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AND THEIR CONTROL
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ENTOMOLOGY DEPARTMENT
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Cattle Grubs and Their Control in South Dakota

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Introduction

CATTLE in South Dakota, primarily in the western and central beef producing counties, are usually infested with cattle grubs each year. The damage caused by these parasites and the losses suffered by cattle raisers are difficult to measure. The losses due to grubs may be classified as losses to producers and losses to the meat, hide and leather industries.

The most apparent damage as viewed by the rancher or farmer is the running of the cattle in the spring, which is usually attributed to heel flies. Cattle have stampeded through fences or have become mired down in mud holes in their efforts to escape the egg laying flies. An animal which is running or standing in a stock water dam to evade the flies is not grazing and producing beef or milk. Also, occasionally an animal is so heavily infested that more than 100 grubs are encysted under its skin and the back of such an animal is just a mass of grubs and holes. One such host, a yearling calf, was found dead on a ranch in Ziebach County. No other contributing factor in the calf's death was reported. Similar cases have been heard discussed by farmers and ranchers.

No serious losses have ever been demonstrated in connection with rates of gain of feed lot cattle. Such reported losses have not been substantiated by significant data.

The most serious direct financial losses are suffered by those in the meat and hide industry. When the larvae first arrive under the skin of the backs and before they are encysted they cause a "slickening" of the fatty covering of the back. Such tissue becomes gelatinous and greenish and must be trimmed out. The trimming may account for actual loss of weight and also results in a less desirable carcass which is usually downgraded.

Hides containing five or more grub holes are graded "grubby" and are discounted by hide buyers. The majority of the holes occur in the most valuable part of the hide, resulting in loss of quality leather. Total losses due to grubs in the United States are estimated by the USDA at approximately $150,000,000 annually.

The purposes of the research work carried on from 1947 to 1953 by the South Dakota Agricultural Experiment Station were: to study the distribution and seasonal abundance of cattle grubs in South Dakota; to measure effects of grub infestations and methods of control on rates of gain of feed lot cattle; to evaluate and improve methods of control; and to investigate the practicability of cattle grub control on an area or community-wide basis.

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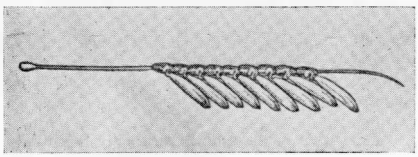
General Life History

The life cycles of the two species of grubs are quite similar. The eggs are deposited on the hair usually on the legs below the dew claws, although they may be found on other parts of the body, especially the eggs of *H. bovis* (northern grub). The eggs of *H. lineatum* (common grub) are laid in rows of four to twelve or more on a single hair while the eggs of the northern species are almost invariably laid singly. The eggs hatch in about a week and the young larvae or grubs crawl down the hair and begin to burrow into the skin at the base of the hair.

After entering the animal's body the grubs migrate through the connective tissues of the host. The common grubs move to the esophagus or gullet and from there to the back of the animal. The northern grubs move to the spinal canal enroute to the back. This migration takes several months and finally the grubs reach the back, the common grubs arriving earlier. When the grubs come to rest under the skin of the back they begin to produce a hole through the skin of the host. At the same time the animal produces a sac or cyst around the grub. The perforations through the skin are produced largely by means of digestive enzymes secreted by the grubs.

A few days after arriving in the back the grubs molt, or shed their skins, for the first time and enter the second larval stage. About 25 days later the grubs molt again and become third stage grubs. When the larva is fully grown it works its way out of the hole through the host's skin and falls to the ground. The grubs do not burrow down into hard soil but their movements cause them to move into depressions, cracks and under debris where they become more or less protected. The skin of the grubs then becomes black, hard and wrinkled forming a protective shell or case for the transforming insect. This case is called the puparium and the insect inside enters the pupal stage. At this point the transformation from grub to fly takes place. The change takes from 20 to 75 days for the common grub and 15 to 25 days for the northern species. The speed of this change is dependent on temperature and other weather and soil conditions.

Row of *H. lineatum* eggs on hair

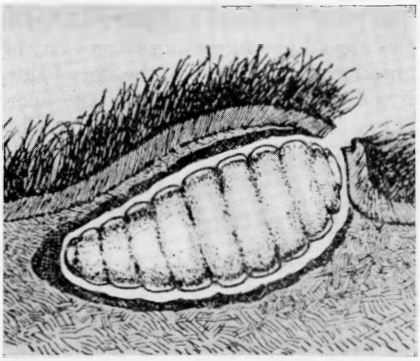


When the fly is developed and environmental conditions are favorable the fly emerges from the puparium by way of a small flap, or operculum, at the anterior end of the puparium. A short time after emerging, the fly is able to fly, mate and lay eggs. Each female fly is capable of laying up to 500 eggs and lives from a few hours to about a week.

The egg laying activity of the flies, especially the northern species, causes the well known, characteristic running of the cattle. The causes for this running are not thoroughly understood but it is generally believed that the noise made by the fly and its persistence produce this peculiar reaction in cattle. The fly has no sting or functional mouth parts so it is impossible for it to bite or sting the animal upon which it is ovipositing. The eggs hatch in a few days and the cycle is continued.

Descriptions

The adults of cattle grubs are flies about the size of worker honey bees and are covered with hair. The fly of the common grub has transverse bands of white and yellow hairs and the end of the abdomen is clothed with reddish



Third stage grub encysted under the skin

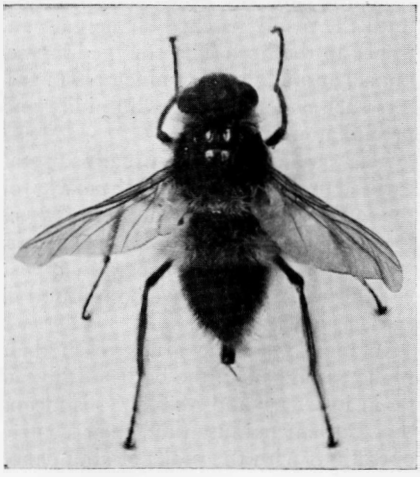
orange hairs. The thorax has four shiny, longitudinal lines. The legs are well covered with black and orange hairs. The wing veins are dark brown to black. The adult northern grub fly is larger and heavier bodied than the common species. The thorax is more densely covered with hair which partly obscures the shiny lines. The abdomen is colored about the same as the common grub fly except that the posterior band of hairs is much paler in color and wider. The wing veins are reddish brown and the legs are not as hairy as the legs of *H. lineatum.*

The eggs are smooth and dull yellowish white in color. They are narrowly oval in shape and slightly larger at the base than at the distal end. They are about 0.8 millimeters long and 0.25 millimeters wide at the widest part. (A millimeter is about 1/25 of an inch.) The eggs are equipped at the end of a short petiole or stalk with a clasping device which is clamped around a hair of the host.

The grubs, or larvae, pass through two molts and three stages. When first hatched the grubs are about 0.65 millimeters long and about 0.20 millimeters wide. They are creamy white in color and are densely covered with spines. After the first molt, the grubs enter the second stage and are about nine-sixteenths inch long and three-sixteenths inch wide. On the posterior end is a pair of spiracles, each of which is composed of a group of breathing pores. Each group of pores numbers about 20 to 25 in the common grubs and averages about 35 in the northern grubs. These pores are disc-like openings. In the northern grubs they are fused closely together, while in the second stage common grubs they are grouped loosely.

The third stage larvae when full grown are about 1 inch long and three-eighths to one-half inch wide. The dorsal side is flat and on the rounded ventral side are regular bands of spines. The common grubs have these bands on the second to the tenth segments, inclusive. The northern species have spiny bands on the second to the ninth segment, but the tenth segment is without this band of spines. The posterior spiracles of the third stage grubs are kidney-shaped plates in which are many ring-like openings. These plates of the common grub are flat while those of the northern grub are concave or slightly funnel-shaped. When newly molted the

Adult *H. lineatum*



third stage larvae are creamy white, but when they are ready to emerge from the cattle they are almost black.

The puparium is the hardened skin of the third or last larval stage. Inside this tough case the grub transforms to a fly. The larval segments and posterior spiracles are visible on the puparium. At the anterior, or head end on the dorsal side, is a flap-like structure called the operculum which is pushed up like a trap door by the emerging fly.

Cattle Grubs in South Dakota

Both species of cattle grubs are widely distributed in South Dakota. Fewer grubs are found in eastern South Dakota than in the central and western parts of the state. Bruce (4)[5] in 1938 found that soil moisture was a factor in explaining the absence of common cattle grubs in the Red River Valley of North Dakota and Minnesota. It is likely that this condition applies to the eastern edge of South Dakota although the northern grubs are found regularly in native cattle in this area. The northern grubs are found under a wider range of ecological conditions than are the common grubs in the state, although where both species occur, *H. lineatum*, the common grub, is usually the dominant species.

Seasonal Appearances

Weather conditions in South Dakota are quite variable from year to year. These weather factors affect, directly or indirectly, most of the insects found here and, consequently, the appearance and abundance of cattle grubs vary widely from one year to the next. The point in the life cycle of the grubs most affected by external environmental factors is from the time the grubs leave the host until the newly hatched larvae gain entrance to the host. The emerged larvae, pupae, and adults are vulnerable to factors such as temperature, humidity and precipitation.

The common grubs usually appear earliest under the skin of the backs of the cattle. They may be found as early as December 20 in South Dakota cattle.

The northern grubs generally appear late in February and have been found in cattle as late as July 3.

In most years the grubs reach their highest numbers in the backs of the cattle in February and March. This means that cattlemen must time their control operations with the peaks of abundance of the grubs each year for best results. No definite dates can be set in advance for treatment of the cattle. Additional discussion of this matter is presented in connection with the control studies later in the bulletin.

The larvae arrive in the hosts' backs over a considerable period of time and emerge from the cattle as they attain full growth. There are no data available to correlate the emergence of grubs with external environmental factors although Bishopp, *et al* (1) reported that most of the grubs emerged between 8:00 a.m. and 10:00 a.m. and again between 3:00 and 5:00 p.m. Hardly any larvae emerged during the night. They propose that the activity of the animals may stimulate the fully grown grubs into emerging and that the warming of the backs of the cattle by the sun following a cool night may tend to stimulate emergence.

The time the larvae spend encysted in the hosts' backs is variable. It was observed that the earliest appearing common grubs spent a longer time in the cysts than did the later appearing larvae. This condition was not so noticeable with the northern species. Bishopp,

[5]Numbers in parentheses refer to *Literature Cited*, p. 30.

et al, (1) found this to be true in Texas and Scharff (43) in Montana found that the first *H. lineatum* to arrive in the backs remained about three weeks longer than the later appearing grubs. This means that the first grubs to appear stay in the backs of cattle a longer period of time than those which appear later, which is important in carrying on a control program. Scharff *(op. cit.)* states that this variation in time spent in the cysts is probably correlated with the daily amount of heat absorbed from the sun by the grubs in the cysts.

The length of the pupal stage is very dependent upon temperatures and soil moisture conditions. It may last from 15 to 75 days with an average of about 35 to 40 days. Since the time required for the flies to develop and emerge is so dependent upon temperature there is a great variation in times of appearance of the flies during the same season, even in a rather small area. The temperature at ground level where one pupa is located may be quite different from the temperature at the location of another pupa only a short distance away. The flies from these pupae may emerge at quite different times even though the larvae in question emerged from the hosts at the same time.

It is difficult to determine accurately the time of year the adults appear by merely observing the actions of cattle. It is possible that stimuli other than heel flies may cause the cattle to run with their tails up, and it is probable that some oviposition takes place without this reaction of the cattle. Ranchers sometimes report running of cattle attributed to heel flies as early as mid-February, when it is doubtful if by that time grubs have emerged, pupated and emerged from the puparia as flies.

Adult appearance is extremely variable from year to year, but usually takes place from the middle of May to the middle of July.

Relative Abundance

As stated before, where both species are present the common grub is usually the dominant species except when control programs have been carried on for a number of seasons. The northern grubs, however, are more widely distibuted in South Dakota than are the common grubs, being found in eastern counties and in the higher elevations in the Black Hills where the incidence of the common grubs is low.

Actual numbers of grubs, or the severity of infestations, vary widely from one year to the next. The most heavily infested animal observed was a calf in which there were 175 encysted third stage grubs, almost all of which were the common species. In 1950, yearling cattle in Hughes County had an average of 90 grubs per head for the season. In 1951, cattle harbored an average of 30 grubs per head. This is a two-thirds reduction from one year to the next due only to natural factors. In 1952 the average infestation in yearlings was again about 30 grubs per head. In 1953 the average increased to 35 per head.

It has been reported by many investigators that young animals are more heavily infested than are older cattle. This condition holds true for South Dakota. In 1947, infestations in two-year-old heifers and old cows were measured by two palpations, one in March and one in April. The results were an average of 12 grubs per head in the two-year-olds and 2.45 grubs per head in the aged cows. In 1950 the grub infestations in calves and cows were measured by three extractions, one each in February, March and April. The cows had an average of 9.92 grubs per head and the calves had 32.02 per head. The main reason for this difference in infestations is probably the development of resistance after several infestations as described by Scharff (43), Hadwen (26) and Bishopp, *et al* (1).

Control Methods

At present, the most practicable time in the life cycle of the parasites to conduct control measures is during the larval stages after the openings through the hosts' skin are produced and before emergence from the hosts takes place. In South Dakota this period will fall somewhere between the end of January and the first of June, depending on the year. During this research most of the treatments were applied in February, March and April. Occasionally a fourth application was made in May.

The currently recommended control methods include rotenone applied as a spray, wash or dust. The spray formula is 7½ pounds of 5 percent rotenone-bearing cubé or derris powder per 100 gallons of water. (Rotenone is a plant-derived insecticide.) The spray is applied in such a manner as to allow the rotenone to penetrate the cyst openings and contact the grubs. This may be done by careful selection of nozzles and spray guns and by using sufficient pressure. It is likely that the thoroughness of application is more important than the gauge pressure of the sprayer. Better results will be obtained by doing a careful job at 250 or 300 pounds per square inch gauge pressure using a coarse droplet, narrow cone, driving spray than a careless job at 600 pounds gauge pressure with a fine droplet spray or fog.

The wash is prepared by mixing 12 ounces of the 5 percent rotenone powder and 2 ounces of soap flakes in each gallon of warm water. The wash is applied at the rate of about 1 pint per animal and scrubbed into the hair coat on to the skin with a long-bristled brush. Higher kills and more consistent results have been obtained with washes than any other method tried.

The dust is formulated by mixing one part of 5 percent rotenone powder with two parts of a diluent such as pyrophyllite or talc. It is applied at the rate of 3 ounces per head and rubbed into the hair coat on to the skin of the animal with a rotary motion of the finger tips. Many commercial dusts containing from 1.50 to 1.67 percent rotenone are available. Various automatic applicators have been tried with little success.

Complete, or 100 percent, kills of the larvae present at any one time in the backs of the cattle are rarely, if ever, obtained. There has been observed a great variation in grub kills as a result of applications of rotenone. This variation is difficult to explain since the results vary when using the same equipment and materials under similar conditions. Mortalities of larvae obtained in 1950 are shown in Table 1. (The grubs were extracted and examined seven to nine days after treatment.)

In 1951 additional mortality data were obtained. The larvae present were third stage *H. Bovis* almost exclusively. They were extracted and examined seven to nine days after treatment (Table 2.)

Timing the applications of rotenone is extremely important. It was learned in conducting the area control programs that two applications applied at just the right times were the most practicable in most years. The first application was

Table 1. Kills of Grubs Obtained by Sprayer-Operators and Ranchers with Rotenone, 1950

Method	Average of Both Species: Percent Mortality Second Stage	Average of Both Species: Percent Mortality Third Stage
Spray (400 to 600 lbs./sq. in. pressure)	43.0	46.1
" "	42.7	79.1
" "	31.8	95.5
" "	50.0	60.0
" "	55.8	82.8
" "	15.3	43.0
" "	39.0	71.4
Dust	49.7	46.4

given just before emergence started. This date varied from year to year and from one herd to another in the same year. For example, in 1950 the first treatment was applied to cattle in central counties from February 10 to 20.

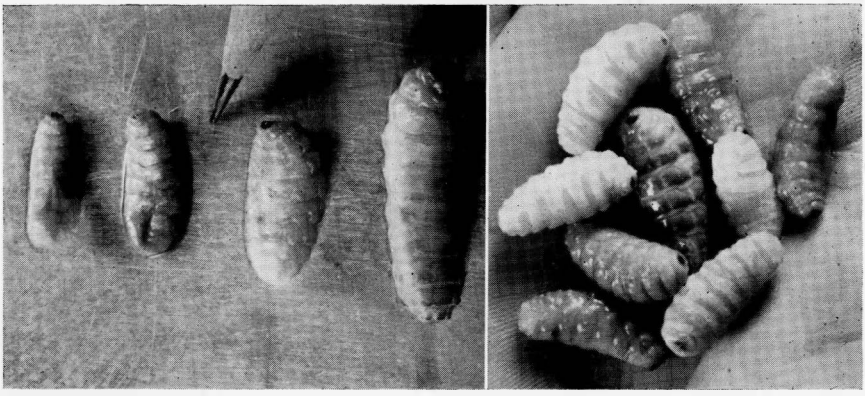
In western South Dakota this treatment was applied from February 5 to 15. The second treatment was applied March 10 to 25 in both sections and a few herds required a third application of rotenone from April 10 to 25 in cases where the treatments were started too early. This was done to contact some later appearing *H. bovis*. In 1951 the grubs arrived late as a result of the late cool spring in 1950. The first treatment was not applied until March 10 in central South Dakota and February 25 to March 1 in the western area. The second application was administered from April 15 to 30 in both areas. In 1952 the grubs appeared late in a similar manner.

This illustrates the need for examining cattle in each herd each year in order to determine the best time to apply the rotenone treatments. The best recommendation at the present time is to apply the first treatment about 35 to 60 days after the first grubs appear in the backs of the cattle or just before larval emergence. The second application will have to be applied from 30 to 40 days after the first. In some years a third application may have to be applied to contact late appearing northern grubs. To be effective, such a two- or three-treatment schedule would have to be timed accurately by careful examination of the larvae as they appear under the skin of the backs of the cattle. For dairy herds or

Table 2. Kills of *H. bovis* Obtained by Sprayer-Operators and Ranchers with Rotenone, 1951

Method	Percent Mortality Third Stage *H. bovis*
Sprayed (400 to 500 lbs./sq. in. pressure)	
Two nozzle broom, whirl plates removed, 7/64 inch discs	98.3
Orchard gun, whirl plates removed, 5/64 inch discs	90.0
Three nozzle broom, 4/64 inch discs	81.4
Three nozzle broom, 4/64 inch discs	78.3
Three nozzle broom, 4/64 inch discs	76.4
Orchard gun, 5/64 inch disc, whirl plate removed	75.3
Three nozzle broom, 4/64 inch discs	69.5
Three nozzle broom, 4/64 inch discs	65.8
Three nozzle broom, 4/64 inch discs	47.1
Wash	
1 pint per head	92.8
1 pint per head	72.3
Dust	
3 ounces per head	62.8
3 ounces per head	44.0

(Left) Second and third stage *H. bovis*. (Right) A group of third stage grubs



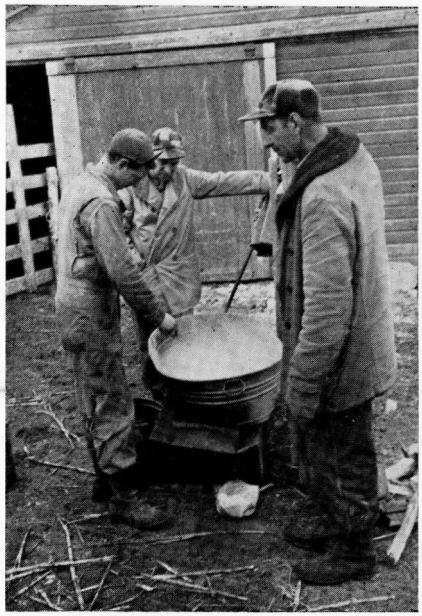
small groups of animals which are easily handled without major round-ups, it is best to apply the first treatment one month after the first grubs appear in the back and apply additional treatments at monthly intervals until no young grubs appear. This program involves three or four applications.

The presently recommended methods for controlling heel flies and cattle grubs are not practicable in all cases. For example, the treatments now applied to cattle do not result in 100 percent mortality of the larvae which are present under the skin of the cattle when treated. The process of rounding up cattle for three or four treatments in the winter and spring is often difficult.

Tests with Various Insecticides

During the grub seasons of 1950 and 1951, tests were performed with washes in an attempt to find more effective formulations and materials to use for controlling grubs, Roberts *et al* (41).

Preparing rotenone wash



On April 4, 1950, a series of tests with various materials was made at the Central Substation at Highmore. The cattle involved were 44 Hereford calves which weighed approximately 400 pounds each. All calves were heavily infested with third stage *H. bovis*. The materials tested were as follows:

1. A 25 percent emulsifiable nitro-paraffin derivative consisting of

2 nitro-1, 1-bis (P-chlorophenyl) propane	8.33%
2 nitro-1, 1-bis (P-chlorophenyl) butane	16.67%
Pine oil	70.00%
Emulsifier	5.00%

2. A mixture of:

Rotenone	2.5%
Pyrethrins	0.5%
Piperonyl butoxide	10.0%

Applied at the rates of 6 and 12 ounces per gallon.

3. An aerosol "cow bomb" containing:

Rotenone	0.30%
Rotenoids	0.45%
Piperonyl cyclonene	1.20%
Acetone	48.05%
Methyl chloride	50.00%

At 1 minute and 1½ minute applications.

4. Cubé powder containing 5 percent rotenone applied at the rate of 6 ounces per gallon and also at 12 ounces per gallon.

All materials except the aerosol were applied as washes in a uniform manner. Five hundred milliliters (about 1 pint) were applied to each animal and the wash was scrubbed thoroughly into the hair coat and onto the skin with long bristled brushes. Warm water was used and about 3 ounces of a granulated detergent were added to each gallon.

The "cow bomb" delivered its contents in the form of a fine mist or aerosol. The main body of the bomb was similar to the common household aerosol bomb only larger, holding 4 pounds of material in a 5-pound cylinder. The cylinder was equipped with a valve and a one-quarter inch copper tube 15 inches long. The nozzle discharged the

Table 3. Percent of Mortality of *H. bovis* With Indicated Materials

Material	Number Head Treated	Total Larvae Extracted	Total Dead	Total Alive	Percent Mortality
2 nitro-1, 1-bis (P-chlorophenyl) propane; 2 nitro-1, 1-bis (P-chlorophenyl) butane, 25% 1-100 parts	6	67	7	60	10.4
Aerosol, 1 min.	7	129	33	96	25.6
Aerosol, 1½ min.	5	49	16	33	32.6
Rotenone, 2.5% Pyrethrins, 0.5% Piperonyl butoxide, 10% 6 oz./gal.	7	150	61	89	40.7
Rotenone, 2.5% Pyrethrins, 0.5% Piperonyl butoxide, 10% 12 oz./gal.	8	215	123	92	57.2
Cube rotenone, 5% 6 oz./gal.	6	144	75	69	52.1
Cube rotenone, 5% 12 oz./gal.	5	80	68	12	85.0

aerosol at the rate of 1 gram per second in a cone of about 45 degrees. The nozzle was held from one-half to 2 inches from the backs of the animals treated. The cubé rotenone wash containing 12 ounces of the 5 percent powder per gallon of water is the standard, recommended wash and was used as the check.

On April 13, after a 9-day interval, all the cattle were examined and all the larvae were extracted with small curved forceps. The viability of each larva was determined and recorded. It was found that almost all of the larvae present were third stage *H. bovis*. A few second instar *H. bovis* were extracted but these were discarded and only the third instar specimens were recorded. The results of the tests are tabulated in Table 3.

It is evident from the data that none of the materials came up to the standards of the regular rotenone wash. It also seems apparent that the rotenone, pyrethrins, piperonyl butoxide material owes its toxicity to cattle grubs to the rotenone content present, since the wash containing 12 ounces of the 2.5 percent rotenone bearing material gave about the same results as the 5 percent rotenone bearing cubé at 6 ounces per gallon.

Another series of tests was conducted at the Central Substation at Highmore in 1951. The materials used were:

1. Five percent methoxychlor suspension formulated from 50 percent wettable powder (12.8 ounces per gallon of water) with 2 ounces of soap per gallon.
2. Ten percent ryania suspension (12.8 ounces of the 100 percent ground stem per gallon of water) with 2 ounces of soap per gallon.
3. Five percent rotenone bearing cube powder at 6 ounces per gallon of water, sodium tripolyphosphate (1.28 ounces per gallon) and 2 ounces of soap per gallon.
4. Five percent rotenone at 6 ounces per gallon of water and 1.28 ounces of sodium tripolyphosphate per gallon.
5. Five percent rotenone at 6 ounces per gallon of water with 2 ounces of soap per gallon.
6. Piperonyl cyclonene, pyrethrum, rotenone (commercial formulation) 6 ounces per gallon of water containing:

Piperonyl cyclonene	2.470%
Pyrethrum	2.247%
Rotenone	1.230%
Unknown dry diluents	96.053%

with 2 ounces of soap per gallon.

7. One percent toxaphene suspension formulated from 40 percent wettable powder (3.2 ounces per gallon of water) with 2 ounces of soap per gallon.

All the materials were uniformly applied to cattle as washes at the rate of 500 milliliters per head. The suspensions were poured out of a beaker on to the backs of the test animals and the material was scrubbed in thoroughly with long bristled brushes. The soap used was a high grade laundry soap.

Test animals were uniform Hereford yearling calves and all were moderately infested with third stage *H. bovis*. Each test consisted of five head, except the

toxaphene test in which four animals were treated. Applications in tests 1, 2, 3, 4 and 5 were made on April 3.

The larvae were extracted after a 9-day interval on April 12 at which time applications in tests 6 and 7 were made. The larvae in the latter tests were extracted after an 8-day interval on April 20. All grubs were extracted and carefully examined for signs of life. The results of the tests are indicated in Table 4.

The methoxychlor, ryania, toxaphene and the pyrenone-rotenone combination failed to kill a significant number of the larvae in the treated animals while the cubé rotenone formulations even at half the usually recommended strength, killed a high proportion of the grubs.

The sodium tripolyphosphate is a water softening or sequestering agent and was tested with and without soap in combination with rotenone in an effort to determine its value in a wash. The data show that the rotenone and soap alone killed 81.6 percent of the grubs, the rotenone and soap with the softener killed 85.7 percent of the larvae, while the rotenone with only the sodium tripolyphosphate killed 91.9 percent of the grubs. Since the number of animals treated was so small, these differences are not significant; however, the high mortality obtained with the material containing the sequestering agent indicates that further investigation with these and similar agents is warranted.

Table 4. Percent Mortality of *H. bovis* With Indicated Materials

Material*	Total Larvae Dead	Total Larvae Alive	Percent Mortality
Methoxychlor, 5% with soap	1	62	1.50
Ryania, 10% with soap	5	57	8.10
Rotenone, sodium tripolyphosphate with soap	54	9	85.71
Rotenone and sodium tripolyphosphate without soap	68	6	91.90
Rotenone and soap	62	14	81.58
Pyrenone-rotenone and soap	4	50	7.60
Toxaphene, 1% with soap	7	48	12.72

*Formulations are given on page 11.

Rotenone applied as a wash in one of the control areas

Effect of Control on Gains of Yearling Cattle in Feed Lot

As a part of this study the Animal Husbandry Department, in cooperation with John Morrell & Co., conducted a series of feeding trials with yearling cattle. The purpose of these trials was to determine what effect grub infestation had on the feed lot performance of cattle being finished for market and whether grub control practices would improve gains and efficiency of gains.

The over-all value of a control program cannot be evaluated on the basis of feed lot performances alone. The effect of heel fly attacks on cattle and damage done by grubs under conditions different from those encountered in presently reported trials must be considered before definite conclusions are drawn.

How the Trials Were Conducted

Yearling Hereford steers were purchased each year for this experiment. The first three years they were fed at the John Morrell & Co. feed lots at Sioux Falls. The fourth year they were fed at South Dakota State College Agricultural Experiment Station. Animal Husbandry staff members supervised the collection of data each year.

The first year, 52 cattle were purchased, from the western part of the state. From these, one group of 10 was selected as being relatively grub-free (average of 2.1 grubs per animal). Forty of the remaining 42 were divided into four lots of 10 each. These had moderate grub infestation averaging 10.4 grubs per animal.

The second year a slightly different procedure was followed. The cattle to be used were contracted for from a rancher early in the year and 11 of these were moved from the area during the heel fly season and brought to Brookings. After that time they were returned to the range until all the cattle were brought to the feed lot. Ten of the 11 were used as the grub-free lot (average of 0 grubs per animal) and 40 infested cattle (average of 9.3 grubs per animal) were divided into four equal lots.

A similar procedure was followed the third year but the movement of the "grub-free" lot out of the infested area took place a little late so slight infestation occurred (average of 1.9 grubs per animal). Those left on the range all season had an average of 5.0 grubs per animal.

This practice was followed again in the fourth year with the result that the "grub-free" cattle averaged 1.9 grubs per animal and the infested animals 26.8 grubs. This was the only year of the four in which grub infestation approached a severe condition.

Five lots of cattle were used each of the first three years as follows:

1. "Grub-free"—very light infestation of grubs. No grub control treatment in the feed lot.
2. Grubby—hand dusted with powder made up of two parts pyrophyllite carrier to one part of 5 percent rotenone rubbed into the backs of the cattle.
3. Grubby—check group. No grub control treatment.
4. Grubby—free access to an automatic currier using a dust made up of 1 percent rotenone, 20 percent sulphur, 2 percent derris resins, and 77 percent pyrophyllite.
5. Grubby—rotenone spray of 7.5 pounds of 5 percent rotenone in 100 gallons of water and applied at spray pressure of 400 to 600 pounds.

The fourth year only four lots of cattle were used with a slight change in treatment:

1. "Grub-free" — no grub control treatment.
2. Grubby—hand dusted
3. Grubby—rotenone power spray

4. Grubby — power sprayed with water only

Four grub control treatments were given each year at monthly intervals beginning about February 15 (except that the cattle in Lot 4 had free access to the automatic currier at all times after treatment started). Grub counts were made just before the larvae began to emerge and before each treatment.

During each year all steers were managed and fed alike in the feed lots except for the grub control treatments. Standard rations of hay, corn-and-cob meal, corn, and soybean oil meal were fed, though the proportions varied from year to year. Salt and water were provided at all times.

When the cattle had been fed to the desired finish they were slaughtered at John Morrell & Co. plant at Sioux Falls. At slaughter the hides and carcasses were examined for grub damage.

What Were the Results?

The first point of interest is whether the various treatments were effective in destroying the grubs in the cattle. A measure of this effectiveness can be obtained from the data in Table 5, which show the average number of grubs per animal at the time of first and subsequent treatments.

The average infestation of grubs was not heavy in any of the lots. Further, the data show the gradual normal decrease in grub numbers as the season advances and the grubs emerge. It is evident that each treatment had some effect in destroying grubs with the hand dusting and power spray methods being more effective than the automatic currier.

The next question to be considered is whether the presence of grubs, in the number found in these cattle, had any effect on rate of gain and efficiency of gain. Also whether treatment for destruction of grubs had any effect on these two factors. A summary of the data for the first three trials is given in Table 6.

The data in Table 6 do not provide support for the theory that grub infestation, at the level found in these cattle, has an undesirable effect on feed lot gains or efficiency of gains of yearling cattle. The average daily gain of the grubby, untreated cattle was higher than those of the "grub-free" cattle and as high as those of the cattle treated by hand dusting or with the automatic currier. The only group that gave slight indication of benefit from treatment was the one treated with the power spray.

Also, in terms of feed required per 100 pounds of gain no real differences are evident.

In the fourth year of the experiment the grubby, untreated lot and the automatic currier lot were eliminated and the lot treated with water spray (no active ingredients) at 400 to 600 pounds gauge pressure was included along with the "grub-free," hand dusted, and power sprayed lots. This provided an additional trial for the last three mentioned treatments. The data for the four years of these treatments are shown in Table 7.

Table 5. Average Grub Count at Time of Initial Treatment and Subsequent Treatments in Yearling Cattle in the Feed Lot. Three-Year Average 1947, 1947-48, 1948-49 (By Palpation)

	"Grub-free" No Treatment	Grubby Hand Dusted	Grubby No Treatment	Grubby Automatic Currier	Grubby Power Spray
Initial	3.5	10.0	11.9	9.1	9.8
2nd	3.7	1.7	11.2	6.8	1.5
3rd	1.5	0.6	4.7	2.6	1.1
4th	0.6	0.4	1.6	1.3	0.1
Total	**9.3**	**12.7**	**29.4**	**19.8**	**13.5**

Table 6. Feed Lot Performance Data on "Grub-free" Cattle and Grub-infested Cattle Receiving Various Treatments. Average Results for Three Trials 1947, 1947-48, 1948-49

	"Grub-free"	Grubby Hand Dusted	Grubby Untreated	Grubby Automatic Currier	Grubby Power Sprayed
Total Number Steers	29	30	29	30	28
Average initial weight, lbs.	800.0	839.5	831.6	825.3	828.8
Average final weight, lbs.	1167.8	1208.7	1213.1	1205.2	1226.2
Average gain, lbs.	367.8	369.2	381.5	379.9	397.4
Average daily gain, lbs.	1.98	1.97	2.04	2.05	2.16
Feed consumption per cwt. gain					
Hay, lbs.	234.6	230.0	225.2	223.0	216.4
Oats, lbs.	27.9	31.1	29.2	28.3	26.1
Corn and cob meal, lbs.	896.6	893.3	870.4	871.4	840.6
Shelled corn, lbs.	159.6	159.3	155.4	152.3	143.6
Soybean oil meal, lbs.	76.2	75.6	73.6	73.2	69.9
Grub Counts—average number per animal					
First count	3.5	10.0	11.9	9.1	9.8
Second count	3.7	1.7	11.2	6.8	1.5
Third count	1.5	0.6	4.7	2.6	1.1
Fourth count	0.6	0.4	1.6	1.3	0.1
Grub holes in hides at slaughter—average per animal	1.2	6.0	3.9	3.2	4.1

The results for the four trials, as shown in Table 7, tell the same story as those for three years in Table 6. The "grub-free" lot showed the poorest performance in the feed lot. Destruction of grubs in itself was not a factor as the hand dusted cattle, on which grub destruction was as efficient as on those sprayed, did not measure up fully in performance to the power sprayed lot.

The data for the fourth trial are set forth in Table 8. It may be noted that the grub infestation was heavier in the grubby cattle than had been the case in

Table 7. Feed Lot Performance of "Grub-free" Cattle and Grub-infested Cattle Receiving Various Treatments. Average Results for Four Trials, 1947, 1947-48, 1948-49 and 1949-50

	"Grub-free"	Grubby Hand Dusted	Grubby Power Sprayed
Number of steers	39	40	38
Average initial weight, lbs.	812.0	837.2	827.3
Average final weight, lbs.	1178.0	1208.2	1229.4
Average gain, lbs.	366.0	371.0	402.1
Average daily gain, lbs.	2.0	2.01	2.21
Feed consumption per cwt. gain			
Hay, lbs.	258.5	251.6	235.4
Oats, lbs.	20.8	23.2	19.0
Corn and cob meal, lbs.	943.2	929.3	867.6
Shelled corn, lbs.	119.2	118.9	104.6
Soybean oil meal, lbs.	68.4	67.5	61.6
Grub counts—average number per animal			
First count	3.1	14.6	14.7
Second count	3.3	3.4	2.4
Third count	1.3	1.1	1.3
Fourth count	0.4	0.3	0.1
Grub holes in hides at slaughter—average per animal	1.1	5.7	4.4

Table 8. Feed Lot Performance of "Grub-free" Cattle and Grub-infested Cattle Receiving Various Treatments, 1949-50

	"Grub-free"	Grubby Hand Dusted	Grubby Power Sprayed Rotenone	Grubby Power Sprayed Water
Number of steers	10	10	10	10
Average initial weight, lbs.	846.8	830.2	823.4	829.8
Average final weight, lbs.	1207.8	1207.0	1238.2	1208.8
Average gain, lbs.	361.0	376.8	414.8	379.0
Average daily gain, lbs.	2.04	2.13	2.34	2.14
Feed consumption per cwt. gain				
Hay, lbs.	329.1	315.3	286.4	313.4
Corn and cob meal, lbs.	1080.7	1035.0	940.2	1029.0
Soybean oil meal, lbs.	45.4	43.6	39.6	43.6
Grub counts—average number per animal				
First count	1.9	28.1	28.6	23.7
Second count	2.2	8.6	4.9	13.5
Third count	0.8	2.7	1.7	1.9
Fourth count	0.0	0.0	0.0	0.1
Grub holes in hides at slaughter—average per animal	0.6	5.0	5.4	2.7

any previous year. Despite this fact the "grub-free" cattle again had the poorest performance record and the power spray, with rotenone, showed a slight advantage over the "grub-free" and other treatments.

What Do the Results Mean?

In interpreting the results of these trials several facts must be kept in mind. The average grub infestation in the experimental cattle could not be considered as being heavy and consequently the effect of grub infestation would probably not be as severe as with heavier infestations. The second factor is that emergence normally is completed early in May so that the cattle had about two months in the feed lot (May and June) without any grubs.

The data do show that hand dusting and power spraying with rotenone were effective treatments in destroying grubs. The automatic currier was not as effective, though the use of this treatment caused some destruction of grubs. Thus, from the standpoint of reducing heel fly infestation the following season, treatment can be recommended.

Considering only rates of gain and efficiency of gains, it is doubtful that treatments have any beneficial effect at the level of infestation found in the experimental cattle. The data do suggest some benefit from power spraying with rotenone but not from any of the other treatments used.

Hide damage is one of the serious effects of grub infestation and from this standpoint there was definite benefit in having "grub-free" cattle. The experimental cattle were slaughtered in late June or early July, six to eight weeks after the emergence of the last grubs, so time was available for healing many of the holes. If slaughter had taken place in April or May the hide damage would have appeared even greater in the grub-infested cattle.

A somewhat similar situation existed with regard to carcass damage. Observations in packing plants have shown that, when slaughter takes place while grubs are present in large numbers, serious damage to carcasses is evident and severe loss in value may result. As slaughter of the experimental cattle took place in early July, after recovery from carcass damage that may have existed earlier, no serious damage was noted.

Cattle Grub Control on an Area or Community Basis

There is little evidence that indicates benefits to be gained in one year by treating cattle for grubs. That is, no marked higher rates of gain were made by treated cattle; damage to hides was not lowered and the treatment of one herd in a cattle producing area did not prevent reinfestation of the treated cattle in the following year. Therefore, a long-range program of grub control must be considered. The possibility of reducing the infestations of grubs in cattle in large areas or communities was investigated. Questions to be answered were: (1) How large an area must be organized for effective grub control? (2) How many years would it take to reduce cattle grub infestation? (3) What degree of farmer cooperation would be necessary?

How the Program Was Set Up

In 1947-48, groups of ranchers in Hughes, Haakon, Meade, Lawrence, and Harding counties were assisted by the Extension Service of South Dakota State College in setting up organized cattle grub control programs. Rotenone was furnished free of charge by several insecticide companies. During the first two years most of the emphasis was placed on interesting the cattlemen in these neighborhoods in grub control. Efforts were made by such means as meetings, demonstrations and news releases, to get a high percentage of the cattle treated. In 1949 the Haakon county area was neglected because of transfer of the county agent and lack of personnel to actively organize the work. The ranchers there carried on the work, however.

In the fall of 1949, additional funds and personnel were available to start collecting the desired data. Funds from the USDA's Bureau of Animal Industry were used to purchase the rotenone for treating the cattle in the Hughes, Meade, Lawrence and Harding county areas. The insecticide was put into bags and distributed from central points in each area. A considerable amount of time was spent encouraging the ranchers to treat their cattle. Notification of proper times to apply the treatment was made by radio and newspaper releases and by personal contact.

It was impossible to collect complete data from all areas so full attention was given to the Hughes-Hyde county program in 1950. Data from the other areas were collected as time permitted. In the following seasons two of the programs were studied carefully — the Hughes-Hyde county area and the Meade-Pennington county area. The data collected included: size of areas, number of cattle and ranchers in the program, percent of cattle treated, methods of treatment used, and reductions of grub populations. Observations of seasonal appearances, relative abundance and effectiveness of treatments for killing grubs were also made and are reported elsewhere in the bulletin. The data were obtained by surveying the area by personal contact.

The reductions of grub populations from year to year were measured by a method of sampling which has proved consistent and reliable. Sample herds were selected as to location in the area and presence of facilities for handling cattle. In each of these herds a random sample of the calves was taken. Any late calves, those born after the heel fly season, and calves brought into the herd after the heel fly season of the preceding spring were cut out. Each animal was marked by means of a hair clip on the flank or tailhead to enable re-examination. Just before the first larvae emerged from the cattle all grubs were extracted from the sample calves by means of small curved Kelly forceps. About a

month later a second extraction was made. Subsequent extractions were made until all larvae were accounted for. The species, instar, and viability of the extracted grubs were recorded.

This method of sampling in the areas and also around the edges outside the areas provided a fairly accurate picture of the grub population for each year.

Hughes-Hyde County Area

Size of Area. When the program started in 1948 there were approximately 3500 head of cattle involved. The area was about 100 square miles in size located south of Harrold, South Dakota (Fig. 1). In 1949 the size remained the same, but efforts were made to obtain more cooperation on the part of ranchers.

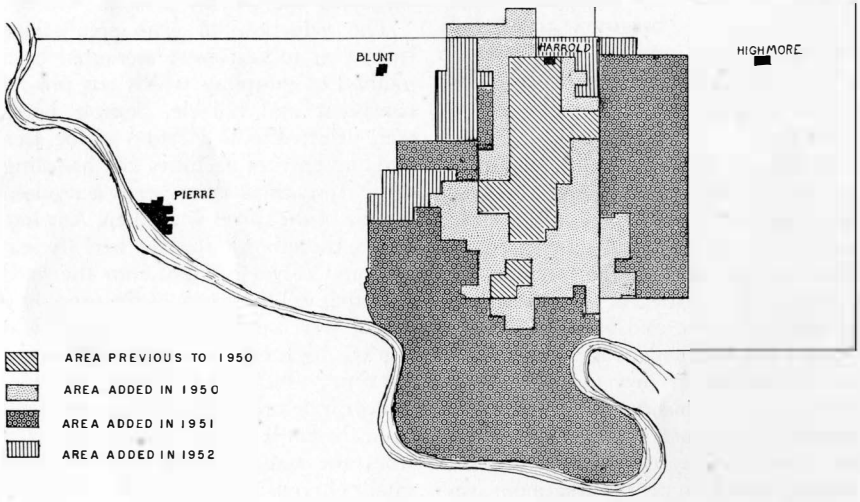
In 1950 the area was enlarged to about 250 square miles. The eastern boundary was roughly the Hughes-Hyde county line with a few herds located in Hyde County. The northern boundary ran along Highway 14. The area extended west from the county line about 9 miles and south from the highway about 25 miles. There were 9,520 head of cattle on 89 ranch units in the program. The area was not isolated by any barriers to prevent reinfestation; that is, untreated cattle were adjacent to treated herds around the outer limits of the area.

In 1951 this area was increased in size to about 12 townships and included 19,520 head of cattle on 177 ranch units or premises. The eastern boundary was 6 miles east of the Hughes-Hyde county line including the three western townships of Hyde County. The northern limit was Highway 14, and the Missouri River formed the southern boundary. On the west the boundary was about 5 miles west of Harrold and angled to the southwest to a point on the Missouri about 4 miles west of DeGrey.

In 1952 and 1953 the area remained essentially the same. The only changes straightened the western boundary somewhat. There were 20,350 head of cattle in 166 ranch herds in the program in 1952 and 1953.

Organization and Cooperation. The first two years an attempt was made to interest the ranchers in grub control by

Fig. 1. Hughes-Hyde County control area



educational methods involving meetings, demonstrations, farm visits, radio and newspaper releases and circular letters. This was done in cooperation with the county agents and the extension workers. At organizational meetings several neighborhood leaders were selected. Their duties were to contact a certain group of neighbors, and determine the method each neighbor preferred for treating his cattle.

After it was known how many cattle were to be sprayed, dusted and washed, the rotenone was prepared for distribution. The insecticide for sprayers was sacked in 7½-pound bags; that for washes was put in 1½- and 3-pound bags. The dust was mixed with pyrophyllite as the carrier at a mixing station at Harrold and sacked in 4-pound and 2-pound bags.

The sacked rotenone was then picked up by the neighborhood leaders and also delivered to the farms or ranches by the field workers. Some ranchers as well as the sprayer operators picked up their insecticide at the Harrold headquarters. The sprayer operators were then given training in cattle grub control methods and lined up with ranchers who wanted the spray service so that all were taken care of.

A uniform rate of charging for spraying cattle was agreed on each season. As mentioned earlier, the rotenone was furnished to cattle owners free. The time for starting treatments was determined and widely publicized. During the period of treating the cattle, farm visits were made at which time techniques were observed and suggestions for improvement offered. Whenever possible, the mortalities of grubs were determined by random extractions.

A wide variety of responses was expected and observed. Some ranchers were very enthusiastic about the work and treated their cattle conscientiously while others thought the whole program a waste of time and never did treat their herds.

The unfavorable weather, cold, heavy snow, and muddy roads, did more to curtail the actual treatment of cattle than anything else. These conditions may be expected each year in South Dakota. Heavy snows with blizzard-like conditions often drift the corrals and chutes shut making it impossible to handle the cattle. In the spring, sudden thaws make quagmires of the county roads so that trucks and sprayers cannot reach the farms. Below-zero temperatures make cattlemen reluctant to spray their cattle. In spite of these handicaps the data collected indicate results from the treatments.

It was apparent that most cooperators would treat their cattle once, a few a second time, and very few a third time. For example, in 1950 the extent of treatment was:

1st Treatment (Feb. 6 to 20)

Total cattle treated	6,395 in 54 herds
Total cattle sprayed	2,776 in 22 herds
Total cattle dusted	1,734 in 26 herds
Total cattle washed	1,885 in 6 herds
Total cattle not treated	3,125 in 35 herds
Percent of cattle treated 1st time	67.2

2nd Treatment (Mar. 10 to 25)

Total cattle treated	7,181 in 58 herds
Total cattle sprayed	3,163 in 28 herds
Total cattle dusted	2,102 in 23 herds
Total cattle washed	1,916 in 7 herds
Total cattle not treated	2,339 in 31 herds
Percent cattle treated 2nd time	75.3

3rd Treatment (April 10 to 30)

Total cattle treated	6,477 in 48 herds
Total cattle sprayed	2,988 in 24 herds
Total cattle dusted	1,573 in 17 herds
Total cattle washed	1,916 in 7 herds
Total cattle not treated	3,043 in 41 herds
Percent cattle treated 3rd time	68

Receiving *all three* treatments were 4,553 head in 33 herds or 47.8 percent of the total cattle in the area; 990 head were not treated at all during the 1950 season.

In 1951, a much shorter grub season made it possible to treat the cattle with one well-timed application. This was also partly due to the near elimination of

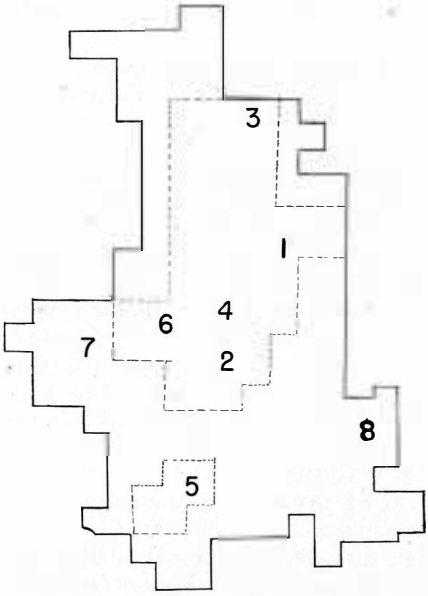


Fig. 2. Location of sample herds, 1950

the *H. lineatum* population. A total of 16,874 head were treated; 7,767 sprayed, 5,816 washed and 3,291 dusted. There were 2,650 head in 33 herds not treated during that year. This indicates that 81.3 percent of the cattle were treated at least once in 1951.

In 1952, which was another short season, severe snow storms and blizzards prevented the treatment of many of the cattle. Roads were blocked and corrals were drifted full of snow. Intentions of the ranchers were good but it was physically impossible to treat many herds. A total of 7,410 head were treated; 2,106 sprayed, 2,089 washed, and 1,645 dusted. Thirty-four percent of the cattle were treated in the 1952 season.

Effect of Treatments on Grub Populations. The object of the project was to determine the effects of the treatments on the grub populations from year to year. The first task was to set up a method of sampling which would give an accurate picture of the population for purposes of comparison. The results of previous work in area control programs were based on differences in number of grubs of the treated cattle from one year to the next, Drummond (17). However, in South Dakota the severity of infestation was found to fluctuate widely from one year to the next in the same region as a result of natural factors, even where no treatments were involved. This method of determining results was therefore discarded.

Instead of using Drummond's procedure, a method of measuring and comparing the infestations in cattle inside the area and cattle immediately outside the area was adopted. In this way the cumulative effects of the treatments given to cattle in preceding years could be estimated. It was decided to count the grubs in cattle located in different parts of the area. Some of the cattle had been treated in previous years, some were outside the boundaries of the area and had never been treated.

In 1950, eight sample herds were selected as to location in the area and facilities for handling cattle (Fig. 2). In each herd a random sample of approximately 10 percent (4 to 15 head) of the calves was taken. It was established that these calves were born before the heel fly season (most had March birth dates) and had spent the spring and summer on the range with the sample herd. Calves were selected because of the heavier and more uniform infestations found in this age class.

Each animal, or sub sample, was marked with a hair clipper to facilitate later identification. Before any grubs emerged from the cattle all the larvae were extracted from the samples and recorded. Subsequent extractions were made until no second stage larvae were found. It was found that three workers made up an efficient extracting crew if some help was available for handling

the cattle. Two men extracted and identified the grubs as to species and instar, the third member of the party recorded the data on mimeographed forms.

At the end of each season the data were compiled. The compilation for 1950 in the Hughes-Hyde county area is given in Table 9. Then, by referring to the location of the samples, the differences in grub numbers could be calculated. In 1950, sample herd No. 4 was the check herd because of its location at the center of the control area. The other samples were compared with No. 4. Sample No. 1 was in the eastern part of the area in which cattle had been treated the previous three years. Sample 2 was in the southern part of this area and sample 3 was near the northern boundary. Sample number 5 was on the south of the area in a neighborhood in which the cattle had not been treated prior to 1949. Sample 6 was near the western edge of the treatment area and sample 7 was on the western edge of the area and in a sector where cattle had not been

Table 9. Extraction of Grubs, Hughes-Hyde Area, 1950

Sample Herd		Extraction 1	2	3	Totals
	Average number larvae per head, total	15.00	12.00	0.78	27.78
No. 3	Average 2nd instar per head	8.78	5.33	0.00	
9 head	Average 3rd instar per head	2.88	6.67	0.78	
	Date extracted	2–16–50	3–16–50	4– 4–50	
	Average larvae per head, total	10.93	4.00	0.60	15.53
No. 4	Average 2nd instar per head	7.33	2.80	0.00	
15 head	Average 3rd instar per head	1.47	1.20	0.60	
	Date extracted	2–16–50	3–16–50	4–18–50	
	Average larvae per head, total	18.55	10.80	2.67	32.02
No. 1	Average 2nd instar per head	11.26	4.00	0.00	
11 head	Average 3rd instar per head	2.17	6.80	2.67	
	Date extracted	2–14–50	3–21–50	4–20–50	
	Average larvae per head, total	16.25	9.33	0.20	25.78
No. 2	Average 2nd instar per head	14.00	5.67	0.00	
4 head	Average 3rd instar per head	1.25	3.67	0.20	
	Date extracted	2–15–50	3–15–50	4–19–50	
	Average larvae per head, total	28.25	3.88	0.80	32.93
No. 6	Average 2nd instar per head	14.99	1.25	0.40	
8 head	Average 3rd instar per head	8.75	2.63	0.40	
	Date extracted	2–21–50	3–20–50	4–21–50	
	Average larvae per head, total	28.22	7.67	0.80	36.69
No. 5	Average 2nd instar per head	13.77	4.00	0.20	
9 head	Average 3rd instar per head	10.55	3.67	0.60	
	Date extracted	2–17–50	3–22–50	4–19–50	
	Average larvae per head, total	61.20	4.67	0.67	66.54
No. 7	Average 2nd instar per head	31.40	1.00	0.00	
5 head	Average 3rd instar per head	27.60	3.67	0.67	
	Date extracted	2–22–50	3–21–50	4–20–50	
	Average larvae per head, total	56.85	30.00	2.60	89.45
No. 8	Average 2nd instar per head	31.57	2.00	0.00	
7 head	Average 3rd instar per head	19.14	28.00	2.60	
	Date extracted	2–22–50	3–23–50	4–21–50	

Table 10. Number of Grubs per Head, Hughes-Hyde Area, 1950

Sample Number	Average No. of Grubs per Head	
4 (check)	15.5	
1, 2, 3, 6 ("old area")	30.2	48% higher than check
5 (out of old area but treated in 1949)	36.7	58% higher than check
7, 8 (new area)	77.9	80% higher than check

treated. Sample 8 was on the east in a sector where cattle had not been treated prior to 1950. Locations of these sample herds are indicated in Fig. 2. The total larvae per head for 1950 in the Hughes-Hyde area are:

Sample No.	1st Extraction	2nd Extraction	3rd Extraction	Total
1	18.5	10.8	2.7	32.0
2	16.2	9.3	0.2	25.8
3	15.0	12.0	0.8	27.8
4	10.9	4.0	0.6	15.5
5	28.2	7.7	0.8	36.7
6	28.2	3.9	0.8	32.9
7	61.2	4.7	0.7	66.5
8	56.8	30.0	2.6	89.4

These data, obtained from the three extractions during the cattle grub season in Hughes County, indicate significant differences in the infestations of *Hypoderma* larvae in the test herds. The center herd (No. 4) had the lowest total infestation and the outer herds (Nos. 7 and 8) had the highest. There is a difference of about 80 percent between the infestation in the center of the area in which the cattle were treated and in the cattle outside of this area represented by herds 7 and 8.

To illustrate further the differences of grub infestations in the 1950 project, the area was divided into zones representing the previous year's work. Sample herd No. 4 was again the check herd because of its central location. The data from samples 1, 2, 3 and 6 were combined into an average representing the total number of larvae per calf for the season in this section of the area in which the cattle had been treated for three successive years prior to 1950. Or it may be said that sample No. 4 represents the center of this "old area" while samples 1, 2, 3 and 6 represent the periphery of this "old area."

Table 11. Extractions of Grubs, Hughes-Hyde Area, 1951

Sample No.	No. of Head	Average Grubs Per Head and Date Extracted				
		Date	1st	Date	2nd	Total
1	10	3-27	26.00	4-25	2.20	28.20
2	8	3-22	14.50	4-25	0.71	15.21
3	10	3-23	13.80	4-25	0.90	14.70
4	15	3-26	28.27	4-25	2.07	30.34
5	15	3-29	22.60	5-1	2.63	25.23
6	15	3-15	8.00	4-18	0.67	8.67
7	11	3-15	11.27	5-1	0.17	11.44
8	12	4-3	9.17	5-1	0.76	9.93
9	24	3-14	2.04	4-12	0.13	2.17
10	14	3-22	5.07	4-19	1.57	6.67
11	13	3-28	8.92	5-3	0.91	9.83
12	18	3-28	5.89	4-27	1.45	7.34
13	20	3-28	10.80	4-17	0.94	11.74
14	13	3-28	7.15	4-26	0.33	7.48
15	16	3-22	11.25	4-26	0.73	11.98

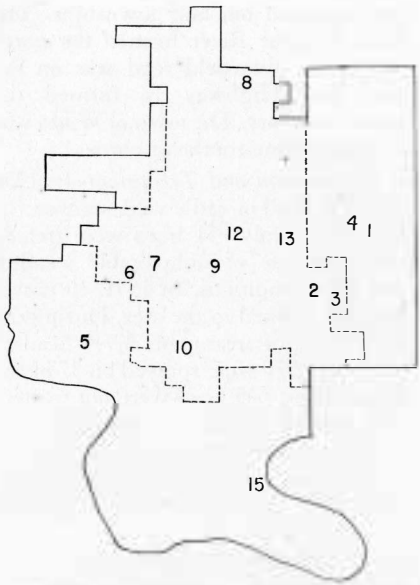


Fig. 3. Location of sample herds, 1951

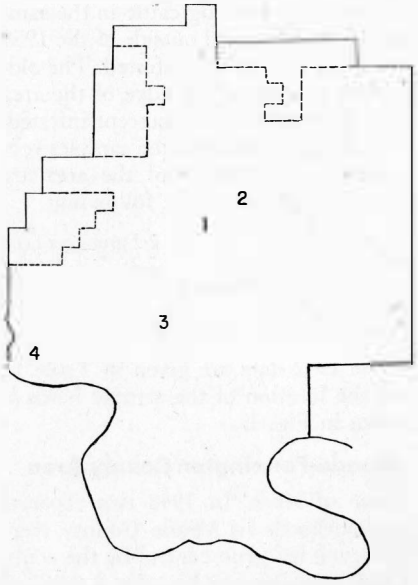


Fig. 4. Location of sample herds, 1952

Sample No. 5 seems to be a special case. This whole herd (230 head) had been treated the year before (1949) but had been surrounded by untreated cattle. It was not representative of the area in which the cattle had not been treated before 1950, nor was it part of the "old area" in which the cattle were treated for three years. Consequently, the data from this sample are considered separately. Samples 7 and 8 were combined into one average representing the total infestation per calf in the "new area" or that area in which the cattle had not been previously treated (Table 10).

A similar procedure was followed in 1951, except that 15 sample herds were selected with 8 to 24 head per sample. The locations of the samples are shown in Fig. 3. The average numbers of grubs extracted in 1951 are given in Table 11.

It was observed that the yearling cattle sampled in herd No. 9, which is in the center of the area, were 67 percent

Table 12. Extractions of Grubs, Hughes-Hyde Area, 1952

Sample No.	No. of Head	Average Grubs Per Head and Date Extracted				
		Date	1st	Date	2nd	Total
1	20	3-27	1.65	4-23	0.37	2.02
2*	9	3-27	2.3	—	—	2.3*
3	19	3-26	3.00	4-25	0.45	3.45
4	12	4-1	18.75	4-25	2.20	20.95
5*	11	3-12	20.95	—	—	20.95*
6	9	3-11	22.44	4-10	9.22	31.66

*Extraction partially completed and only first extraction made.

infested. The yearling cattle in the samples on the edge and outside of the 1950 area were 100 percent infested. The older cows located on the edge of the area were approximately 45 percent infested.

When the data from the samples representing each section of the area are averaged, they show the following:

Center of area	2.2	grubs per head
Off-center, exposed	7.2	" " "
Edge of 1950 area, exposed	10.6	" " "
Outside of 1950 area, untreated	27.9	" " "

The 1952 data are given in Table 12 and the location of the sample herds is shown in Fig. 4.

Meade-Pennington County Area

Size of Area. In 1948 two separate neighborhoods in Meade County were organized for grub control by the county extension agent (Fig. 5). A total of 2,000 head of cattle on about 30 premises were in the project. In 1949 and 1950 the work was consolidated for study into one area on the southern edge of Meade County. One rancher who also operated a power sprayer was largely responsible for organizing the ranchers. All the cattle treated in this area were sprayed. Three power sprayers were operated in the area in 1949 and 1950. Ten sprayers, mostly rancher-owned, were used in 1951 and 1952. The rotenone was delivered in 7½-pound bags to the sprayer operators.

In 1950 there were 1,748 head of cattle on 26 premises in the area. In 1951 the program was enlarged to 4,570 head on 44 ranch units and covered about five and one-half townships. The southern boundary was generally the Meade-Pennington county line, the breaks of the Belle Fourche River were on the north, the Elm Springs-Wasta road was on the east and the Viewfield road marked the west boundary. In 1952 the work again expanded. There were 10,023 head of cattle on 85 ranches and the area covered ten and one-half townships. The Belle Fourche River formed the north limits, the Viewfield road was on the west and Highway 16 formed the south boundary. The town of Wasta was in the extreme southeast corner.

Cooperation and Treatment. In 1950 all 1,748 head of cattle were sprayed the first time. Only 751 head were treated twice because of unfavorable weather and road conditions. In 1951, 10 power sprayers worked in the area. During the first round of treatments 3,945 head of the total 4,570 were sprayed on 37 of the 44 premises; 625 head were not treated. The second treatment was given to 2,714 head in 22 herds, and a few bunches of calves were sprayed a third time.

In 1952, 2,228 head on 75 premises

Applying rotenone spray

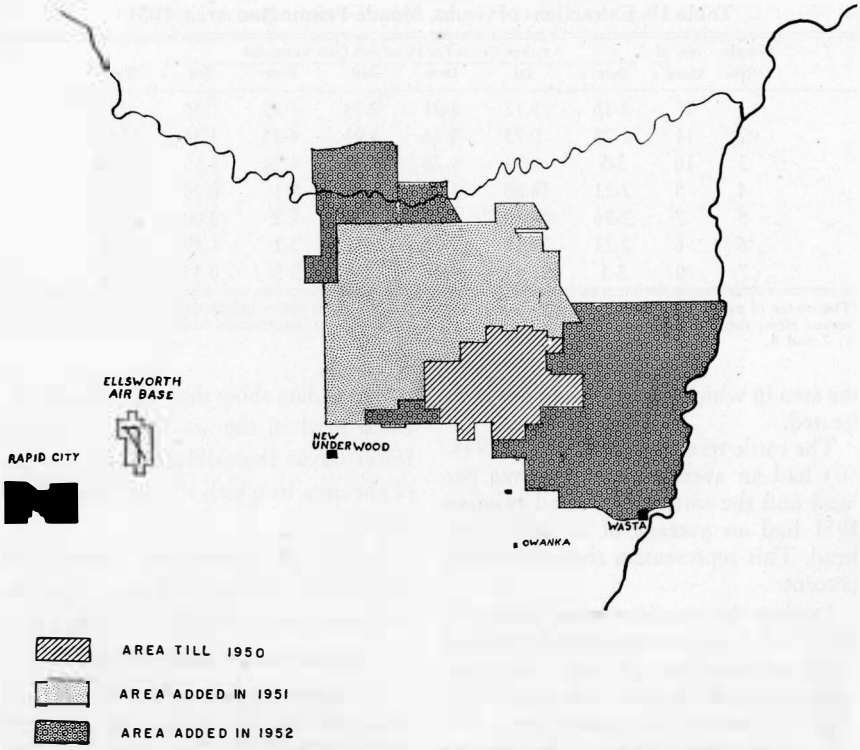


Fig. 5. Meade-Pennington County control area

received the first treatment; 1,983 head received a second spraying. A total of 2,795 head on 10 ranch units were not treated.

Effect of Treatments on Grub Population. The method of sampling used in the Hughes-Hyde county project was also used in this area. Grubs were extracted from calves in sample herds throughout the area and the data were handled in a similar manner.

In 1950 time and personnel were not available to collect sufficient data for comparisons. In 1951, seven sample herds were selected. These were located as indicated in Fig. 6. The data in Table 13 represent the grubs extracted per head in 1951.

As shown on the map, herds 1, 2, 3 and 4 represent the area in which the cattle had been treated previous to 1951, while herds 5, 6 and 7 represent

Fig. 6. Location of sample herds, 1951

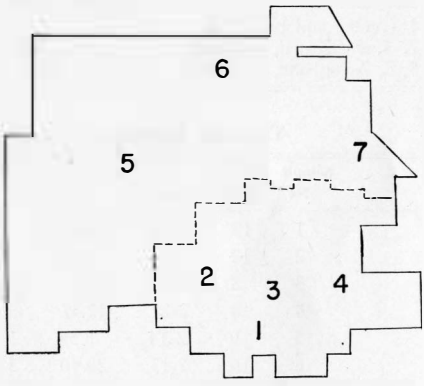


Table 13. Extractions of Grubs, Meade-Pennington Area, 1951

Sample No.	No. of Head	Average Grubs Per Head and Date Extracted						Total
		Date	1st	Date	2nd	Date	3rd	
1	17	2-16	5.12	3-21	2.53	4-23	1.46	9.11
2	11	2-23	9.73	3-26	3.91	4-23	1.36	15.00
3	10	3-5	9.73	3-26	3.91	4-23	1.36	15.00
4	5	2-21	18.80	3-22	1.40	5-1	0.40	20.60
5	7	2-26	27.00	3-29	3.71	5-2	2.00	32.71
6	6	2-21	20.17	3-22	2.67	5-1	1.49	24.33
7	9	3-1	22.88	4-2	0.67	5-2	0.45	24.00

*The owner of sample herd No. 3 sold his cattle including the sample of calves before they could be examined the second time; therefore, the data for the second and third extraction are interpolated from the average of samples 1, 2 and 4.

the area in which the cattle had not been treated.

The cattle treated prior to 1951 (1948-50) had an average of 15.5 larvae per head and the cattle not treated prior to 1951 had an average of 27 larvae per head. This represents a reduction of 42 percent.

During the previous years of work, herd No. 1 was surrounded by treated cattle and samples 2, 3 and 4 were less advantageously located in the area in regard to nearness to untreated cattle. Table 14 shows the degree of infestation of herds inside and outside the control area.

Table 14. Number of Larvae per Head Inside and Outside Meade-Pennington Area, 1951

Sample Number	Average No. of Larvae per Head
1 (center and protected)	9.1
2, 3, 4 (treated, exposed)	17.7
5, 6, 7 (outside, untreated)	27.0

These data show that the favorably located herd in the area had 67 percent fewer larvae than did the herds outside of the area in which the cattle had been treated.

In 1952 six samples were obtained and situated as indicated in Fig. 7. The data collected are presented in Table 15.

Discussion of Area Program

It is apparent that the numbers of cattle grubs can be reduced by concerted community efforts. In a period of about five years a reduction of over 90 percent was obtained in one area and over 85 percent in the other. During the period of research, cooperation of cattlemen was never 100 percent and mortalities of grubs resulting from the treatments rarely exceeded 90 percent and, on occasion, fell as low as 35 percent.

Percent of Cattle Infested. It was also observed that the percent of the cattle in-

Table 15. Extrations of Grubs, Meade-Pennington Area, 1952

Sample No.	No. of Head	Average Grubs Per Head and Date Extracted						Total
		Date	1st	Date	2nd	Date	3rd	
1	15	2-15	3.13	3-20	0.13	4-16	0.54	3.80
2	12	2-12	6.66	3-19	3.58	4-19	1.66	11.90
3	8	2-13	11.12	3-19	3.88	4-17	0.62	15.62
4	8	2-27	12.37	3-26	2.87	4-17	0.87	16.11
5	9	2-14	8.55	3.20	4.71	4-16	1.12	14.38
6	10	2-13	20.40	3-24	11.10	4-16	1.75	33.25

fested became lower as the program continued. At the start, 100 percent of the calves were infested. After five years, about 50 percent of the calves and yearlings were infested and only very few of the older animals were grubby. This may be a stumbling block. When a rancher sees that only half of his yearlings and none of his cows are grubby he may be reluctant to spend money to treat them. The result is that infestations may build up again in a short time.

Effect of Grub Reduction on Relative Abundance of the Species. Where both species occur, *H. lineatum* has usually been found to be dominant; however, after the control program had been in operation for several years the relative numbers of the two species were changed. In the central parts of the areas the populations of *H. lineatum* were practically eliminated while those of *H. bovis* were merely reduced (Tables 16 and 17).

This may be explained mainly by the fact that the greatest number of treatments was given at the time when *H. lineatum* was at the peak of abundance, which was when the first application was given each season. When, later in the season, *H. bovis* was present in largest numbers, applications were given by fewer cooperators. There is also the possibility that *H. lineatum* is easier to kill with rotenone than is *H. bovis,* Furman and Douglas (18).

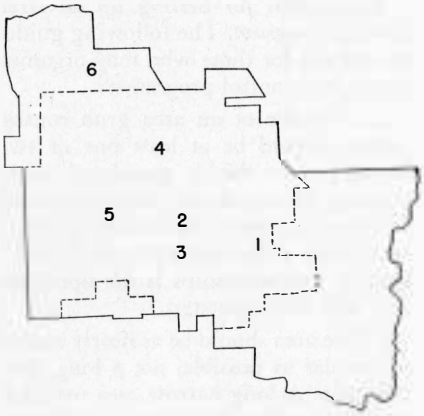


Fig. 7. Location of sample herds, 1952

Table 16. Relative Abundance of *H. lineatum* and *H. bovis* Found After Several Years of Control in Meade County, 1953

Location of Sample	Total *lineatum*	Total *bovis*	Percent *lineatum*	Percent *bovis*
Outside of area	216	179	54.6	45.4
Edge of control area	46	85	35.1	64.9
Center of area	13	160	7.5	92.5

Table 17. Relative Abundance of *H. lineatum* and *H. bovis* Found After Several Years of Control in the Hughes-Hyde Area, 1953

Location of Sample	Total *lineatum*	Total *bovis*	Percent *lineatum*	Percent *bovis*
Outside of area	99	161	38.0	62.0
Center of area	24	194	11.0	89.0

Suggestions for Setting up an Area Control Program. The following guides are offered for those who may organize cattle grub control programs:

1. The size of an area grub control project should be at least one or two townships. In thickly populated, or in dairying areas a single township would be large enough to start with. In range areas, such as in western South Dakota, four or five townships is the optimum size with which to start.

2. The area should be as nearly square or circular as possible, not a long, narrow strip. A long narrow area makes it possible for flies to reinfest quickly the treated herds from untreated herds along the boundaries.

3. The program should be well organized and administered by a committee or by an existing organization such as a livestock improvement association. The use of neighborhood leaders to account for every cattle owner in an area is recommended. Educational efforts should be directed at the people in the area to increase or stimulate the desire to control grubs. They should be informed of control methods and of the biology and economics of grubs.

4. Adequate supplies of rotenone should be provided for, either through local dealers or by cooperative purchase from an insecticide company.

5. Sprayer operators should be lined up with the cattlemen who wish spray service. Operators should agree on charges and be schooled in methods of spraying for best results.

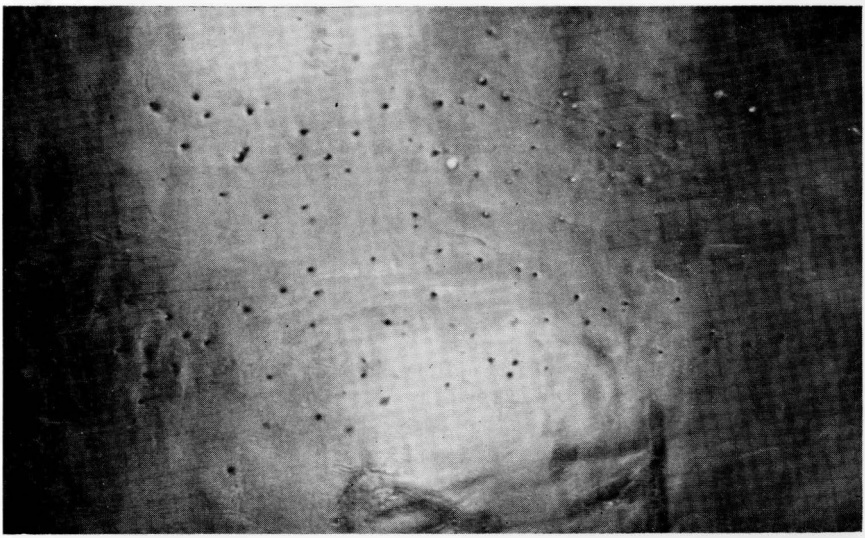
6. Efforts should be made to increase the size of the area slowly and to keep it a solid block of treated cattle.

7. A map of the area should be prepared indicating each farm or ranch.

8. Techniques of treatment should be constantly improved.

9. A period of at least three consecutive years must be spent in a concerted effort against grubs before results will appear.

Tanned cowhide showing holes made by grubs



History of Cattle Grub Research

The literature on cattle grubs is voluminous. The task of observing and describing the life cycles and habits of these insects started with the work of Vallisnieri (46, 47), an Italian naturalist, in 1710. In 1797 Bracy Clark (13) published his observations of cattle grubs as well as other members of the family Oestridae. In 1843 Clark (14) attempted to describe the noise made by the ovipositing flies. Earlier he attributed the wild running of the cattle to the action of the fly depositing eggs under the skin. In the later paper, however, he states that the cause for fright among cattle is the noise of the fly. Brauer, an Austrian entomologist, published an article in 1863 (2) in which he described a method for differentiating *Hypoderma lineatum* (common grub) from *H. bovis* (northern grub) in the last larval stage. Most of these early writers were of the impression that the eggs were deposited by the flies under the skin of the host, although in 1739 Linnaeus advanced the theory that the related reindeer bot fly fastened her eggs to the skin or hair of the host.

Up until the late 1880's only the subdermal larval stages were known. Nothing was known of the migration of the larvae in the hosts until 1888 when Hinrichsen (28) described finding *Hypoderma* larvae in the spinal canal of cattle as a common occurrence. At this time it was generally believed that the eggs were ingested and that the larvae reached the spinal canal from the digestive tract. During the late 1890's and in early 1900's investigators in Denmark, Germany, England and Ireland made great progress in unraveling the life cycles of *Hypoderma*. The most important of this work was done in Ireland from 1908 to 1922 by Carpenter and his associates (5 to 11). These entomologists conducted experiments on muzzled calves and demonstrated that the young grubs penetrate through the skin of the host to cause the infestation. An English entomologist, Ormerod, published extensively on cattle grubs. Her most notable work was in 1900 (38) at which time she described the insects very carefully and advanced suggestions for controlling the parasites.

The work in North America started in the early 1890's with publications by Riley (40), Curtice (15, 16) and Marlatt (33, 34). These workers assumed that the eggs were licked from the hair by the host and ingested. In 1912, '15, '16, '17, '18 and '19 Seymour Hadwen, a Canadian, added greatly to the store of information on cattle grubs (20-26). He observed and described the method of oviposition and the entry of the larvae into the hosts. His publications contain the most accurate descriptions and plates available.

The first attempt at controlling cattle grubs was made in Germany in 1912 to 1916 during which time a special commission was appointed to study the problem. In 1920 and 1922 Carpenter and his co-workers (10, 11) reported successful grub control experiments in isolated regions in Ireland. Since then coordinated control programs have been conducted in Denmark, England, Canada and the United States.

One of the most complete investigations conducted in the United States was the work of Bishopp, Laake, Brundrett and Wells published in 1926 (1). More recent work has been conducted in the United States on seasonal occurrences and control measures by Mills, *et al* (36), and Scharff (43) in Montana; Case (12) in Virginia; Knowlton and Sorenson (29) in Utah; Matthysse (35) in New York; Haseman (27) in Mis-

souri; Furman, *et al* (18) in California; Wells (48, 49) and Laake (30, 31, 32) of the USDA, and others.

There is little information available on the anatomy and physiology of *Hypoderma*. Ono (37) in 1932 published an account of morphologic studies of *H. lineatum* larvae. In 1938 Bruce (4) published the findings of his work in the Red River Valley of the North dealing with the effect of soil moisture on the mortality of cattle grubs. Simmons (44, 45) published two articles in 1939 dealing with digestive enzymes of the larvae and the histological reactions of the host infested with grubs. In 1944 Salt (42) reported on studies made on the effect of sub-zero temperatures on *H. lineatum* larvae. This was followed in 1947 by the work of Pfadt (39) in Wyoming on the effect of temperature and humidity on the larvae and pupae.

In 1948 Haberman, *et al,* (19) reported on their research on the migration of cattle grubs in cattle. They found that *H. lineatum* normally spend considerable time in the esophagi and that *H. bovis* congregate in the fatty connective tissues of the spinal canals before moving on to the sub-dermal tissues of the backs of the hosts.

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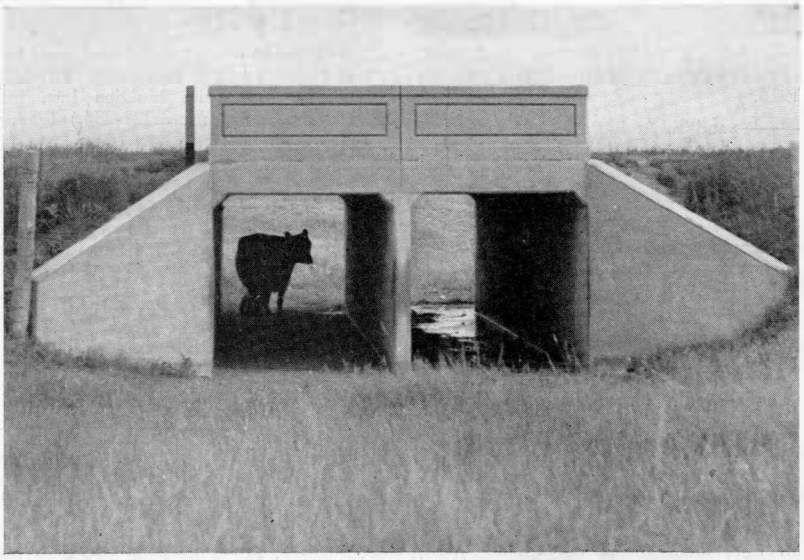

Cow seeking shelter in deep shade from ovipositing heel flies

Facts About Grub Control

Both species of cattle grubs are practically state wide in distribution in South Dakota. The northern grub *(H. bovis)* is found under a wider range of environmental conditions than is *H. lineatum* (common grub). Where both species occur the common grub is usually the most abundant. The time of appearance in the backs of cattle and the degree of infestation varies widely from year to year.

Rotenone applied as dust, as a spray, or in the form of a wash remains without equal as a method for killing grubs. Timing the application of rotenone is very important and must be determined each season.

No significant differences in rates of gain of grubby treated cattle, grubby untreated cattle and grub-free cattle in the feed lot were observed.

Well organized cattle grub control programs on an area or community basis will effectively reduce, but probably will not eliminate, grub infestations in cattle.