbit population.

"Rabbits will breed better and grow bigger if we do nothing but lime and fertilize the soil," says Latham (1952:5), "but outstanding results are achieved when additional food and cover work is done." It is Bruna's opinion that "...as the rabbit population increases, the average hunter kill does not rise in proportion. The only substantial increase is usually in the number of people hunting rabbits." (Bruna 1952:73). Since a primary aim in game management is to provide more hours of outdoor recreation, this situation is an encouraging facet of management.

PREDATOR CONTROL

Predator control in wildlife management is a highly controversial subject. Like most controversial subjects, predator control probably is neither all good nor all bad.

This study was not concerned primarily with predation and the only practice of control on Camp Pickett was the periodic removal of foxes.

The control of highly mobile species on areas of farm size is probably not feasible due to influx from adjoining territory, particularly if prey is more readily available on the area under consideration. Likewise, it is unsound to attempt predator control on a county or state wide basis for the simple fact that cost would be prohibitive, due to the magnitude of the area.

On an area such as Camp Pickett, however, the control of mammalian predators is perhaps within the realm of possibility. The area is too large for much influx; but small enough that a significant number of mammalian predators can be removed by trapping in the spring and destroying pregnant females.

The indescriminate control of predators, however, may be dangerous. The removal of all hawks by well intentioned persons leaves ecological niches which may well be filled by the more harmful accipiters (Leopold, 1933:242).

COST COMPARISONS OF CULTURAL TREATMENTS

It is the writer's opinion that a reliable test of rabbit usage was not made of the rescue grass. Cost figures would be abnormally high, due to the scarcity of rescue grass seed at the time of planting; therefore this discussion will be concerned with only the annual mixture and the clover-winter grain combination plantings.

The annual mixture plot establishment is broken down on a cost per one-half acre as follows:

Annual mixture seed	$1.80
Fertilizer 2:12:12	4.05
Labor	1.25
Gas and oil	.20
Total	$7.30

The clover-winter grain was broken down as follows per one-half acre plot.

Winter grain seed	$2.28
Clover seed	1.59
Fertilizer 2:12:12	5.22
Lime	7.50
Labor	1.30
Gas and oil	.20
Total	$18.09

It will be noted that the annual mix was rated 19.6 per cent higher in rabbit usage (during a fall trapping period) than was the clover-winter

grain. It will also be noted that an annual mix plot is $10.79 (67.7 per cent) less expensive to install than a clover plot. These data appear in Table 8.

From the foregoing information it appears that the installation of annual mix plots is a more desirable rabbit management practice than is the establishment of clover-winter grain plots. It must be pointed out, however, that had measurments been made in the spring, a higher usage of the clover plantings may well have been observed. It is also true that while less expensive to install initially, the annual type plot must be replanted every year. The clover-winter grain type plot is a perennial, the grain being primarily a nurse crop. In the long run, the clover-winter grain plot is the most economical and probably just as valuable as the annual mix, if the spring usage is considered. Where food is being provided for cottontails on private land or intensively managed public land, costs and labor are items of concern. If the game manager can justify establishment of annual plots on a sustained basis, then this type plot would be most desirable because its foods will be utilized by quail, turkeys, and songbirds. However, if labor and costs over a three to five year period do not permit establishment of annuals, the sound approach would be to install clover-winter grain plots.

Table 8. Cost and rabbit usage comparisons of cultural treatments

	Annual mix	Clover-winter grain combination	Per cent of difference
Rabbit usage			
Rabbits per acre	2.75	2.30	
Total rabbits marked	55	46	19.6
Costs per one-half acre			
Seed	$1.80	$3.87	
Fertilizer	4.05	5.22	
Lime		7.50	
Labor	1.25	1.30	
Gas and oil	.20	.20	
Total	$7.30	$18.09	67.7

SUMMARY AND CONCLUSIONS

In order to evaluate rabbit usage, live trapping was conducted on 15 five-acre sites, each of which contained a plot that had received a cultural treatment, consisting of eight annuals, planted in one-half acre plots. Four sites were sown to a clover-winter grain combination; three were located along an established fire break and were sown to rescue grass and four were located in a control area which had received no cultural treatment. Nine traps were gridded on each five-acre area to cover the entire site; a 100 foot radius of influence was allowed for each trap. Pellet counts were also conducted on the trapped site. Twelve counts were made on each trapping site by using a one foot square quadrat. These trap and pellet data indicate that the annual mix was the more heavily used; 40.8 per cent of all marked rabbits were captured in this type. Of all pellets counted, 41.4 per cent were in the annual mix. The clover plots were second with 34.1 per cent of all rabbits marked and 34.2 per cent of all pellets. Thirdly, rescue grass produced 11.9 per cent of all rabbits marked and 9.2 per cent of pellets counted. On the control area were found 13.3 per cent of the animals tagged and 15.2 per cent of the pellets. Since the rescue grass study area consisted of three sites (15 acres) as compared to four (20 acres) each for the other three types, comparisons were made based on rabbits marked per acre. The annual mix produced 2.7 rabbits per acre; the clover 2.3; rescue grass 1.07 and the control 0.90 rabbit per acre. This evaluation was considered inadequate for the rescue grass as it was sown in a fire lane bulldozed through a loblolly pine forest. The pine type afforded little cover for rabbits.

A vegetative study was instigated to evaluate mowing and burning practices as rabbit management techniques. An area was selected which was burned in March 1958 by a slow light ground fire. This site was gridded on a work map into two one-half acre plots of which six were randomly selected as study areas. These six plots were located on the ground by compass and pacing and one mil-acre quadrat was established in the approximate plot center. A total vegetation count was made within these quadrats.

Six acres were selected at random which had been mowed with a rotary mower approximately one year previous to this study. Mil-acre quadrats were established and counting was conducted on these areas in the same manner as the burn. Results of this study indicate that mowing and burning are valuable rabbit management tools.

A portable rabbit-proof fence was erected around three of the five-acre trapping sites. The site was then mowed in an effort to check the results of the trapping. All rabbits flushed were captured in a fish dip net and placed outside the fence. On an area where 33 rabbits had been marked, six were captured inside the fence. In an area where 12 had been marked, five were captured and in another area where 10 had been tagged, no rabbits were flushed. It appeared that when a given area was fenced, mowed and the rabbits counted by flushing, a reliable index to abundance was not obtained.

The portable fence was again erected around a five-acre area considered to be good rabbit habitat. The area was then live trapped and 13 individuals were captured; 10 of these were marked, then released inside the pen in order to have a known population on which to test the population estimation formulae, the Lincoln index, Krumholz formula and the

Schumacher-Eschmeyer formula. It soon became evident that rabbits were being lost to predation and other factors. In view of the objective, the trapping for a population estimate was divided into three periods. Twice additional rabbits were stocked into the pen to bolster the dwindling population. After the last trapping period the pen was mowed and the rabbits flush counted; eight individuals were present. For this study period the Lincoln index gave a population estimate of 9.0 rabbits, the Krumholz formula 7.1 rabbits and the Schumacher-Eschmeyer formula 7.0 rabbits. From these data it appears that the three formula do not differ markedly. It is the investigator's opinion that too few rabbits were handled to give a sound evaluation.

The hunting season harvest on Camp Pickett has increased markedly since 1956 when intense management was instigated. According to hunting season harvest records maintained over the past three years by the Virginia Commission of Game and Inland Fisheries, the kill increased by 68 per cent from the 1957-1958 season to the 1958-1959 season while hunting pressure for the same period increased only 33 per cent. From the 1956-1957 season to the 1958-1959 season the rabbit kill increased by 70.2 per cent. This appreciable increase in hunting kill is probably the result of the management effort. Assuming a rabbit population on Camp Pickett of 11,000 animals (based on the limited tag returns in the hunter bag) approximately 26 per cent of the population was harvested.

Bi-monthly morbidity reports received by the Virginia Cooperative Wildlife Research Unit from the Bureau of Communicable Disease Control of the Virginia Department of Health indicate two areas of greatest incidence of tularemia in Virginia. One area in south-central and the other in northern

Virginia. The data extracted from these reports demonstrate a decline in the number of human tularemia cases since 1946. As a result of letters of inquiry being sent to each respective county health officer who treated a human tularemia case the cottontail rabbit is the primary source of human infection, responsible for 64 out of 102 cases since 1955. Tick bites were second with 16 out of 102 Virginia cases for the same period. The data indicates a correlation between tularemia and tick activity.

Four rabbits (2.2 per cent) were found to have fibroma tumors among the 325 rabbits handled.

Fleas and ticks were not numerous except during the spring. One hundred fifty-five infestations of Cuterebra larvae were observed. There appeared to be no preference as to sex of the host; 75 males, 65 females and 15 rabbits of undetermined sex were infested. There was, however, a definite heavier parasitism in immature rabbits; 111 larvae on young rabbits, 39 on adults and five on individuals of undetermined age. Larvae were found on 35.1 per cent of all rabbits handled.

Cost comparisons were made for the annual mix plots and clover-winter grain combination plots. The annual mix was installed for $7.30 per one-half acre as to $18.09 per one-half acre for the clover. This is a difference of $10.79 or 67.7 per cent. It must be considered, however, that the clover is a perennial, and will persist from three to five years while the annual mix has to be installed each year. When considering these factors, it appears that clover plots are more economical than the annual mix. If quail and turkeys are taken into consideration, perhaps the annual plots will be most intensively utilized, but from just the rabbit viewpoint the clover plot appears to be the sounder investment.

MANAGEMENT RECOMMENDATIONS

1. Cottontail management on large non-agricultural blocks of land should be directed toward supplying herbaceous-type food and breaking up large homogeneous cover types.
2. Food plots should consist of a mixture of annuals designed to afford food for rabbits through the fall and winter. Clover or fescue plots should be sown for spring greens. Results of this study indicate that a satisfactory plot size is approximately one-half acre; 300 feet long and 75 feet in width. On large areas plots may be long and narrow or serpentine in shape to provide maximum edge effect. Perhaps more important than size is plot location. Food plots should break up large blocks of homogeneous cover and provide approximately one to one and one-half acres of food per 200 acres of land.
3. Areas which have grown beyond maximum rabbit food production and into undesirable brush should be mowed. Mowing will set back ecological succession and encourage the more desirable succulent rabbit food plants. As with the food plots, these mowed areas can be long, narrow strips 20 to 30 yards wide through areas of desirable cover.
4. Within large blocks of cover small areas such as broomsedge and early successional stages can be burned in the early spring (January and February) to stimulate succulent new growth.

In addition, the following recommendations are based upon the writer's general observations. Annuals and clover or fescue grass should be planted along fire breaks, power line rights-of-way, access roads and other areas not currently producing good natural food and cover. It is the

writer's opinion that the clover-winter grain combination plots are more economical in the long run than are the annual mix plots, since the clover is a perennial and may persist for three to five years. Considering this with the fact that the clover is available in winter and early spring as a green food it would seem that clover is the better as far as rabbits are concerned. Annual mix is particularly valuable, however, where other species such as quail, turkeys and deer are concerned.

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APPENDIX

Appendix Table 1. Total game killed at Camp Pickett during 1956-1957, 1957-1958, and 1958-1959 hunting season by months.

1956-1957 Season									
Month	Deer	Turkey	Quail	Rabbit	Squirrel	Raccoon	Duck	Fox	Snipe
November	34	5	289	195	36	5	101	2	1
December	28	16	230	401	13	2	36	4	4
January	6	2	283	256	1	2	21	0	1
Total	66	23	802	852	50	9	158	6	6

1957-1958 Season									
Month	Deer	Turkey	Quail	Rabbit	Squirrel	Raccoon	Duck	Fox	Snipe
November	23	20	214	503	90	17	122	8	7
December	21	8	342	745	151	8	15	4	2
January	0	2	233	656	44	2	9	1	0
Total	44	30	789	1904	285	27	146	13	9

1958-1959 Season									
Month	Deer	Turkey	Quail	Rabbit	Squirrel	Raccoon	Duck	Fox	Snipe
November	60	0	672	1102	225	6	61	2	6
December	32	2	701	1085	224	7	93	2	4
January	25	1	349	676	114	2	3	1	0
Total	117	3	1722	2863	563	15	157	5	10

Appendix Table 2. Some plant species used by rabbits as food and cover, Camp Pickett, Virginia, 1958

Common Name	Scientific Name	Food	Cover
Apple	Pyrus Malus	x	x
Aster	Aster spp.	x	x
Barley	Hordeum spp.	x	
Basswood	Tilia spp.	x	
Bramble	Rubus spp.	x	x
Broomsedge	Andropogon spp.		x
Bluegrass	Poa spp.	x	x
Chicory	Cichorium Intybus	x	
Clover, red	Trifolium pratense	x	
Clover, white	Trifolium repens	x	
Corn	Zea Mays	x	x
Dandelion	Taraxacum spp.	x	
Dogwood	Cornus spp.	x	
Fescue	Festuca spp.	x	x
Goldenrod	Solidago spp.	x	x
Grape	Vitis spp.	x	
Greenbriar	Smilax spp.	x	
Hazel	Corylus spp.	x	
Hickory	Carya spp.	x	x
Horse nettle	Solanum carolinense	x	
Japanese honeysuckle	Lonicera japonica	x	x
Milkweed	Asclipius spp.	x	x
Oak	Quercus spp.	x	x
Oats	Avena sativa	x	
Orchard grass	Dactylis glomerata	x	
Panic grass	Panicum spp.	x	x
Paspulum	Paspulum spp.	x	
Pine	Pinus spp.		x
Plantain	Plantago spp.	x	
Poplar	Populus spp.	x	x
Pussy's toes	Antenaria sp.	x	
Queen Ann's Lace	Daucus carota	x	x
Ragweed	Ambrosia artemisiifolia	x	
Rape	Brassica Rapa	x	
Red cedar	Juniperus virginia		x
Red top	Agrostis ventriculata	x	x
Rye	Secale cereale	x	
Serecia lespedeza	Lespedeza cuniata	x	x
Sheepsorrel	Rumex Acetosella	x	
Sorghum	Sorgum vulgare	x	
Soybeans	Glycine Max	x	x
Sumac	Rhus spp.	x	x
Thorn	Crataegus spp.	x	
Turnip	Brassica Napus	x	

Appendix Table 2. Some plant species used by rabbits as food and cover, Camp Pickett, Virginia, 1958 (Continued)

Common Name	Scientific Name	Food	Cover
Wheat	Triticum aestivum	x	
Wild plum	Prunus spp.	x	
Wild rose	Rosa spp.	x	
Wild strawberry	Fragaria spp.	x	
Willow	Salix spp.	x	x
Yarrow	Archillia spp.	x	

Appendix Table 3. Original capture of animals handled on the study area from September 16, 1958 through May 31, 1959, Camp Pickett, Virginia

Common Name	Scientific Name	Adult Female	Adult Male	Juvenile	Total
Black snake	Coluber constrictor				1
Box turtle	Terrapene carolina				1
Bob-white	Colinus virginianus		1		1
Gray squirrel	Sciurus carolinensis	4	8	2	14
Meadow mouse	Microtus pennsylvanicus	1	2	1	4
Mink	Mustela vison				2
Opossum	Didelphis virginiana		1	3	4
Rabbit	Sylvilagus floridanus	43	60	70	176*
Woodchuck	Marmota monax				4
				Total	207

* 3 of unknown sex and age

Appendix Table 4. Predators observed on Camp Pickett during this investigation, August, 1958 - June, 1959

Class	Scientific Name	Common Name
Mammalian	*Vulpes fulva*	Red fox
	Canis familiaris	Domestic dog
	Felis domesticus	House cat
	Mustela vison	Mink
	Mephitis mephitis	Skunk
	Procyon lotor	Raccoon
Avian	*Falco sparverius*	Sparrow hawk
	Accipiter cooperii	Cooper's hawk
	Circus cyaneus hudsonius	Marsh hawk
	Corvus brachyrhynchos	Crow
	Buteo jamaicensis	Red-tailed hawk
	Buteo lineatus	Red-shouldered hawk
	Tyto alba pratincola	Barn owl
Reptilian	*Coluber constrictor*	Black snake
	Agkistrodon mokasen	Copperhead snake
	Heterodon platyrhynchos	Hog-nosed snake

Appendix Table 5. Mammals observed on study area during this investigation, Camp Pickett, Virginia, 1959

Order	Scientific Name	Common Name
Carnivora	Vulpes fulva	Red fox
	Canis familiaris	Domestic dog
	Felis domesticus	House cat
	Mustela vison	Mink
	Procyon lotor	Raccoon
Insectivora	Blarina brevicauda	Short-tailed shrew
Marsupialia	Didelphis virginiana	Opossum
Artiodactyla	Odocoileus virginianus	White-tail deer
Rodentia	Marmota monax	Woodchuck
	Tamias striatus	Eastern chipmunk
	Sciurus carolinensis	Gray squirrel
	Microtus pennsylvanicus	Meadow vole
	Zapus hudsonius	Meadow jumping mouse
Lagomorpha	Sylvilagus floridanus mallurus	Cottontail rabbit

Appendix Table 6. Soil analysis of mowed and burned areas, Camp Pickett, Virginia, March 1959

Area	pH	Ca	Mg	Organic matter	P	K
			Burned			
1	4.5	M	H	3.4	M	H
2	4.8	L	M	2.0	L	M
3	5.3	M	H	0.8	L	H
4	5.3	L	M	0.9	L	M
5	5.1	M	H	0.7	L	M
6	5.4	L	M	1.4	L	M
Avg.	5.1			1.5		
			Mowed			
7	5.6	L	M	1.0	M	H
8	5.8	H	H	1.3	M	M
9	5.9	VH	H	2.4	L	VH
10	6.9	VH	VH	1.6	M	H
11	5.6	M	M	1.3	M	M
12	5.8	M	M	1.4	L	M
Avg.	5.9			1.5		

MEANING OF SYMBOLS

Symbol	Minerals	Organic Matter
VH	Very high	Above 3%
H	High	2-3%
M	Medium	1-2%
L	Low	Below 1%

ABSTRACT

This study, conducted at Camp Pickett, Virginia, attempted to evaluate several rabbit management practices currently in use on this deactivated military reservation. The methods being applied by the Virginia Commission of Game and Inland Fisheries consist of establishment of wildlife food plots, the seeding of fire lanes and mowing and burning as a means of retarding ecological succession. Results of these evaluations indicated that the annual mixture plot is the type most heavily utilized by rabbits during the fall. Next in importance was the clover-winter grain combination planting. These conclusions were determined by means of live trapping and these trapping data were substantiated by pellet counts. A total of 211 rabbits were handled in this phase of the study; 135 were marked and 76 were recaptured. Of the 135 animals marked, 40.8 per cent were marked in the annual mix plots.

This trapping demonstrated a sex ratio of 130 males to 100 females and an immature to adult female ratio of 2.3:1. A relationship between trapping success and temperature seemed to exist; a coefficient of correlation of -0.273 was calculated. A vegetative inventory inferred that both mowing and burning may be desirable rabbit management practices.

An attempt was made to test three population estimation formulae on a known, enclosed rabbit population. Results of trapping within the five acre enclosure gave a comparable population estimate for the Lincoln index, the Krumholz formula and the Schumacher-Eschmeyer formula. This experiment was not carried to the refined point of supplying definite conclusions; further investigation is necessary before concrete recommendations may be made.

Records of the hunting season harvest were maintained. When these kill figures were combined with a rough estimate of the rabbit population on Camp Pickett, it was indicated that approximately 26 per cent of the cottontails were harvested. Hunting kill records maintained by the Game Commission over the past three years show a marked increase in hunter success, probably due to the effects of management.

All bot fly parasitism cases were noted; 155 infestations were observed among the 325 rabbits handled. The larvae demonstrated no preference as to sex of the host but immature cottontails were more heavily parasitized than were adults.

Records of tularemia incidence throughout Virginia have been maintained. Two areas of greater incidence occur; however, the Camp Pickett area appears to be average for the state.

Cost comparisons were made between annual mix plots and clover-winter grain plots. The annual mix type of food plot cost an estimated $7.30 per half acre to install; the clover plot cost $18.09 per half acre. Which type plot, annual or perennial, is used depends upon the budget and labor available. The writer favors use of the clover plots for rabbits both from the economical and biological points of view.