

**CASE STUDY: IMPACT OF *HYPODERMA LINEATUM* UPON LIVE GROWTH,
CARCASS ATTRIBUTES, AND HIDE VALUE OF FED BEEF CATTLE**

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ABSTRACT

A case study was done at the West Texas A&M University Research Feedlot, Canyon, from 14 November 2014 to 5 August 2015. While processing crossbred bulls (n=32) upon arrival (d0), some animals in the load of cattle were identified to be infested with grubs, later identified as the common cattle grub, *Hypoderma lineatum* (Villers). Metaphylaxis was administered upon arrival (d 0) to the feedlot; additionally, cattle were vaccinated against respiratory viruses, dewormed, and individually identified. Cattle were placed on a starter ration (d0) and transitioned to a finishing ration by d45. Twelve days after arrival, all cattle were re-weighed and manually palpated to quantify infestation by grubs; a hide map was used to record the location of the individual grubs. Grubs were manually extracted from the left side of infested animals to assess potential need for physical removal; right side grubs remained in the animals. Also, on d12, animals were administered a growth-promoting implant, and band-castrated. Two grub-infested cattle were slaughtered (d18) at the WTAMU Meat Laboratory to document hide damage; hides were manually fleshed and converted into rawhide. Two animals (grub-free) died from bovine respiratory disease during the study period (d15, d50). The remaining cattle were reweighed (d12, d40, d70, d96, d124, d152, d180, d208, d234, d236, and d264) to assess potential differences in growth rate. Cattle were slaughtered in two groups (n=9 on d234; n=19 on d264) at a local beef processor. Data collected during slaughter and grading processes included individual animal identification, liver score, hot

carcass weight, longissimus muscle area, 12th rib subcutaneous fat depth, kidney-pelvic-heart fat, yield grade, marbling score, and quality grade. Hides were individually identified and tracked through the facility to hide processing. Hides were green de-fleshed, lime de-fleshed, and de-haired for 24 h. Hides were then exposed to blue-chroming chemicals for 24 h; subsequently, blue-chrome hides were individually graded as #1, #2, or #3 hides. No difference in initial weight ($P = 0.89$), finished weight ($P = 0.35$), average daily gain ($P = 0.59$), hot carcass weight ($P = 0.38$), longissimus muscle area ($P = 0.91$), 12th rib subcutaneous fat depth ($P = 0.64$), calculated yield grade ($P = 0.84$), or kidney-pelvic-heart fat ($P = 0.38$) was detected between grub-free and grub-infested cattle. Grub-infested cattle tended to have more marbling ($P = 0.07$) than grub-free cattle. No difference in hide damage or value occurred between left sides (manually extracted) and right sides (grubs allowed to remain). Infestation by grubs did not negatively affect growth or carcass attributes. Hide damage in feeder calves resolved during the finishing period and grub-damaged hides met #1 criteria. Timely application of avermectin can prevent this problem from reducing beef system value.

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CHAPTER 1

INTRODUCTION

Cattle grubs (*Hypoderma lineatum* (Villers) and *Hypoderma bovis* (Linnaeus) are a topic in the beef industry that has not been a contemporary issue because of modern methods of control. The adult stage, called a heel fly, can reduce cattle comfort and impact daily growth, whereas the immature grubs can damage the hide and lessen its value (Bishopp et al., 1944). Today, two species of cattle grubs are common in the U.S.; the most widespread is the common cattle grub, *Hypoderma lineatum*, which has become established in every state, and the other is the northern cattle grub, *Hypoderma bovis*, which in the 1920's had not reached the southern part of the country (Bishopp et al., 1944). The northern cattle grub is more limited in distribution and as of 2013 was found primarily north of a line running across the country, from northern California through Kansas to the Carolinas. Historically, populations of the northern cattle grub have been reported in central Florida on cattle shipped in from more northern states. Infestations of native cattle with the northern cattle grub suggest the insect is an established pest in Florida (Kaufman and Weeks, 2013). Heel flies develop from grubs that have dropped from the backs of cattle. Common heel flies appear during the first warm days of spring and their activity increases as the season advances, until at the end of about 6 weeks the last of them has disappeared (Scholl, 1993). Heel flies usually attach themselves low on the legs, particularly above the hoof. The flies locate themselves very close to the skin and deposit as many as 300 eggs, which are attached firmly to the hair of the animal. This is why the name "heel fly" has been used throughout time. Control of cattle grubs

or heel flies was one of the most important insect problems confronting the U.S. cattle industry at until the 1960's (Bishopp et al., 1944).

CHAPTER 2

REVIEW OF LITERATURE

2.1 History of the cattle grub

Cattle grubs, also called wolves or warbles are the larval or maggot stage of insects also known as heel flies, warble flies, or gadflies (Bishopp et al., 1926). Hypodermosis of cattle is caused by larvae of flies whose scientific classification is the following: kingdom Animalia, phylum Arthropoda, class Hexapoda, order Diptera, family Oestridae, subfamily Hypodermatinae, and genus *hypoderma*. Two major species of *hypoderma* are found between 25 and 60° latitudes in the northern hemisphere and are present in more than 50 countries on the continents of Africa, America, Asia, and Europe (Aiello and Mays, 1998). The species are *Hypoderma bovis* (Linnaeus, 1758) and *Hypoderma lineatum* (De Villers, 1798). The grubs can cause major damage that affects the cattle industry, including dairies, meat packers, hide tanners, and even consumers. This parasite decreases weight gain and milk production, as well as causes economic loss in hides (Pandero et al., 1997). All of these effects on the animal can be directly attributable to the larvae that are migrating through the tissue in the host (Andrews, 1978; Drummond, 1987). In the United States, there are two species of cattle grubs that have similar habits. The most common cattle grub is *Hypoderma lineatum*, which has become established in every state of the U.S. and is known as the “common cattle grub”. This

species is also found in Canada and northern Mexico. *Hypoderma bovis*, which has become known as the “northern cattle grub”, is typically found north of the 35th parallel (Aiello and Mays, 1998).

2.1 Development and life cycle of heel flies



Figure 2.1 Adult female heel fly ~15mm long.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.



Figure 2.2 Fly laying eggs on the lower legs of a host.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

If the animal is lying down, heel flies may attach themselves to the hair coat in the area below the vulva and along the hair of the udder and belly. The eggs of the common cattle grub are usually attached one above another in a cluster (Figure 2.4), and those of the northern species are attached singly one at a time (Figure 2.5).



Figure 2.3 Eggs of the common heel fly ~0.8 mm long and 0.25 mm wide.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.



Figure 2.4 Eggs of the northern heel fly 0.8 mm long and 0.25 mm wide.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

Warmth of the body of the host allows the eggs to hatch within 3 to 7 days (Bishopp et al., 1944); the larva (~1 mm in length) emerges from the egg shell and forces its way into the skin and into deeper tissues (Carpenter and Hewitt, 1914; Aiello and Mays, 1998). Inflammation usually occurs at the penetration site (Gingrich, 1982). Once the larva enters the host, first-stage larvae (Figure 2.6) slowly migrate through tissues while feeding and growing for about 4-6 months (Hadwen and Bruce, 1916).



Figure 2.5 First-stage larva of the common cattle grub. In this stage insect comes beneath the skin of the backs of cattle 0.8 mm long and 0.25 mm wide

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

Hypoderma lineatum larvae travel from the posterior of the animal to a “resting site”, which is submucosal connective tissue of the esophagus, in the anterior of the animal (Beesley, 1961, 1974). The larvae can be found in the connective tissue on the surface of organs in the abdomen and in-between the mucous and muscular layers of the gullet and spinal canal (Bishopp et al., 1926).

After approximately 8 months, late first-instar larvae (~15 mm in length) leave the “resting site” and migrate to the mid-dorsal region of the animal (Hadwen and Bruce, 1916); once there, they place themselves in the connective tissue just beneath the skin (Simmons, 1939). When they reach this location, they open respiratory holes in the skin

of the host and a cyst forms around the larva (Scholl, 1993). The entire migration cycle from the time eggs hatch to arrival at the back is approximately 8 to 9 months (Scholl, 1993).

The adult or fly stage of the common cattle grub is similar in appearance to the common horse bot fly or nit fly, but smaller in size, measuring about 1.2 cm in length (Bishopp et al., 1944). The common heel fly has a wing expansion of almost 2.5 cm and is darker in color (Bishopp et al., 1944). Most of the body is covered with black hairs, but there is a band of orange and yellow hairs across it (Bishopp et al., 1926). The head is covered in yellowish-white hairs in the front and side parts (Bishopp et al., 1944). During the fly stage, the northern species is somewhat larger and stouter than the other species (Bishopp et al., 1944). The band of hairs on the tip of the stomach is paler and somewhat broader. Although the flies were very abundant and seen in many pastures in the United States decades ago, they are very rare today. The habits of the two kinds of grubs were similar. Heel flies begin attacking cattle for the purpose of laying eggs during the first sunny days of spring (Bishopp et al., 1926). Flies tend to approach animals in pastures or in barns. Northern heel flies appear about a month later, and their activity is extended over a longer period. They prefer cloudy days and showers. Grubs of this species are most abundant in the backs of cattle (Figure 2.7) after those of the common heel fly have disappeared (Bishopp et al., 1944). It has not been uncommon for some northern grubs to be found in cattle during the month of August (Bishopp et al., 1926). Both male and female flies live for only a couple of days, and it is rare for them to live for longer than a week (Bishopp et al., 1944). The flies have no mouthparts and also no need for food (Bishopp et al., 1944). After mating, the females have only one purpose

and that is to deposit eggs on the hairs of cattle. Cattle sense their presence and touch and become bothered (Bishopp et al., 1926).

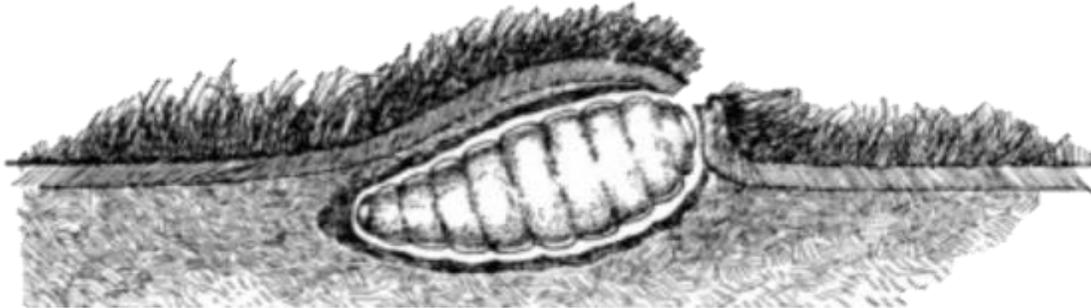


Figure 2.6 Position of the cattle grub underneath the skin ~28 mm long and 13 mm wide.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

Tickling caused by the flies is perceived by the animal being attacked; animals that are under attack reportedly shake and kick to try and rid themselves of the flies (Bishopp et al., 1944). The flies usually attack again and at this point cause the animal to start using its tail for protection (Bishopp et al., 1944). In dairy cattle, flies might attack the animal while it is lying down and this might not disturb the animal (Bishopp et al., 1926). The flies do not sting or cause any pain to the cattle (Bishopp et al., 1926). The flies tend to lay their eggs only on sunny days, although the northern species may also lay eggs after it has rained on cloudy days (Bishopp et al., 1926). Flies usually do not deposit eggs during a breeze, but they seem to not be bothered by cool temperatures

between 4° and 7° C (Bishopp et al., 1944). Throughout history, people have believed that shade will protect the animal against flies; however, shade seems not to give animals any protection (Bishopp et al., 1944). Heel flies usually begin laying their eggs from 0900 to 1000 h in the morning and this may continue until sundown, but most of the time it stops late in the afternoon (Bishopp et al., 1944). During very hot weather, heel flies are less active in the afternoon (Bishopp et al., 1944). Eggs deposited on the animal are yellowish white and have a smooth and shiny surface (Bishopp et al., 1926). The eggs are narrow and their length is fairly equal to that of the egg of the common horse bot fly or nit fly (Bishopp et al., 1926). The bottom portion of the egg contains a clamp, which secures the egg to the hair (Bishopp et al., 1926). Eggs are not often seen by stockmen because they are attached close to the skin and are surrounded by hairs. When the larva penetrates the skin, a small amount of serum is usually excreted, which causes the hair to come together and with the irritation in the skin produces a scab. During the fall, winter, and spring, grubs migrate through the muscular tissues of the back and in a short amount of time reach the under surface of the skin. During the last passage, some of the grubs enter the spinal canal and may hideaway along the spinal cord. At this time the larvae are very slim and white, measuring 1.7 to 2.54 cm in length (Bishopp et al., 1944). The larva is very smooth, except for spines at each end. One to five days later, the grub molts its skin for a third time. After the molt, the skin is set closely with spines. The host body begins to isolate the invading parasite and a small pocket or cyst is developed from the tissues of the host; the cyst is formed around the larva and remains for as long as five weeks or longer (Bishopp et al., 1944). As the larva grows, it causes swelling that becomes very noticeable and the bumps become obvious in the back of the animal.

During the last stage, the color gradually darkens, first becoming yellowish, then brown, and finally turning black.

Penetrating through the skin, a breathing hole is kept open to the surface, and the grub lies with its two breathing pores on the tail end, close to the opening of the skin. As growth occurs, the hole in the skin becomes larger. After the end of development in the back, which requires 35 to 90 days, growth is complete, and the grub works its way out and falls to the ground (Bishopp et al., 1926). The northern cattle grub develops in a similar way, but seems to require a period of at least 60 to 110 days in which to complete its growth in the back (Bishopp et al., 1926). An estimated 80% of northern grubs drop from the backs of animals during daylight, whereas the common cattle grub drops during the evening (Bishopp et al., 1926). After they pupate, some pupa go under the surface of the soil, some creep into narrow openings in rocks or underneath leaves, but many have been observed to pupate on the surface. Twelve to 48 hours after the grub has left the host, the outer skin of the grub becomes hard and blackish and forms a protective case inside which the grub changes into a heel fly (Bishopp et al., 1944). The length of this transformation varies with the temperature, ranging from 20 to 80 days for the common species and 15-25 days for the northern cattle grub (Bishopp et al., 1944). The fly emerges through a hinged flap at the upper forward end of the pupal case (Bishopp et al., 1944). Within 30 minutes after emerging, the wings of the fly have dried, and the fly is able to sustain itself on the wing. A few minutes later, the fly can fly freely and is ready to mate. The female may begin to drop fertile eggs on cattle about 15 minutes after mating, or only slightly more than an hour from emergence from the pupal case. When the flies crawl out from pupal cases, their abdomens are filled with food, which is stored

from the grub stage. The food is sufficient to sustain the flies through their short span of life and enables them to develop eggs, making it unnecessary for them to feed in the adult or fly stage. During their short adult life span of 3–5 days (Zumt, 1965; Papavero, 2012; Colwell et al., 2006), the antennal sensilla is the vital olfactory structures for *H. lineatum* and *H. bovis*. These sensilla are crucial to find mates and suitable hosts (de Freitas Fernandes et al., 2005; Amer and Mehlhorn, 2006; Smallegange et al., 2008; Guhaeta, 2012; Seenivasagan et al., 2012). The antennal sensilla of flies have developed many adaptive features to increase their sensitivity to attractive molecules in the constantly changing environment (Ismail, 1964; Ross, 1992; Sukontason et al., 2004; Zhang et al., 2012; Wang et al., 2014), because *H. lineatum* needs more sensitive olfactory organs to find specific mates and suitable hosts for oviposition (Papavero, 2012; Hunter and Adserballe, 1996; Colwell et al., 2006). Mechanoreceptors are suspected to receive mechanical signals caused by external stimuli of touch and air, which are involved in locomotion, posture, feeding, orientation, and oviposition (McIver, 1975; Bromely et al., 1980). Considering that *H. bovis* and *H. lineatum* are parasites with high host-specificity (Zumt, 1965; Baker, 1967; Colwell et al., 2006; Papavero, 2012), the functions of the antennal sensilla are to trap odor molecules, facilitate odor detection, and enhance olfactory sensitivity (Jobling, 1928; Shanbhag et al., 1995; Hunter and Adserballe, 1996; Zhang et al., 2012). Although the antenna of *H. bovis* has been examined in past years, little is known about the antennal sensilla of adult *H. lineatum* (Hunter and Adserballe, 1996). The life cycle of the insect from egg to adult is about one year, keeping in mind there is only one generation per year in the case of bot species,

although there is variation in the dates that different stages are present (Bishopp et al., 1944).

2.3 Seasonal occurrence

Seasonal occurrence (Figure 2.8) of different phases of the life of the cattle grub is of great importance in connection with control measures being used; differences between the two species exist with seasonal development. Several factors that can influence seasonal development include amounts of rainfall, methods of handling the animal, latitude, altitude, and amount of sunshine (Figure 2.9). Cattle raised at higher elevations in Texas, New Mexico, and Arizona have grub cycles similar to those in northern climates. Producers in those areas are familiar with when grubs appear in backs of their animals (Gojmerac, 1987). Common heel flies begin to appear and attack cattle during the first mild days of spring. In the southwestern United States, particularly in the plateau region of Texas, they occur earlier.

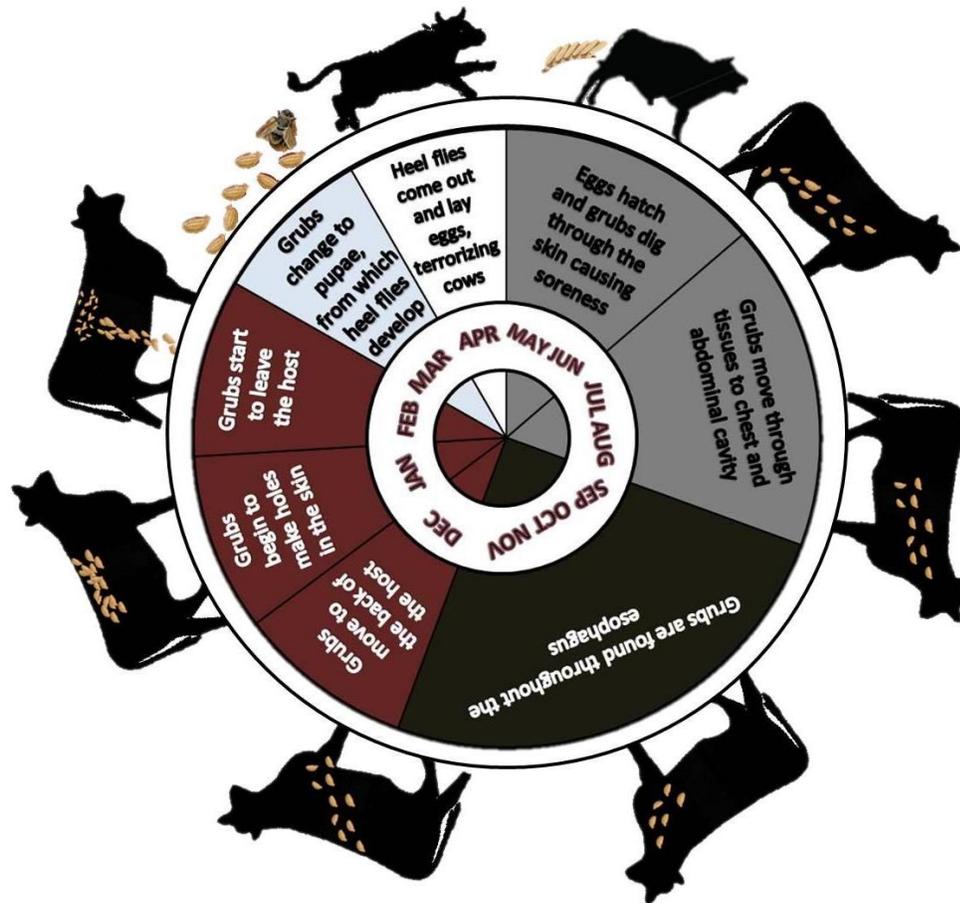


Figure 2.7 Graphic demonstration of the life cycle of the common cattle grub. The seasonal occurrence is shown approximately as it occurs according to latitude levels.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

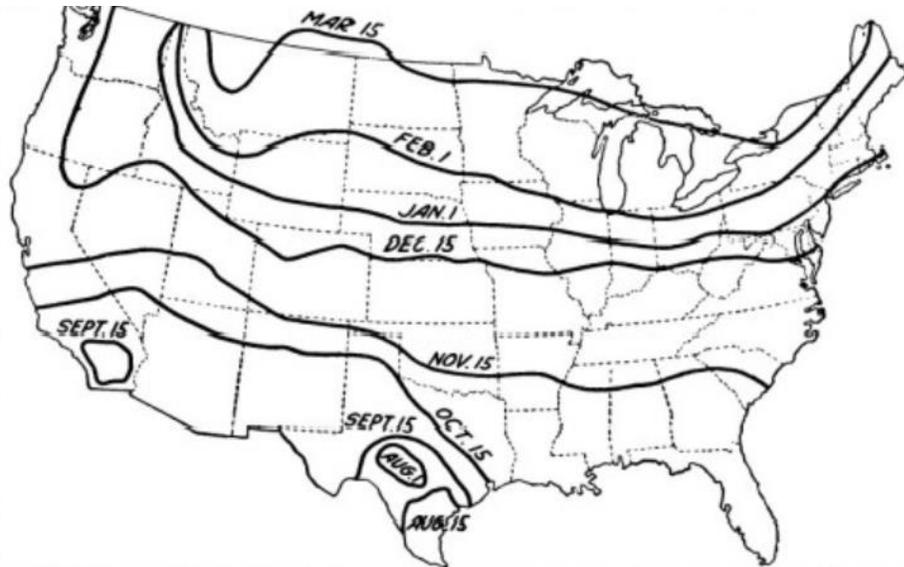


Figure 2.8 Approximate dates of first appearance of the common grub in the backs of cattle.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library.
<http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

Grubs can appear as early as August depending on the temperature and latitude (Figure 2.9), and continue to bother cattle during warm periods throughout the winter; this activity can continue until the first week of April. In the north, the first occurrence of the flies is later (Bishopp et al., 1926). Approximately two and a half months intervene between egg laying and the earliest appearance of young grubs in the esophageal area and elsewhere in the abdominal and chest cavities (Bishopp et al., 1926). Internal organs are infested by the grubs for a period of about nine months of the year. Maximum growth of the grubs on the internal organs occurs when they begin to migrate to the back of the animal. This can vary from year to year, but is usually during July or early August. The seasonal activity of the common cattle grub occurs as follows: during late March and early April, heel flies emerge and lay eggs, which terrorizes cattle. The eggs are placed

upon the hairs of the animal in the month of April, the eggs hatch in May, and grubs dig through the skin causing sores that cows lick (Figure 2.10).



Figure 2.9 Livestock showing discomfort as grubs start penetrating through the skin.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

In June and July, tiny larvae move through tissues to chest and abdominal cavities. From August to early November, grubs are found in the walls of the gullet or weasand and become very abundant. In late November and early December, the grubs move toward the back of the animal and use enzymes capable of digesting skin to cut holes in the skin, to open a 3-mm-wide breathing hole where small bumps start occurring. Before January, grubs are growing in the back of the animals; some mature and drop out early, the rest drop out in February, when they change into pupae. When this final step occurs, the cycle starts over again (Bishopp et al., 1944). From an economic standpoint,

the time when the first grubs mature and leave the cattle is of great importance. This date is correlated naturally with the date when the first grubs of the season reach the back. It is a rare occurrence for grubs to complete development in the back in a minimum of 35 days. Normally the first grubs are mature and leave the animals about 45 days after the holes first appear (Bishopp et al., 1926). Young larvae continue to reach the back during a period of several months, and in the meantime some of the older ones have matured and left the host. The period of infestation in the backs of the animals varies in different herds, but the most prevalent time for the common grub to be in the back of the animal is for four to five months. The northern cattle grub appears in the backs of cattle from one to five weeks later than the common species. Its development in the back is also slower, thus making the period of infestation in the north longer than where the common species alone is found.

2.4 Historical impact of cattle-grubs

One of the most important problems producers deal with is control of grubs. These insect pests have caused loss to dairymen, farmers, and ranchers. In the early 1920's, controlling the insects was a very difficult task. They had not yet discovered any systematic way of controlling or eliminating the pests. The introduction of systemic organophosphorus insecticides in the 1950's gave cattle producers the first opportunity to control cattle grubs for reasonable cost on a large scale (Scholl, 1993). Before this, cattle grubs were controlled by manual removal of second-and third-instar larvae from warbles or by the application of chemicals. The development of systemic insecticides gave producers an opportunity to kill migrating larvae before they arrived at the back of a host and avoid damage to hide and meat in that region (Scholl, 1993). Control of cattle grubs

or heel flies is one of the most historically important insect problems that has confronted the cattle industry in the United States, and although the problem has been recognized as being very harmful to the industry, few of those involved with the industry actually understand the science behind the insects.

2.5 Losses due to cattle grubs

Losses caused by the insects have been difficult to determine and have been poorly tracked throughout the history of the industry. Damage by holes in the hides of the animals has been the major economic loss that cattle grubs cause to the industry (Batte, 1972; Everett et al., 1977). Swelling is caused in the back of cattle when grubs are numerous and pus starts to occur. This occasionally causes death (Bishopp et al., 1944). Some symptoms that occur in infested animals include bloating and vomiting (Scharff et al., 1962; Kahn, 1971). Because cattle are distressed, the flies can affect the level of finish compared to cattle without grubs. Greatest distress often occurs when the animals are weakest, during the spring. During this time many losses are encountered, cattle are very agitated because they are often standing in water or shade to gain relief, when they should be grazing. Carcasses from cattle that are slaughtered before the grubs have reached the back show easily visible symptoms in the areas affected (Bishopp et al., 1926). The areas appear as yellowish watery patches on the carcass, and require removal from the carcass. Meat quality is not affected by grubs, but the amount of trimming done to affected areas damages the appearance of the carcass and it is less suitable for sale (Bishopp et al., 1926). Carcass trimming not only diminishes weight, but increases labor needs, which economically affects the packer. Packers have stated that an average of two

pounds of meat per carcass were removed by trimming (Bishopp et al., 1944). Another loss to packers occurs by the presence of grubs that appear near the weasand; weasands are typically punctured and not suitable for sausage casings, thus limiting their value (Bishopp et al., 1926). The biggest loss to a meat packer is diminished hide value lost to grubs. Before modern methods of control, it was common to find 40 to 100 holes in a hide affected by grubs (Bishopp et al., 1944). Even after the grubs left the back of the affected animal, the holes and scars remained in the hide which decreased hide value. For many years, leather manufacturers, tanneries, and hide dealers have adopted the damaged hides into their business. The holes most often appear in the midline of the back of affected cattle, from where the best leather is cut. Hides damaged with grubs were classified according to the trade, as grade #2 (Bishopp et al., 1944). Hides considered very grubby are known as “pepper boxes”, a term resulting from the quantity of holes in them (Bishopp et al., 1944).

2.6 Factors of nature affecting grubs

Several natural factors may aid in reduction of grubs. Birds and rodents eat many of the grubs after they have left the host and reached the ground. Another known reduction of grubs is by fungi and other diseases (Bishopp et al., 1926). Both stages of the fly are reported to survive underwater, although mature grubs tend to change into flies soon after they have been submerged (Bishopp et al., 1926). Moist soil is reported to kill grubs; many grubs dye and some are unable to emerge from the pupal case (Bishopp et al., 1944). During cold weather, many flies die before depositing eggs; high winds may also reduce the ability of eggs being deposited upon cattle by desiccating and killing the eggs as well as wind blowing flies away preventing them to lay eggs.

2.7 Housing and protection against heel flies

In the 1920's it was common for producers to provide sheds, barns, and water to reduce the number of eggs deposited on the host (Bishopp et al., 1944). It was popular to build sheds on pasture for protection from weather and heel flies. Concrete floors beneath sheds were used in the dairy industry for protection against heel flies (Bishopp et al., 1944).

2.8 Methods to control cattle grubs

Throughout time, scientists have developed methods for controlling cattle grubs, and there has been much interest in developing an effective and practical way to control grubs. Substances have been applied to cattle to repel heel flies and to kill eggs deposited on the legs of the animals. When research began in this area, repellents were applied along the backs of the host, not realizing that the eggs were being deposited in different areas (Bishopp et al., 1926). Some work has shown that the best time to attack the pest was when grubs were in the backs of the cattle (Bishopp et al., 1926). Moreover, treatment has been advised during the early stage of the infestation (Hoelscher et al., 2000). Spray protection against flies has been used by many cattlemen to help reduce the number of grubs in cattle (Bishopp et al., 1944).

2.8.1 Controlling grub infestations by manual removal

Before chemicals were available, grubs were manually extracted from the host. Grubs were extracted by applying pressure with fingers to squeeze the pest out when the larvae were in the back of the host. This was the first method used to eliminate the problem. Tools have also been developed to help remove grubs from the backs of cattle

(Figure 2.11). Where physical control was used, the process might be repeated four to five times per animal in less than 30 days.

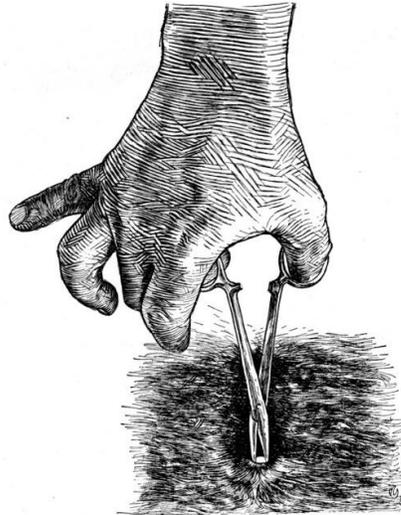


Figure 2.10 Tool developed to manually remove cattle grubs.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

2.8.2 Dipping Vats

In the early 1900's, experiments by the Bureau of Entomology used dipping vats (Figure 2.12) that contained an arsenic solution or a 2% coal-tar creosote solution (Bishopp et al., 1926). In the experiments, the solution was placed in the vats to a depth of about 20 cm and the cattle were moved through the vat at 4-day intervals (Bishopp et al., 1926). The theory was based on the fact that a large number of the eggs of the heel fly were deposited on the legs of the animal and knowing that the incubation time was three or four days, either the eggs or the grubs were going to be destroyed (Bishopp et al., 1926). Producers realized that some of the eggs were deposited in locations not reached

by the solution and eggs were not being killed (Bishopp et al., 1944). The dipping structure was a concrete pool that had a drop in one side and a ramp on the other. Animals were herded through the dipping vat and allowed to swim to the ramp on the other side (McLaren et al., 1998). According to Ng (1999), each bath could contain about 2,800 gallons of solution.



Figure 2.11 Dipping vat used in the 1900's containing arsenic solution or 2% coal-tar creosote solution.

Bishopp, F. C. (Fred Corry), 1884-1970.; Laake, E. W. (Ernest William), 1887-1986. & Wells, R. W. (Roscoe Ward), b. 1890. *Cattle grubs or heel flies with suggestions for their control*. Washington D.C. UNT Digital Library. <http://digital.library.unt.edu/ark:/67531/metadc1750/>. Accessed 11 April 2016.

2.8.3 Rotenone

Early chemicals to fight grubs were administered in powder form (Bishopp et al., 1944). One insecticidal compound was rotenone, which was also known by the trade names of “Derris”, “Prentox”, or “Tubatoxin”. The powder originated from finely ground roots of the jicama vine plant, which usually varied in amount from 2 to 6 percent; material containing 5 percent was recommended (Bishopp et al., 1944). Rotenone worked by interfering with the electron-transport chain in mitochondria. It

inhibited the transfer of electrons from iron-sulfur centers in complex I to ubiquinone. This interfered with NADH during the creation of usable cellular energy (ATP). Complex I was unable to pass its electron to CoQ, creating a back-up of electrons within the mitochondrial matrix. Cellular oxygen was reduced, creating a reactive oxygen species, which damaged DNA and other components of the mitochondria (Mehta and Li, 2009). During the early 1900's this was the most satisfactory substance to kill grubs. The mixture of the powder consisted of one-part derris (of which 5% was rotenone) and two parts of carrier such as pyrophyllite or frianite (McKay, 1952). Historical reports (USDA, 1943) suggested that treatments using rotenone powder and pyrophyllite or frianite were more effective than those made by adding sulfur because they were able to penetrate the hair better and also because double the number of animals could be treated with the same amount of derris. When a shaker can was used to apply the powder, an average application of 2-3 ounces of mixture was required to be sufficient to treat an animal. The mixture would penetrate the hair coat and enter the body through the holes made by the grubs (USDA, 1943). The downfall to this type of application was that the effectiveness of the treatment depended on quantity and size of grub holes. In the 1950's, rotenone was the only toxicant recommended for control of cattle grubs and no benefits were to be expected until the year after treatment (McKay, 1952). During this era, power spraying rotenone became popular. This was the most rapid method of applying the treatment to cattle, and was recommended for larger herds. The treatment used 7.5 to 10 pounds of cube or derris powder containing 5% rotenone, which was added to 100 gallons of water. No matter what method of applying rotenone was used, the most effective time for application was 30 days after the appearance of the first grubs in the

back, and thereafter at 30- to 45-day intervals throughout the grub season. Rotenone was a very toxic chemical and potential poisoning concerns existed because drainage could potentially reach water sources (McKay, 1952).

2.8.4 Organophosphates

Organophosphates became popular in the 1960's. Organophosphorus insecticides inhibit acetylcholinesterase (AChE), an enzyme that hydrolyzes acetylcholine (ACh) in the nervous system of animals. ACh is involved in the transmission of signals from nerves to muscles and between neurons in the brain. The role of AChE is to terminate the transmission of nervous signals where ACh is the neurotransmitter. By inhibiting the activity of AChE, organophosphates prevent the termination of those nervous signals. Subsequently, parasites are paralyzed and die quickly (Bajgar, 2004).

In 1956, two compounds were introduced for testing as systemic organophosphorus insecticides to fight grubs, O-dimethyl O-(2, 4, 5-trichlorophenyl) phosphorothioate (Ronnel), which was administered as a bolus (about 15 grams), or a drench (The Steamboat Pilot, 1957), and O, O-diethyl O-(3-chloro-4-methyl-7-coumarinyl) phosphorothioate (Coumaphos) applied as a spray (Rich et al., 1961). In 1958, both compounds were registered for distribution in the U.S. and Canada. Ronnel was also known as DowET-57 (The Steamboat Pilot, 1957) and was marketed under the trade names of Trolene FM and Rid-Ezy. Coumaphos was known as Bayer 21/199 and marketed under the trade name of Co-Ral (Rich et al., 1961). Trolene was incorporated into a ground sorghum-grain premix and was fed in the complete ration; it was suggested that the premix be incorporated into daily rations for 7-14 days to effectively control

grubs in feedlot cattle (Fink and Riley, 1975). Trolene FM destroyed both young and mature grubs. It was advisable to not treat sick animals with the mixture, and ensuring that cattle had access to water before and after the feeding period was essential (Cooperative Extension Service, 1965).

Co-Ral treatment was available in three application methods, spray, pour-on, and dipping vat solution. In spray form, 12 pounds of Co-Ral 25% was mixed in 100 gallons of water and sprayed on animals; cattle that were sick or animals less than three months of age were not treated. Applying Co-Ral via pour-on was a ready-to-use formulation and administered along the back of cattle, applying one-half fluid ounce per 100 pounds of body weight. The dipping vat solution was effective. This method was formulated like the spray method, adding 8 pounds of Co-Ral 25% to each 100 gallons of water. Dipping over-heated animals was not recommended.

2.8.4.1 Ruelene

In 1960, crumofate was first applied to cattle in southern California (Riehl et al., 1965). It was also known under the trade name of “Ruelene” (4-*tert*-butyl-2-chlorophenyl methyl methylphos-phoramidate). Two methods of Ruelene were used, spray and pour-on (Rogoff et al., 1960). When spraying, two gallons of Ruelene were added to 100 gallons of water, and the resulting solution was applied with a high-pressure sprayer, wetting the skin on the backs of cattle. Mixed Ruelene solution was applied at a rate of 1 gallon per 300 pounds of body weight (Cooperative Extension Service, 1965). When applying Ruelene as a pour-on, one-half gallon of Ruelene was diluted with one gallon of water; one fluid ounce of the mixture per 100 pounds of body weight was

poured along the back of the animal. It was important to not treat animals that were sick or under stress and Ruelene was not to be applied during extremely hot and humid weather because of possible skin blistering (Cooperative Extension Service, 1965). Ruelene was labeled with a 28-day withdrawal period before slaughter (Cooperative Extension Service, 1965).

2.8.4.2 Warbex

The topical use of famphur (O, O-dimethyl O-[p-(dimethylsulfamoyl) phenyl] phosphorothioate) (Henry et al., 1985), also known under the trade name of “Warbex” was tested in the 1960’s. The solution was administered to livestock as a pour-on, feed additive, or by intramuscular injection (Ivey et al., 1976). The efficacy of famphur formulations applied to animals as a pour-on and as a high-concentrate, low-volume intramuscular injection for control of cattle grubs was shown from tests in the 1960’s (Drummond, 1964; Kohler & Rogoff, 1962; Marquardt & Hawkins, 1962). In later tests, effective and safe dosages were reported to range from 40 to 55 mg/kg for the pour-on and 7 to 25 mg/kg for the intramuscular injection (Drummond, 1963). It was not until 1968 that the famphur pour-on formulation was registered for commercial use. During subsequent years, numerous animal systemic insecticides became available in different grubicide formulations for use as sprays, dips, feed additives, mineral supplements, pour-ons, and spot-ons (Loomis et al., 1978).

Similar to famphur, fenthion (O, O dimethyl O-[4-methylthio)-m-tolyl] phosphorothioate), known under the trade names of “Tiguvon” and “Spotton” came onto the market. Formulations were developed for pour-on ready-for-use applications that were well tolerated by the skin (Stendel, 1977). The mixture was used at the rate of one-

half fluid ounce per 100 pounds of body weight placed on the backline of the animal. Only one application per season was made for initial grub control. A second application was made if animals became re-infested and as soon as possible after heel-fly activity ceased. Cattle were not to be slaughtered within 35 days following a single treatment. If a second application was made for grub control, cattle were not to be slaughtered within 45 days of the second treatment. With the pour-on technique, a relatively large amount of the formulation was necessary for treatment of animals. This caused difficulties, which led to development of spot-on formulations. In the formulations, the active ingredient was very concentrated and was absorbed quickly. In comparison with the pour-on method, the insecticide was applied to a relatively small spot on the skin (Stendel, 1977).

2.8.5 Avermectins

A group of anthelmintics were discovered from an actinomycete isolated by Kitasato Institute from a soil sample collected at a golf course at Kawana, Ito City, Shizuoka Prefecture, Japan (Burg, 1979). The actinomycete isolate was sent to Merck Sharp & Dohme Research Laboratories for testing and evaluation. Early tests indicated that whole broth was active against *Nematospiroides dubius* in mice. The anthelmintic activity was isolated and identified as a family of closely related compounds. The complex, which was named avermectin, is very active against a variety of nematodes (Burg, 1979).

The discovery of avermectins in the late 1970's changed the efficiency of how cattle grubs were treated (Burg et al., 1979). Avermectins are naturally occurring compounds produced by fermentation of the soil-dwelling actinomycete *Streptomyces*

avermililis. The first to be developed and tested for efficacy against cattle grubs and other parasites of cattle was ivermectin (Campbel et al., 1983; Leaning, 1984; Preston, 1984). Ivermectin, a semi-synthetic derivative of avermectin B₁, consists of an 80:20 mixture of equipotent homologues, 22, 23-dihydro B_{1a} and 22, 23-dihydro B_{1b} (Goidie et al., 1993). Introduced under the trade name “Ivomec” into the market in the early 1980’s, it has been used extensively for treatment of endo and ectoparasites of livestock and companion animals (Campbell and Benz, 1984; Campbell, 1985). By the early 1980’s, this anthelmintic compound was believed to be one of the most effective insecticides ever developed for systemic use against cattle grubs (Khan et al., 1983).

Ivermectin binds with high affinity to glutamate-gated chloride channels in invertebrate nerve and muscle cells, causing an increase in permeability of the cell membrane to chloride ions with hyperpolarization of the nerve or muscle cell. Hyperpolarization results in paralysis and death of the parasite (Wolstenholme and Rogers, 2005). Today, three similar compounds exist -- ivermectin, doramectin, and eprinomectin. The potency and broad-spectrum activity of ivermectin against endoparasites and ectoparasites of cattle, sheep, swine, dogs, and horses is well documented (Drummond, 1985; Lasota and Dybas, 1991). Moreover, introduction of ivermectin as a veterinary parasiticide in France in 1981 revolutionized animal anti-parasitic chemotherapy (McKellar and Benchaoui, 1996). Within a period of 5 years, ivermectin had captured 16% of the worldwide anti-parasitic sales (Bloomfield, 1988), and by 1990 it was estimated that more than 800 million cattle had been treated with ivermectin (Sutherland, 1989). Despite concerns about possible environmental consequences from its use (Wall and Strong, 1987), ivermectin has unique characteristics

not found in organophosphorus systemics. The first is ability to kill migrating larvae, but unlike systemics, it is also highly efficacious against second- and third-instar larvae in warbles (Kahn et al., 1985). The latter activity permits use of the material as a late-season (Scholl et al., 1984) or pour-on (Alva-Valdes et al., 1986) treatment for grub-infested cattle that is not possible with traditional systemic insecticides, which are ineffective once the larvae are inside their warbles. Additionally, ivermectin at low doses kills 100% of migrating *Hypoderma* larvae of both species (Drummond, 1985). However, because it is used against a wide range of internal and external parasites, the lowest effective dilutions could lead to problems of resistance and reduced efficacy against other targeted species (Leaning, 1984).

Doramectin was first commercialized in 1993 in Brazil and South Africa and has been the subject of extensive worldwide anti-parasitic research. The compound is known under the trade name of “*Dectomax*” (Vercruysse et al., 1993). It is effective as an injectable formulation against cattle mites, cattle lice, and cattle grubs (Hendrickx et al., 1993; Logan et al., 1993). The recommended dosage is 200 µg/kg (Vercruysse et al., 1993).

Eprinomectin is the most recently commercialized avermectin in large animals and was developed in the 1990’s as a topical treatment for use against endo- and ectoparasites in cattle of all classes and ages (Shoop et al., 1996; Shoop and Soll, 2002). Today, eprinomectin is known under the trade name of “*Eprinex*” (Rehbein, 2012).

2.8.6 Milbemycins

Milbemycins were discovered in 1973 and were developed for crop protection (Takiguchi et al., 1980). They worked as insecticidal compounds for crop protection by Sankyo scientists (Shoop et al., 1995). Despite predating the discovery of ivermectin, they were not used in veterinary practice until the mid-1980's. Milbemycins are similar avermectins in mode of action. They open glutamate-sensitive chloride channels in neurons and myocytes of invertebrates, leading to hyperpolarization of the cells and blocking of signal transfer (Martin, 1997). Hyperpolarization results in paralysis and death of the parasite (Wolstenholme and Rogers, 2005). Moxidectin is a milbemycin first marketed in Argentina in 1990. It was commercialized worldwide for use as an injectable in cattle (McKellar and Benchaoui, 1996).

2.9 Immune response and vaccination

Generally, fewer *Hypoderma spp.* larvae appear in the back of older cattle than in calves or yearlings (Bishopp et al., 1944), which suggests development of immunity with increased age. Major advances have occurred in the study of *Hypoderma* digestive enzymes and of the bovine-immune response to infestation by cattle grubs. Initial investigations using extracts of *Hypoderma spp.* larvae as candidate vaccines (Baron and Weintraub, 1986; Kahn et al., 1960; Pruett and Barret, 1985) led to concerted attempts toward the development of a defined vaccine against infestation by cattle grubs. The advantages of a vaccine over chemical control are abundant: less damage to the environment, complete and lifetime conversion of susceptible animals to resistant status, and use in animals such as dairy cattle for which application of systemic insecticide is

prohibited during lactation (Scholl, 1993). Experimental vaccines have not, to date, killed more migrating larvae and protected the subcutaneous tissues of the back or prevented hide damage in individual animals (Scholl, 1993). However, because of increased mortality of larvae arriving at the back, current experimental vaccines are designed to kill more larvae and therefore reduce abundance of *Hypoderma* spp. (Scholl, 1993). Thus, experimental vaccines already developed might have limited value for use in intensive programs to drastically reduce abundance of cattle grubs during a short period of time (Chabaudie et al., 1991). Vaccines might, on the other hand, be useful in less-intensive control programs and as a complement instead of a substitute for chemical control in integrated pest management programs (Scholl, 1993).

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CHAPTER III

CASE STUDY: IMPACT OF *HYPODERMA LINEATUM* UPON LIVE GROWTH, CARCASS ATTRIBUTES, AND HIDE VALUE OF FED BEEF CATTLE

3.1 ABSTRACT

A case study was done at the WTAMU Research Feedlot from 14 November 2014 to 5 August 2015. While processing crossbred bulls (n=32), several cattle were identified to be infested with grubs, later identified as the common cattle grub, *Hypoderma lineatum* (Villers). Metaphylaxis was administered upon arrival (d 0). Cattle were vaccinated, dewormed, and individually identified. Cattle were placed on a starter ration (d0) and transitioned to a finishing ration (d45). Twelve days after arrival, all cattle were re-weighed and palpated to quantify infestation by cattle grubs; a hide map was used to record location of individual grubs. Grubs were manually extracted from the left side while grubs in the right side remained in the animals. Also, on d12, animals were administered a growth-promoting implant and band-castrated. Two grub-infested cattle were euthanized (d18) and examined to quantify damage in the hide and carcass. Hides were fleshed and converted into rawhide to document hide damage in the feeder calves. Grub samples were sent to Texas A&M Veterinary Medical Diagnostic Lab (TVMDL), College Station, Texas (d24); results concluded that the grubs were *Hypoderma lineatum* (d33). Two animals (grub-free) died from bovine respiratory disease during the study (d15, d50). The remaining cattle were reweighed (d12, d40, d70, d96, d124, d152, d180, d208, d234, d236, d264) to assess potential differences in growth rate. Cattle were slaughtered in two groups (n=9 on d234; n=19 on d264) at

Tyson Fresh Meats, Amarillo, TX. Data collected during slaughter and grading processes included individual animal identification, liver score, hot carcass weight, longissimus muscle area, 12th rib subcutaneous fat depth, kidney-pelvic-heart fat, yield grade, marbling score, and quality grade. Hides were individually identified and tracked through the facility to hide processing. Hides were green de-fleshed, lime de-fleshed, and de-haired for 24 h; individual identity was maintained throughout. Hides were then exposed to blue-chroming chemicals for 24 h; next, blue-chrome hides were individually graded as #1, #2, or #3 hides. No difference in initial weight ($P = 0.89$), finished weight ($P = 0.35$), average daily gain ($P = 0.59$), hot carcass weight ($P = 0.38$), longissimus muscle area ($P = 0.91$), 12th rib subcutaneous fat depth ($P = 0.64$), yield grade ($P = 0.84$), or KPH fat ($P = 0.38$) was detected between grub-free and grub-infested cattle. Grub-infested cattle tended to have more marbling ($P = 0.07$) than did grub-free cattle. No difference in hide damage or value occurred between left sides (manually extracted) and right sides (grubs allowed to remain). Infestation by grubs did not negatively affect growth or carcass attributes. Hide damage in feeder calves resolved during the finishing period and grub-damaged hides met #1 criteria.

3.2 INTRODUCTION

Cattle grubs, also called wolves or warbles are the larval or maggot stage of insects known as heel flies, warble flies, or gadflies (Bishopp et al., 1944). Larval stages of the flies are parasites of concern to cattle producers in North America because they cause damage that can decrease the value of the host (Drummond, 1987). Heel flies can reduce cattle comfort and impact daily growth, whereas grubs can damage the hide and lessen its value (Bishopp et al., 1944). Two species of cattle grubs are common to the U.S.; the most widespread is the common cattle grub, *Hypoderma lineatum* (Villers), present in every state; the other is the northern cattle grub, *Hypoderma bovis* (Linnaeus), which is predominant in the northern U.S. (Bishopp et al., 1944). Heel flies develop from grubs that have burrowed to and dropped from the backs of cattle. Common heel flies appear during the first warm days of spring and their activity increases as the season advances.(Scholl, 1993). Heel flies usually attach themselves low on the legs, particularly above the hoof. The flies locate close to the skin and deposit as many as 300 eggs, which are attached firmly to the hair of the animal. This is why the name “heel fly” has been used throughout time. Control of cattle grubs or heel flies has historically been one of the most important insect problems confronting the U.S. cattle industry (Bishopp et al., 1944). Economic losses are primarily attributable to the larvae that migrate through the host tissues and penetrate the skin, resulting in diminished hide value

(Andrews, 1978). Meat of cattle that are slaughtered while infested might also require extensive trimming, which will decrease carcass weight and thus value (Hendrickx et al., 1993).

The 1991 National Beef Quality Audit reported that 1.3% of the carcasses observed had visible grubs (Lorenzen et al. 1993) with a further decline to 0.03% in the subsequent audit in 1995 (Boleman et al, 1998). In the 2000, 2005, and 2011 National Beef Quality Audits no instances of visible grubs were recorded. In contrast, the Canadian Beef Quality Audit reported only 0.1% of carcasses with evidence of grubs in 1996 (Van Donkersgoed et al., 1997) with a further decline to 0.008% in the subsequent audit in 1998 (Van Donkersgoed et al., 2001).

The objective of this research was to determine if there was any significant difference in live growth, carcass attributes, and hide value between cattle with grubs and grub-free fed beef cattle.

3.3 Materials and methods

3.3.1 Initial discovery, cattle processing, and feeding

While processing crossbred bulls (n=32; Origin Producers Livestock Auction Company, San Angelo, TX) upon arrival, some animals in the load of cattle were identified to be infested with grubs whereas others were not affected. Cattle were dewormed with *fenbendazole* (SafeGuard; Merck Animal Health; Summit, NJ) and *doramectin* (Dectomax; Zoetis, Florham Park, NJ) upon arrival (d0) to treat internal parasites and the grubs. In addition, metaphylaxis was administered (*tulathromycin*; Draxxin; Zoetis; Florham Park, NJ), cattle were vaccinated for BVD/PI-3/BRSV (*Vista 5*

SQ; Merck Animal Health; Summit, NJ), and individually identified with a visual ear tag. Cattle were placed on a starter ration (d0) and later transitioned to a finishing ration (d45).

3.3.2 Manual removal, castration, and further processing

Twelve days after arrival, all cattle were re-weighed and manually palpated to quantify infestation by grubs; a hide map was used to record location of the individual grubs. Grubs were manually extracted from the left side of infested animals to assess potential need for or benefit from physical removal; grubs on the right side remained in animals. Also on d12, animals were administered a growth-promoting implant (*200 mg trenbolone acetate and 40 mg estradiol*; Revalor® XS; Merck Animal Health) and castrated using restrictive surgical tube bands (The Callicrate Bander; St. Francis, KS). Grub samples on d24 were sent to Texas A&M Veterinary Medical Diagnostic Lab (TVMDL), College Station, Texas.

3.3.3 Meat laboratory harvest

Two cattle (258, 343 kg) infested with grubs were randomly selected and slaughtered (d 18) at the West Texas A&M University Meat Laboratory to quantify carcass and hide losses in feeder calves. Cattle were immobilized using a captive bolt pistol, exsanguinated, and the hide was removed using a pneumatic de-hider. Esophageal surroundings were inspected for evidence of grubs or grub tracts. De-hided carcasses were evaluated for number of grubs observed in/on the subcutaneous fat (Figures 3.1, 3.2, 3.3). Carcasses were trimmed in locations where grubs were located. Grub samples

collected from the carcasses were preserved in formaldehyde solution. Carcasses were eviscerated and split into halves, then the longissimus muscle was dissected and examined for grubs. After complete examination, both dismantled carcasses were disposed in a local landfill because those animals had not met withdrawal times for *Vista 5 SQ* (21d) or Dectomax (35d). Both hides were manually fleshed and converted into rawhide to document hide damage in the feeder calves (Figure 3.4).

3.3.4 Live animal growth

Two animals (grub free) died from bovine respiratory disease during the course of the study (d15, d50). The remaining cattle were periodically reweighed (d40, d70, d96, d124, d152, d180, d208, d234, d236, d264) to assess potential differences in growth rate.

3.3.5 Commercial slaughter and hide processing

Cattle were individually weighed before shipment for slaughter. Cattle were slaughtered in two groups (n=9 on d234; n=19 on d264) at Tyson Fresh Meats, Amarillo, TX. Data collected during the slaughter and grading processes included individual animal identification, liver score, hot carcass weight, longissimus muscle area, 12th rib subcutaneous fat depth, kidney-pelvic-heart fat, yield grade, marbling score, and quality grade (USDA, 1997). Hides were individually identified and tracked through the facility to hide processing. Hides were green de-fleshed, lime de-fleshed, and placed into containers where they underwent a de-hairing process for 24 hours. Hides were then placed into a different container for 24 hours where they underwent the chroming process to create wet blue chrome leather; after hides were removed from the container they were

individually graded as #1, #2, or #3 hides according to industry standards (United States Hide, Skin & Leather Association).

3.3.6 Statistical analysis

The primary outcome variable of interest was the subjective ordinal hide-grade score. Secondary outcome variables were interval scale live animal growth and both interval and ordinal carcass grading outcomes. Because the case study was unbalanced (grub-infested=23; grub-free=5) and because the assumptions of ANOVA (Independence, normal distribution, and homogeneity of variances) were not met, the data were analyzed using non-parametric methods. The Mann-Whitney U test was chosen to analyze the data because they were represented as two independent samples. Median and quartile deviation for each variable were determined via the UNIVARIATE procedure of SAS (version ##; SAS Institute, Cary, NC).

3.4 RESULTS AND DISCUSSION

3.4.1 Meat laboratory harvest

Grubs observed in the back of the two feeder cattle during the meat laboratory harvest (d18) correspond with timing of the grub cycle on the southern High Plains. The grubs were *Hypoderma lineatum*. Holes from the grubs that were manually extracted from the left side on d12 did not heal in 6 d. No evidence of grubs or grub tracts was observed in the esophageal surroundings. Grub tracts inclusive of holes and subcutaneous fat tears were found throughout the backs of the hosts. No evidence of grub or grub tracts was observed in the longissimus muscle. Hides that were fleshed and converted into rawhide demonstrate the hide damage over the dorsal aspects of the host.

3.4.2 Growth performance

No difference in initial weight ($P = 0.89$), finished weight ($P = 0.35$), or average daily gain ($P = 0.59$) were detected between grub-free and grub-infested cattle. Average daily gain (d40, d70, d96, d124, d152, d180, d208, d234, d236, d264) in grub-free cattle were 3.95, 2.85, 3.44, 3.56, 3.17, 4.61, 3.67, 2.92, 3.57, 2.51, respectively. For comparison, average daily gains of grub-infested cattle were ¹1.87, ²3.50, ³3.16, ⁴3.28, ⁵2.97, ⁶4.21, ⁷3.65, ⁸2.68, ⁹3.34, and ¹⁰2.39, respectively. The 40d average daily gain of the grub-infested cattle was substantially less than for the grub-free cattle. This might be related to the grub cycle in the cattle during that particular time.

3.4.3 Carcass attributes

Carcass attributes including hot carcass weight ($P = 0.38$), longissimus muscle area ($P = 0.91$), 12th rib subcutaneous fat depth ($P = 0.64$), KPH fat ($P = 0.38$), or yield grade ($P = 0.84$) did not differ because of infestation by grubs. Grub-free cattle had a median hot carcass weight of 435 kg whereas grub-infested cattle weighed 418 kg. Longissimus muscle area of grub-free cattle was 92.84 whereas longissimus muscle area for grub-infested cattle was 91.10. Yield grades for grub-free cattle averaged 3.26 whereas yield grade of grub-infested cattle averaged 3.35.

Grub-infested cattle tended to have more marbling ($P = 0.07$) than did grub-free cattle. The numbers can lead to assumptions, but in reality it is a result of small sample size rather than a repeatable result. Given the fact that there were only eight grub-free cattle, an outlier (i.e., unusually high or low KPH or marbling) can make a large difference in the mean value.

Marbling scores for grub-free and grub-infested cattle were Slight⁵¹ and Small²² ($P = 0.06$), whereas 12th rib back-fat depth was 0.49 and 0.54, respectively ($P = 0.57$). Kidney-pelvic-fat values for grub-free and grub-infested cattle were 1.73 and 1.92, respectively ($P = 0.06$). Percentages of abscessed livers were 0% and 3.57% respectively ($P = 0.06$). A study by Scholl et al. (1988) found that infestation by cattle grubs did not affect carcass grade, back-fat thickness, marbling score, or rib-eye area when steers were slaughtered. Results suggested that relatively few cattle grubs did not produce measurable effects on performance of cattle on feed. Also, the amount of infestation by cattle grubs on the growth of the steers during the period when the larvae were migrating to and emerging from the backs of the animals did not influence the rate of gain, feed intake, or feed-to-gain ratio of the steers.

3.4.4 Hide damage

No difference in hide damage or value occurred between left sides (manually extracted) and right sides (grubs allowed to remain) of the cattle. Hide damage in feeder calves resolved during the finishing period and all grub-damaged hides met #1 criteria (Figures 3.5, 3.6, 3.7).

3.5 CONCLUSION

In conclusion, modern anthelmintic technology has made it possible to eliminate grubs/heel flies from cattle populations without great amounts of effort. By successfully applying treatments, all of the flies can be destroyed. If no grubs come from the animal, no flies can appear to produce another generation and affect producers. Administration of anthelmintics is crucial to maximize growth, carcass attributes, and hide value.

Timely application of avermectins can prevent the grubs from reducing beef-system value.

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Table 3.1 Median \pm quartile deviation of initial weight, average number of grubs, periodic average daily gain, finished-weight, and total ADG of grub-free cattle and grub-infested cattle.

	Grub Free	Grub Infested	P-value
Initial Weight, kg	304.00	301.93	0.89
n-grubs	0	16	
ADG, d0-d12, kg	1.28 \pm 1.25	0.76 \pm 0.34	0.22
ADG, d12-d40, kg	0.84 \pm 1.96	1.64 \pm 0.48	0.21
ADG, d40-d70, kg	1.57 \pm 0.66	1.41 \pm 0.25	0.68
ADG, d70-d96, kg	1.66 \pm 0.045	1.55 \pm 0.24	0.52
ADG, d96-d124, kg	1.38 \pm 0.14	1.30 \pm 0.22	0.41
ADG, d124-d152, kg	1.91 \pm 0.21	1.90 \pm 0.23	0.50
ADG, d152-d180, kg	1.68 \pm 0.14	1.65 \pm 0.16	1.00
ADG, d180-d208, kg	1.30 \pm 0.02	1.30 \pm 0.26	0.67
ADG, d208-d236, kg	1.68 \pm 0.23	1.47 \pm 0.22	0.66
ADG, d236-d264, kg	1.07 \pm 0.05	1.00 \pm 0.16	0.62
Finished Weight, kg	678.03	658.00	0.35
Total Average Daily Gain, kg	1.47 \pm 0.06	1.49 \pm 0.16	0.59
Hot Carcass Weight, kg	435.58	417.76	0.38
Longissimus Muscle Area	92.84	91.10	0.91
Yield Grade	3.26	3.35	0.84
Marbling	350.78	422.21	0.07
12 th Rib Subcutaneous Fat	0.49	0.54	0.64
KPH	1.73	1.92	0.38
Liver Abscessed %	0.00%	3.57%	0.06

1 USDA YG = 2.5 + (2.5 \times 12th-rib subcutaneous fat thickness, in.) + (0.0038 \times HCW, lb) + (0.2 \times percentage KPH) - (0.32 \times LM area, in.²).

2 Marbling Scores: 30 = Slight; 40 = Small; 50 = Modest.

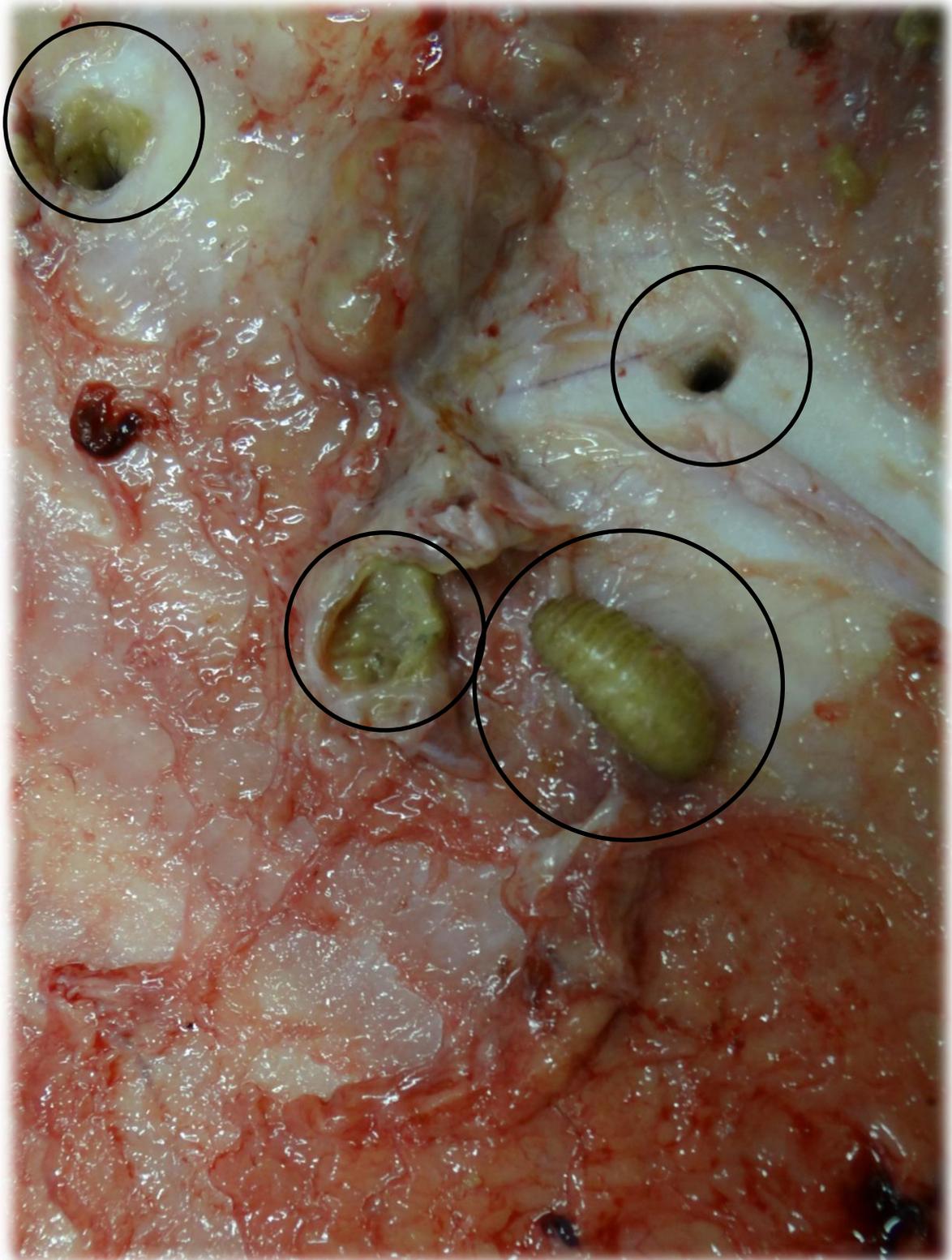


Figure 3.1 Cattle grubs and hide damage in a feeder calf harvested at the WTAMU Meat Laboratory (d18).



Figure 3.5 Individually identified blue-chrome hide from a grub-free animal.



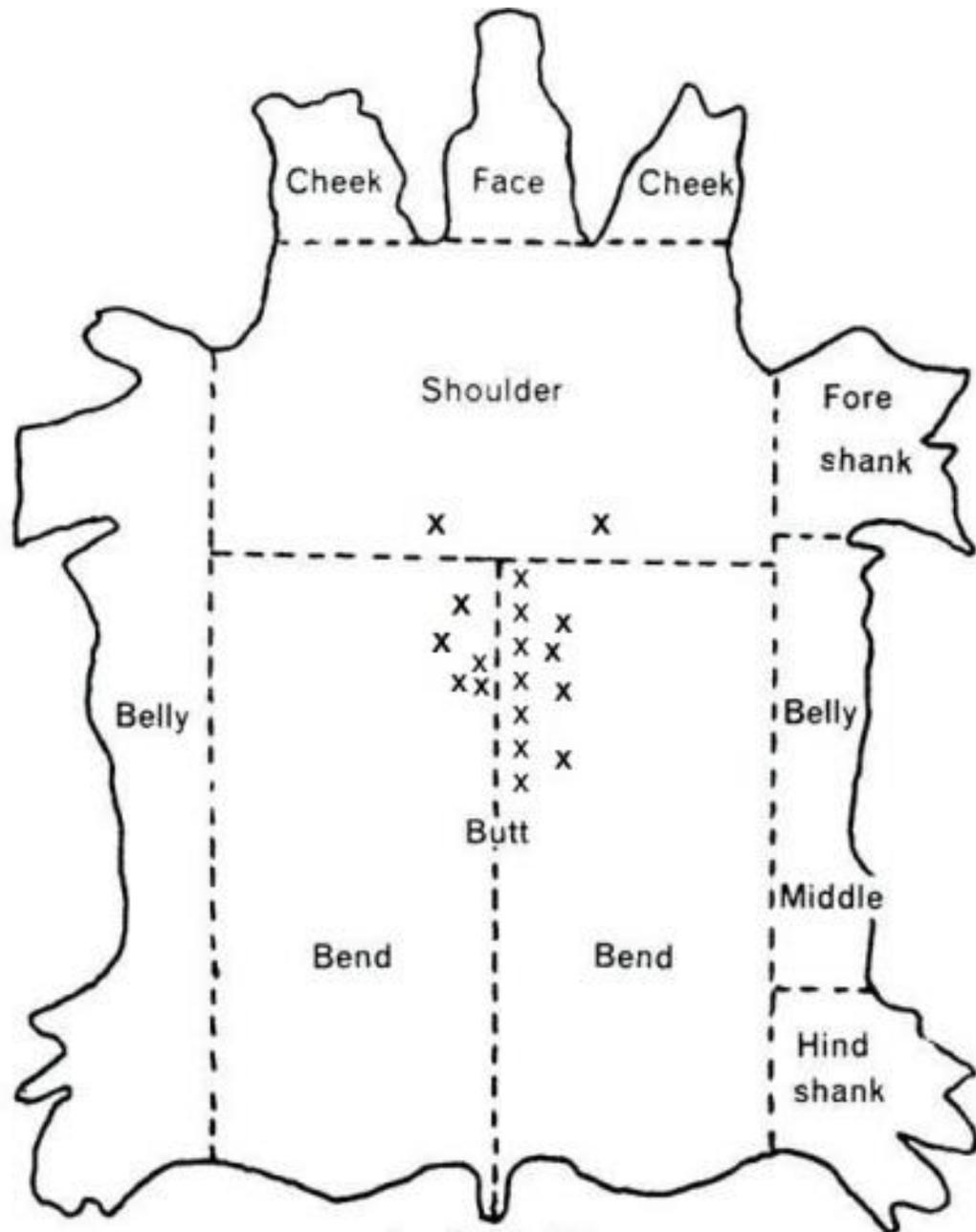
Figure 3.6 Cattle grub on hide at slaughter (d264).



Figure 3.7 Hole from cattle grub in blue-chrome hide at slaughter (d264).

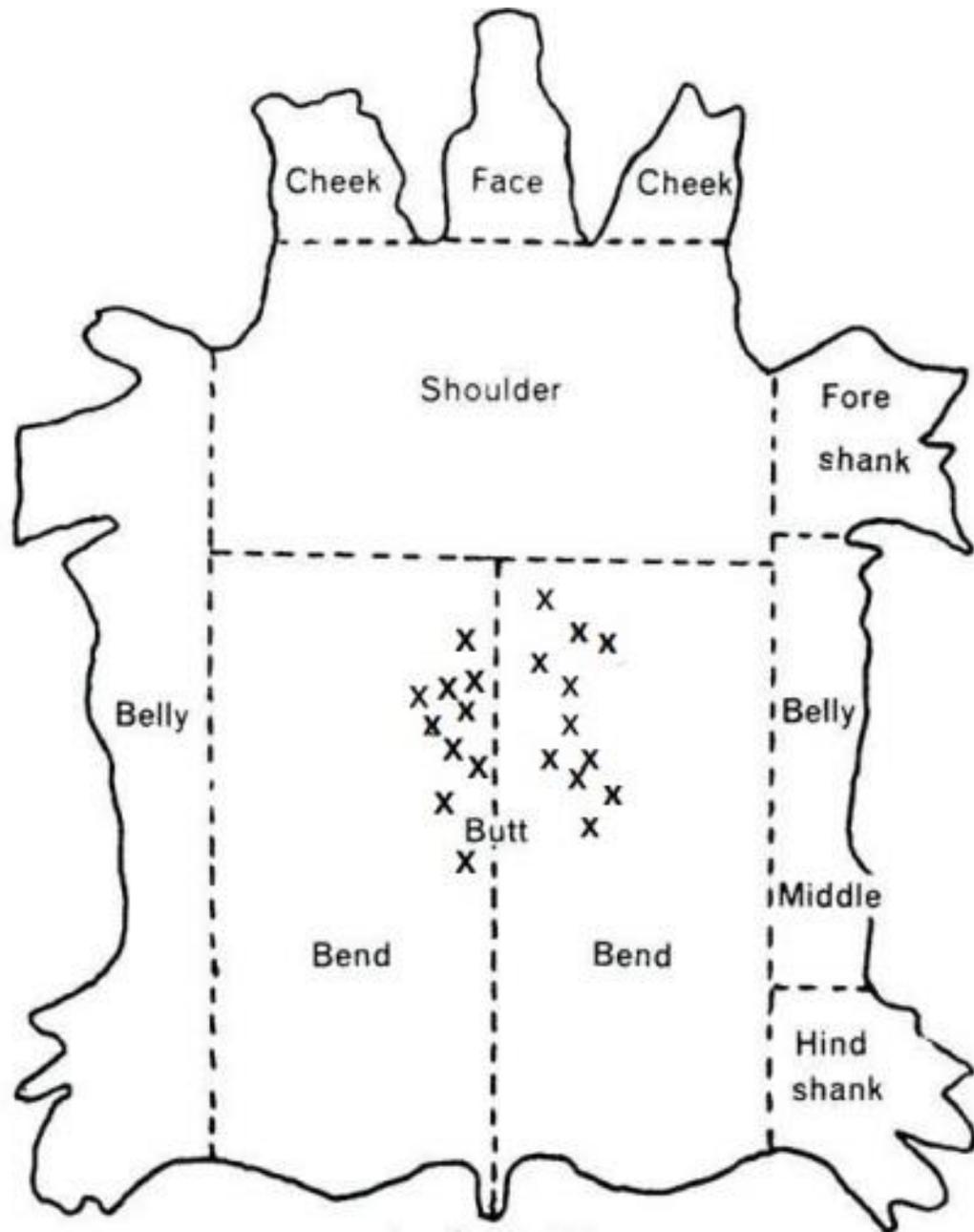
APPENDICES

**Complete data on palpated grub hide maps, live cattle performance, slaughter data,
and grade data**



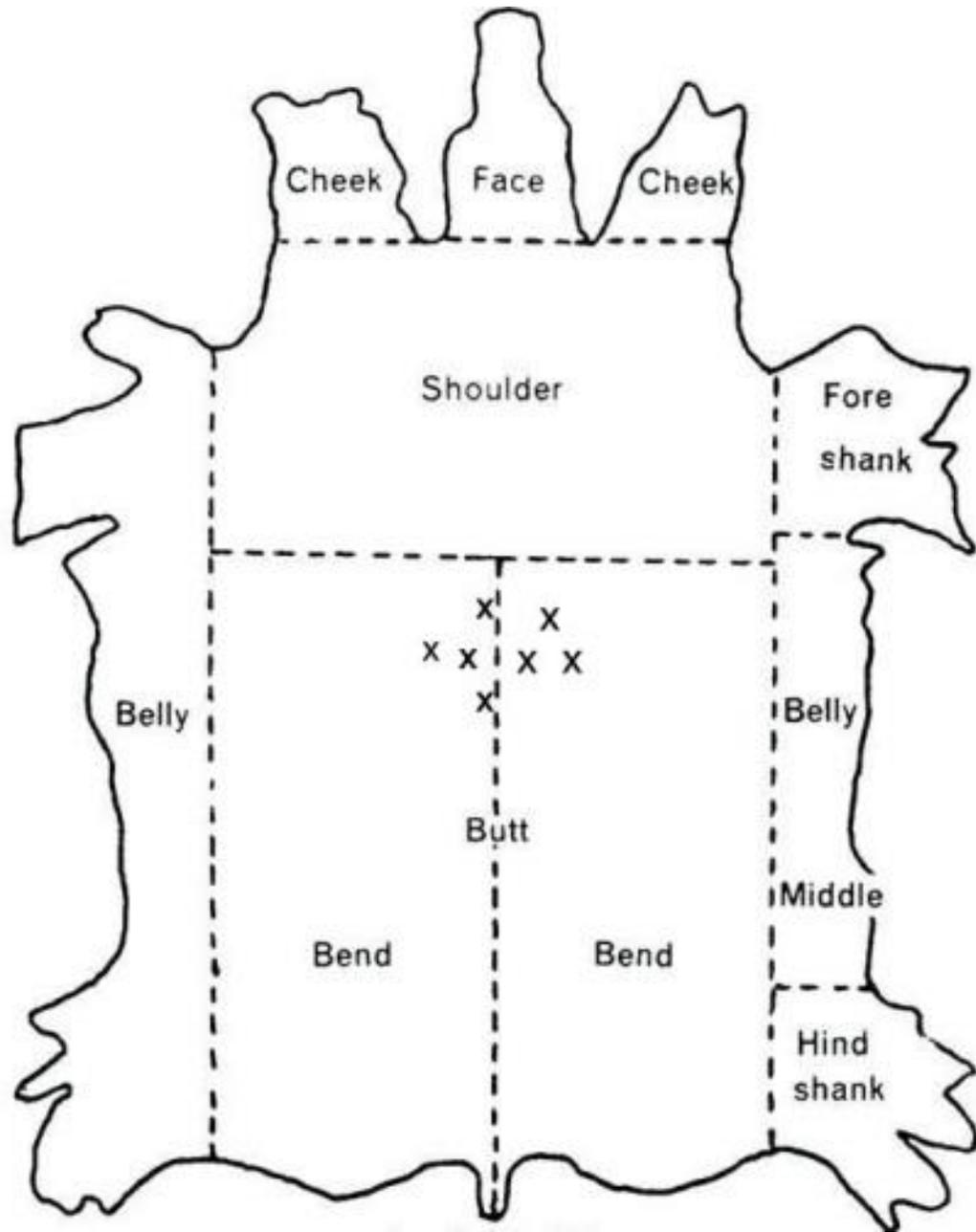
Appendix A

Animal 0015-017
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 18



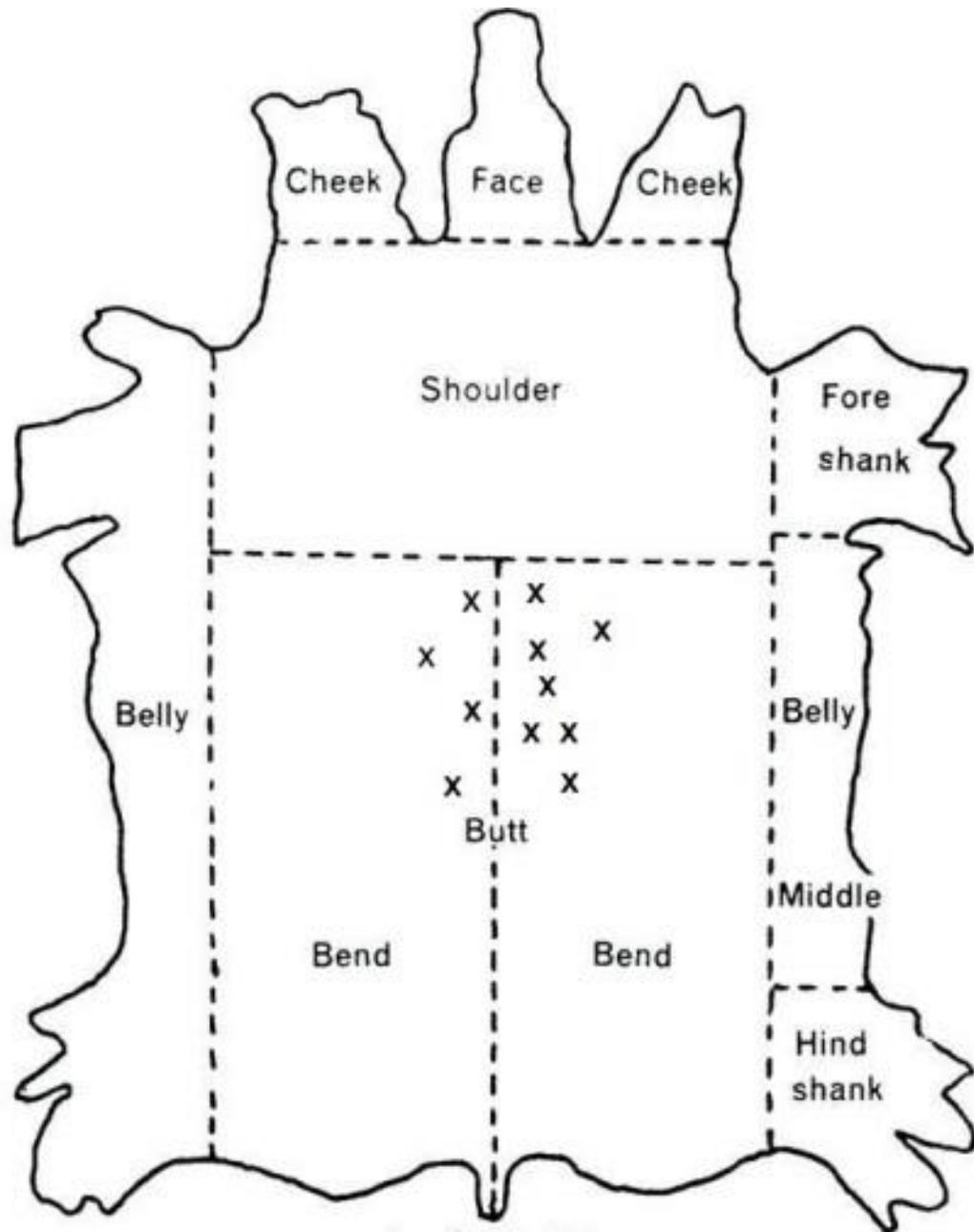
Appendix B

Animal 0015-018
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 21



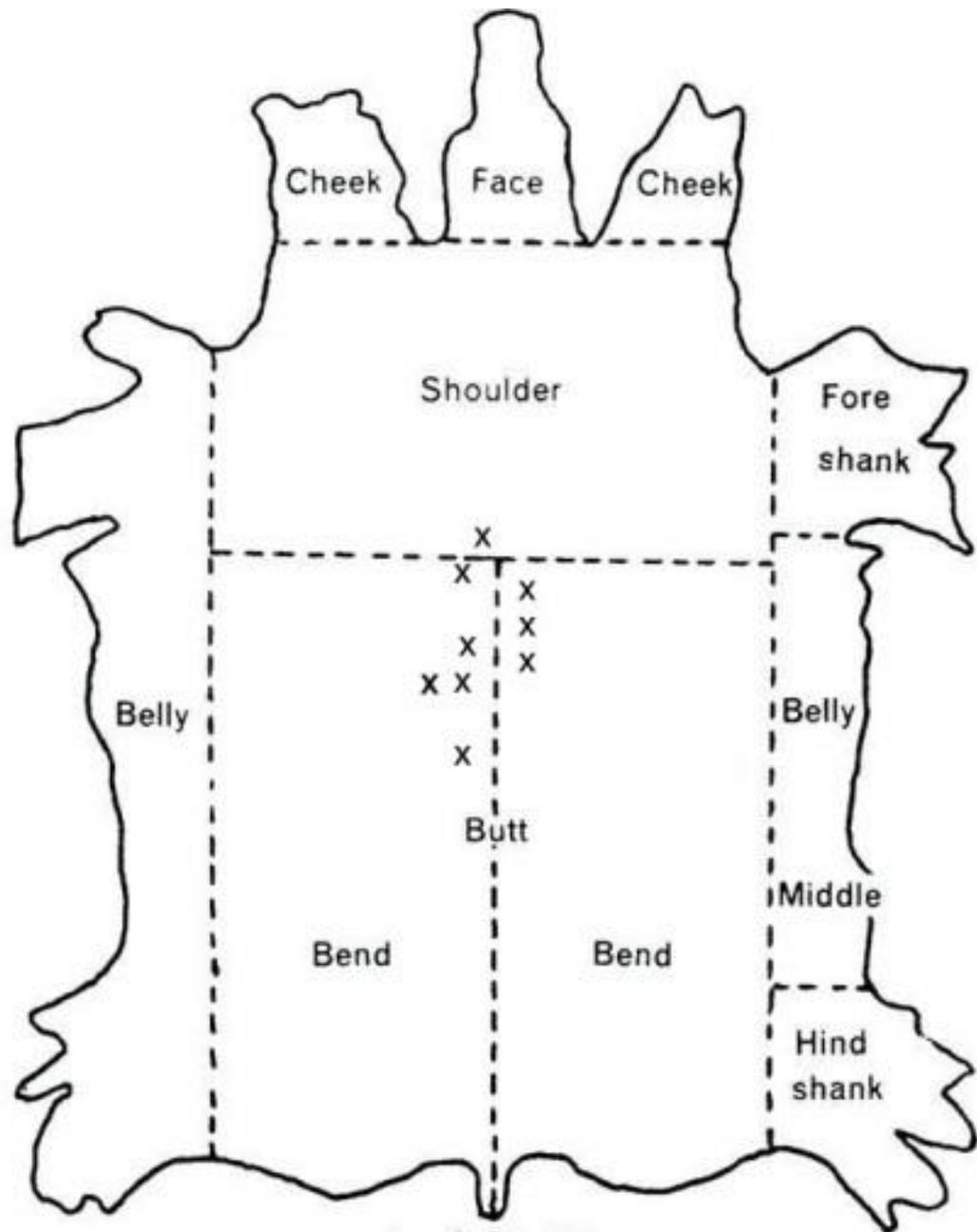
Appendix C

Animal 0015-019
 Date Slaughtered: 5 August 2015
 Total Grubs Palpatated: 7

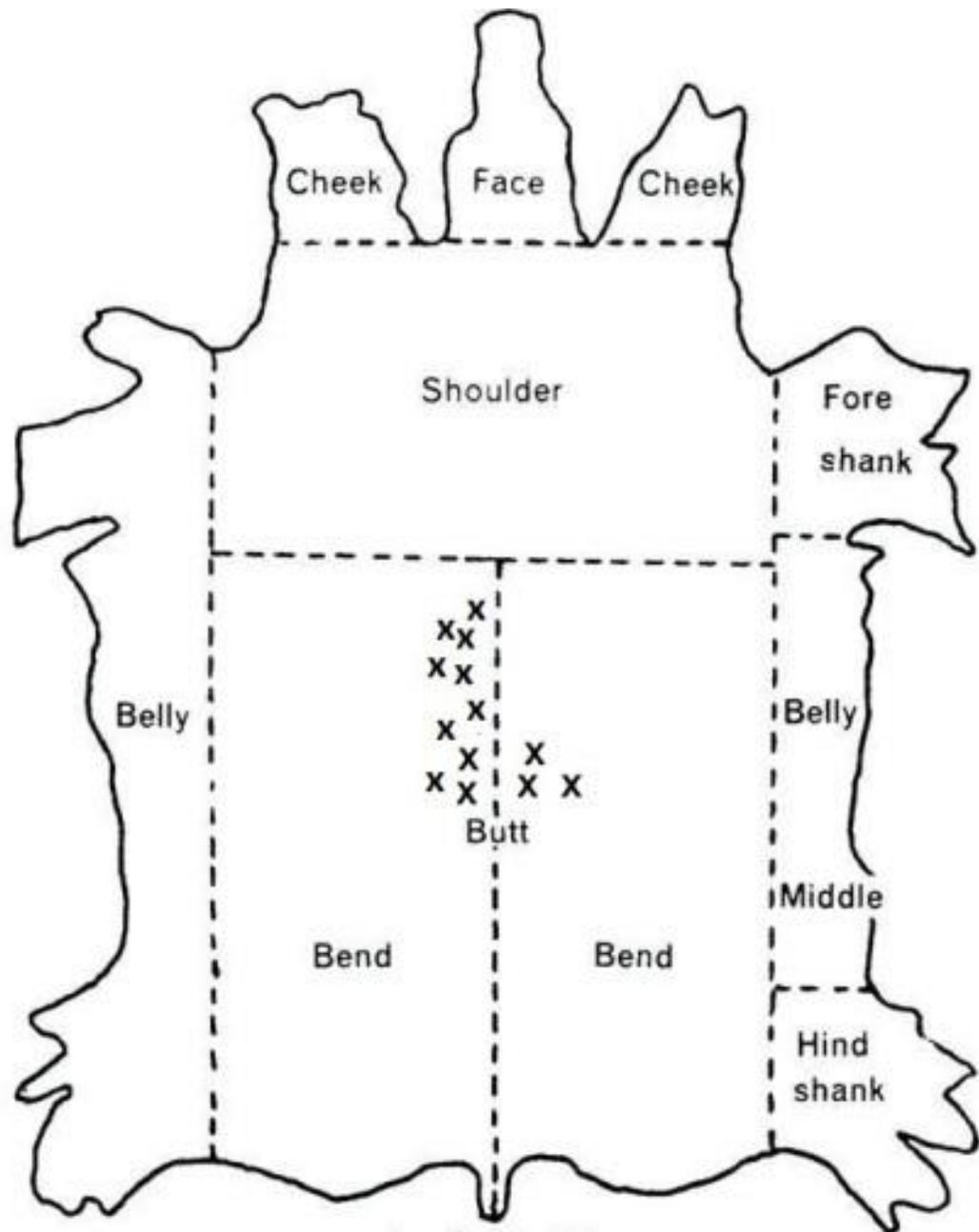


Appendix D

Animal 0015-020
 Date Slaughtered: 5 August 2015
 Total Grubs Palpatated: 11

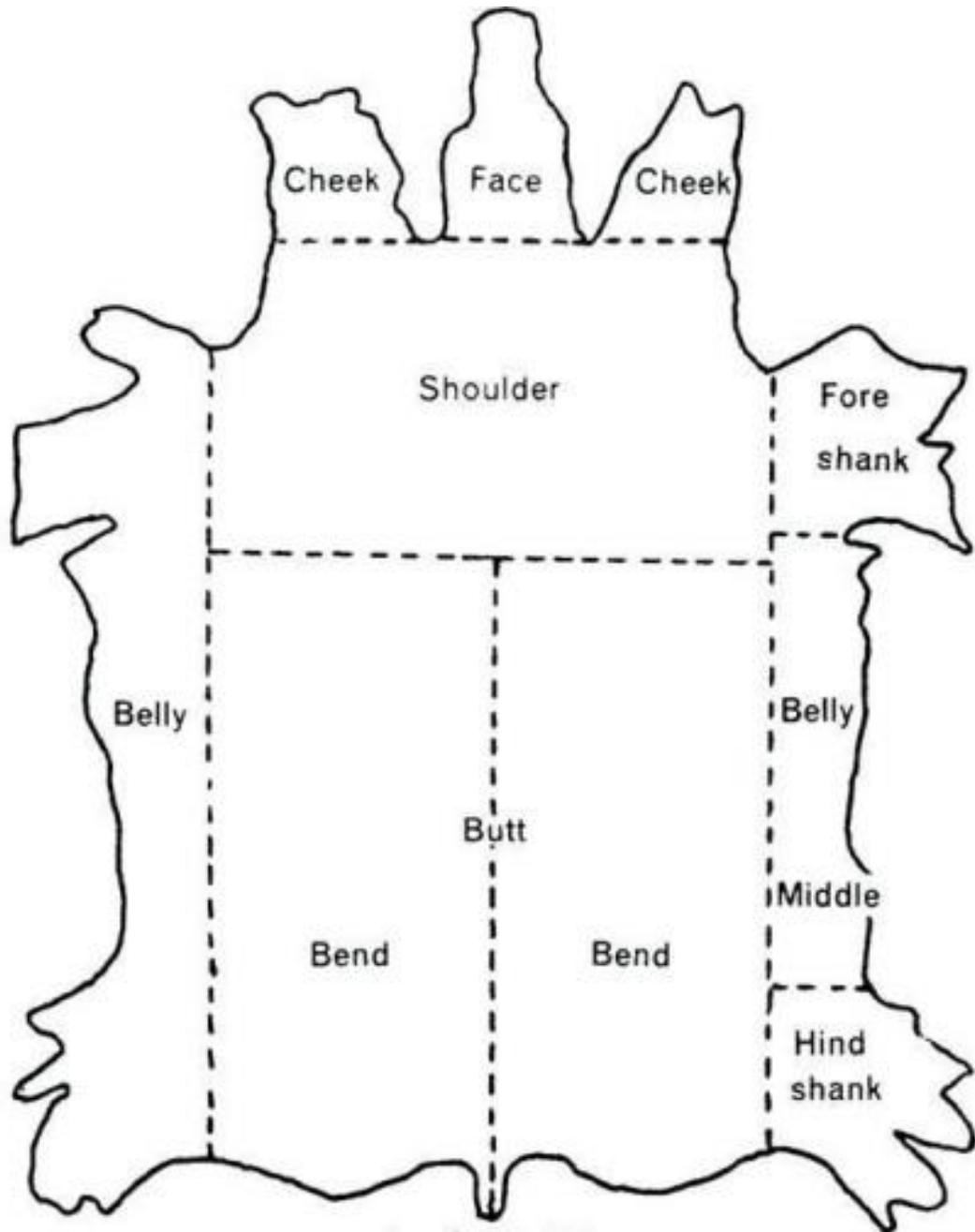


Appendix E Animal 0015-021
 Date Slaughtered: 2 December 2014 - Harvested at WTAMU Meat
 Laboratory
 Total Grubs Palpated: 9

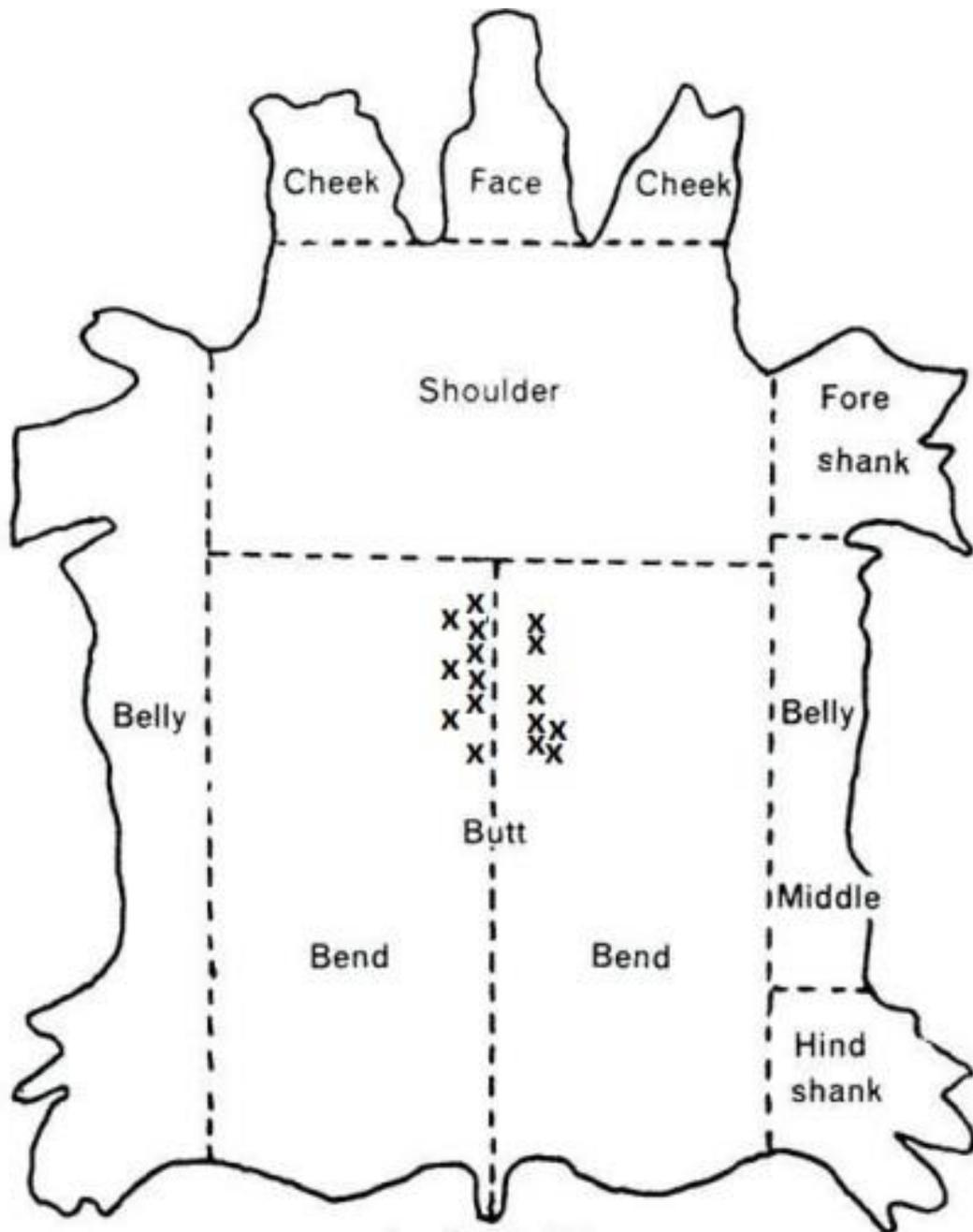


Appendix F

Animal 0015-022
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 13

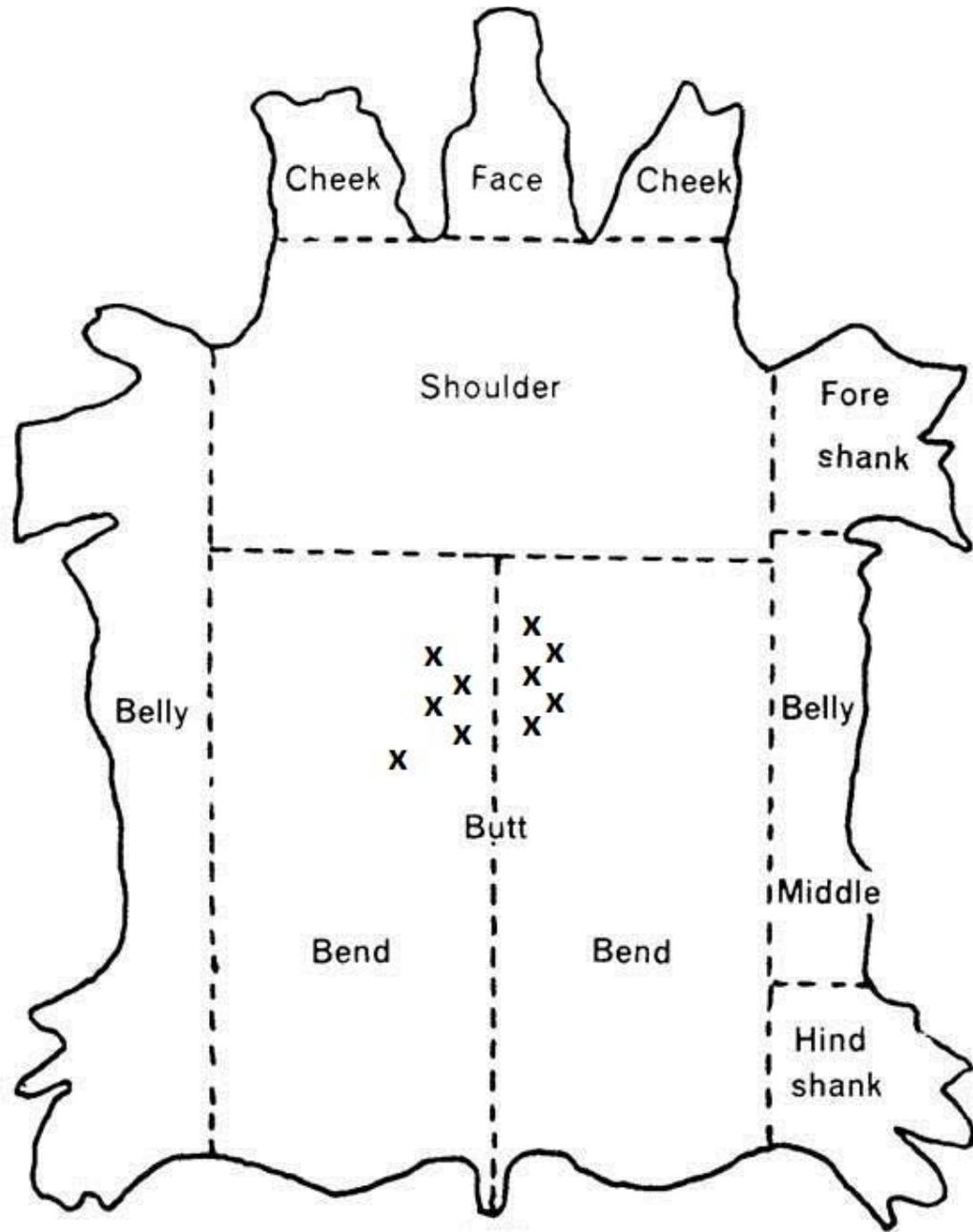


Appendix G Animal 0015-023
Date Slaughtered: N/A - Died 03 January 2015 – WTAMU Research Feedlot
Total Grubs Palpated: 0 – Ticks Present



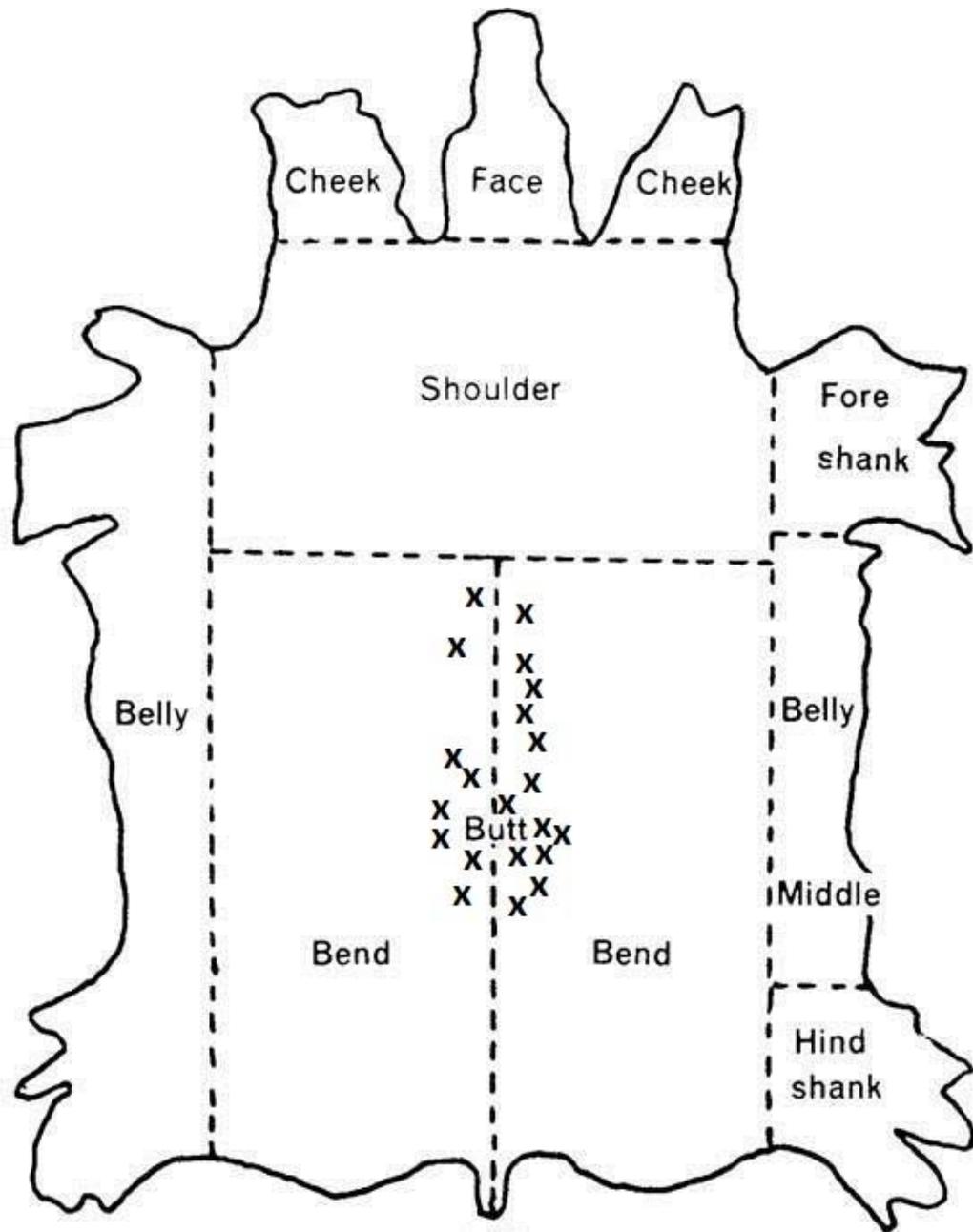
Appendix H

Animal 0015-024
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 16



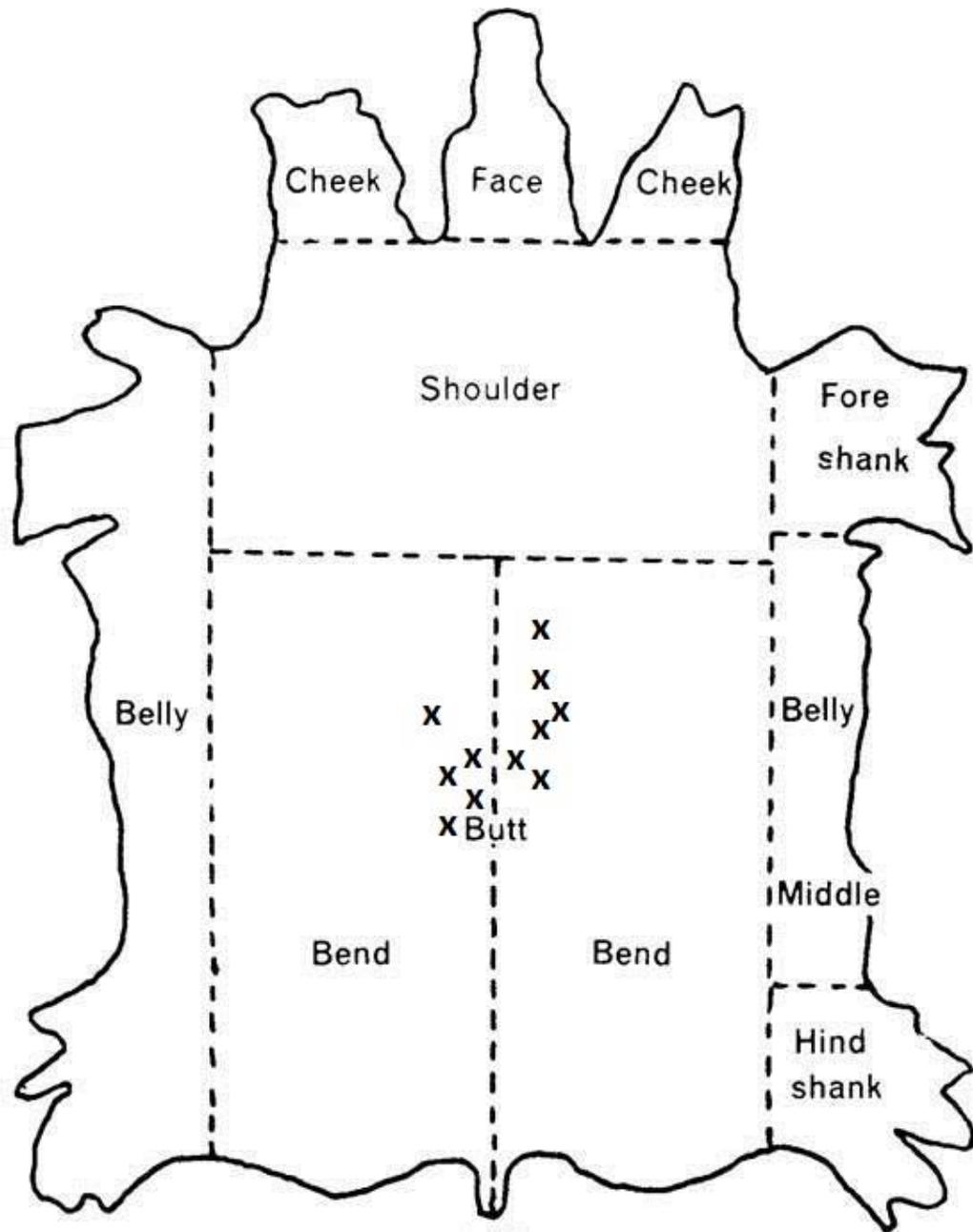
Appendix I

Animal 0016-037
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 10



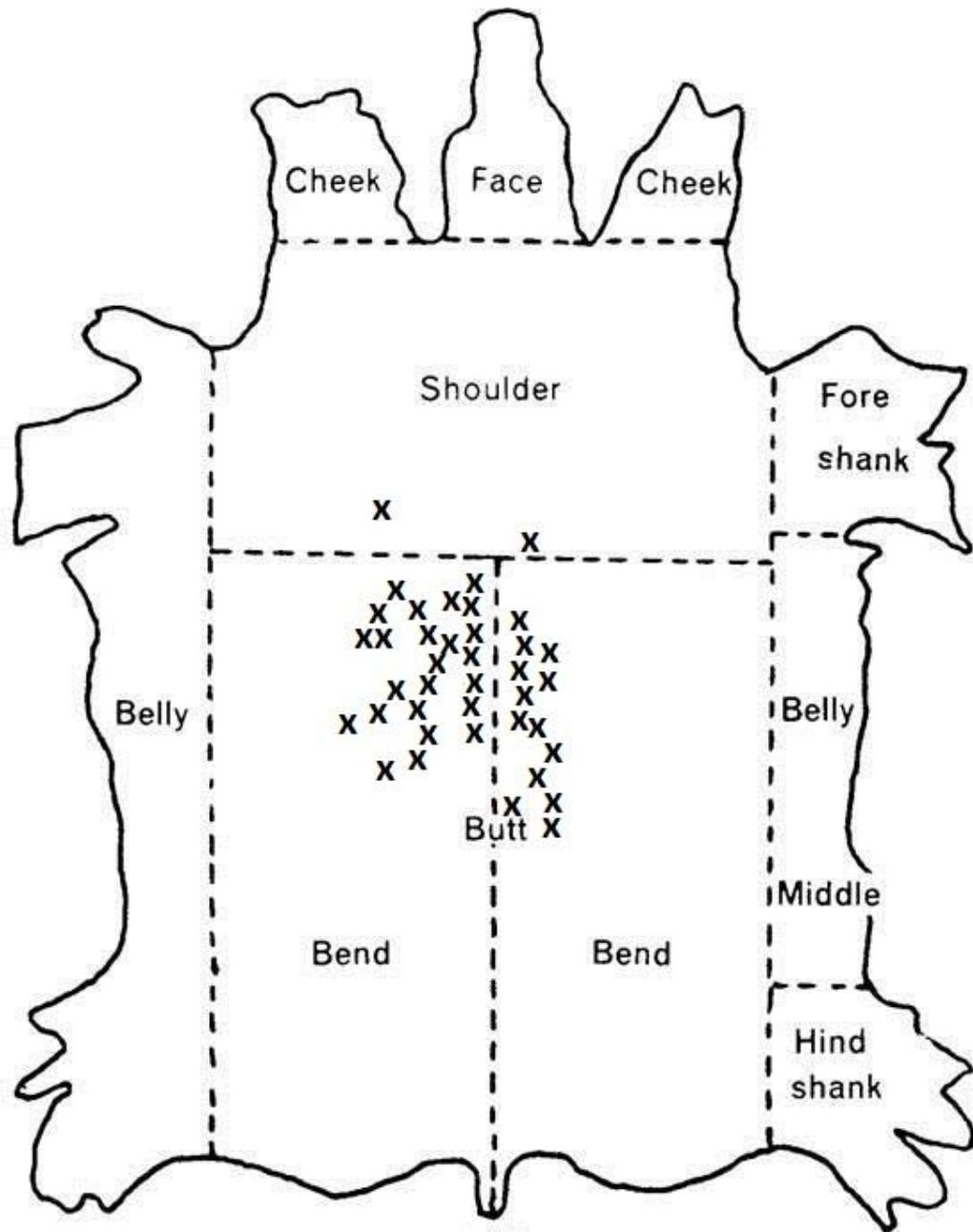
Appendix J

Animal 0016-038
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 21



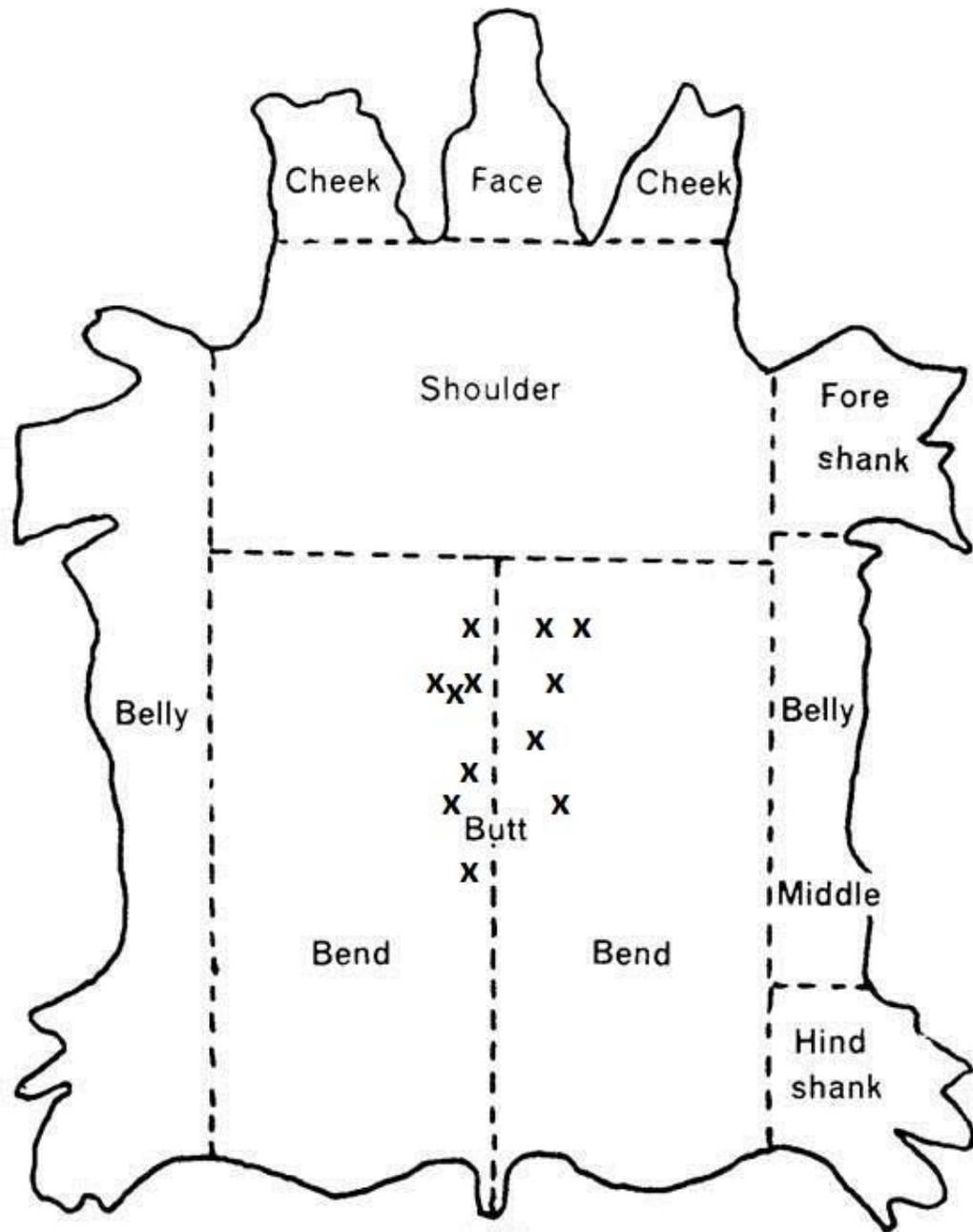
Appendix K

Animal 0016-039
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 11



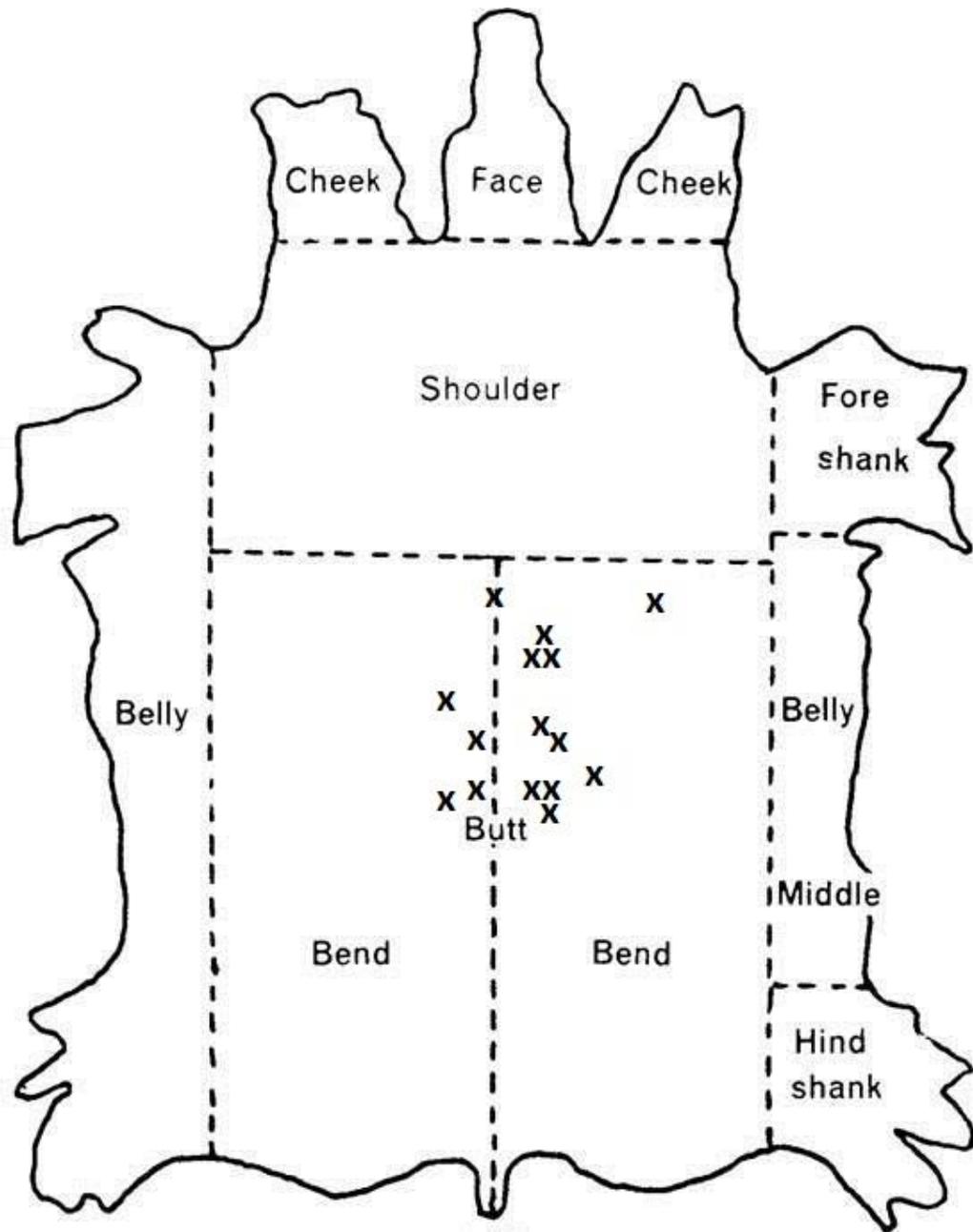
Appendix L

Animal 0016-040
 Date Slaughtered: 5 August 2015
 Total Grubs Palpatated: 39



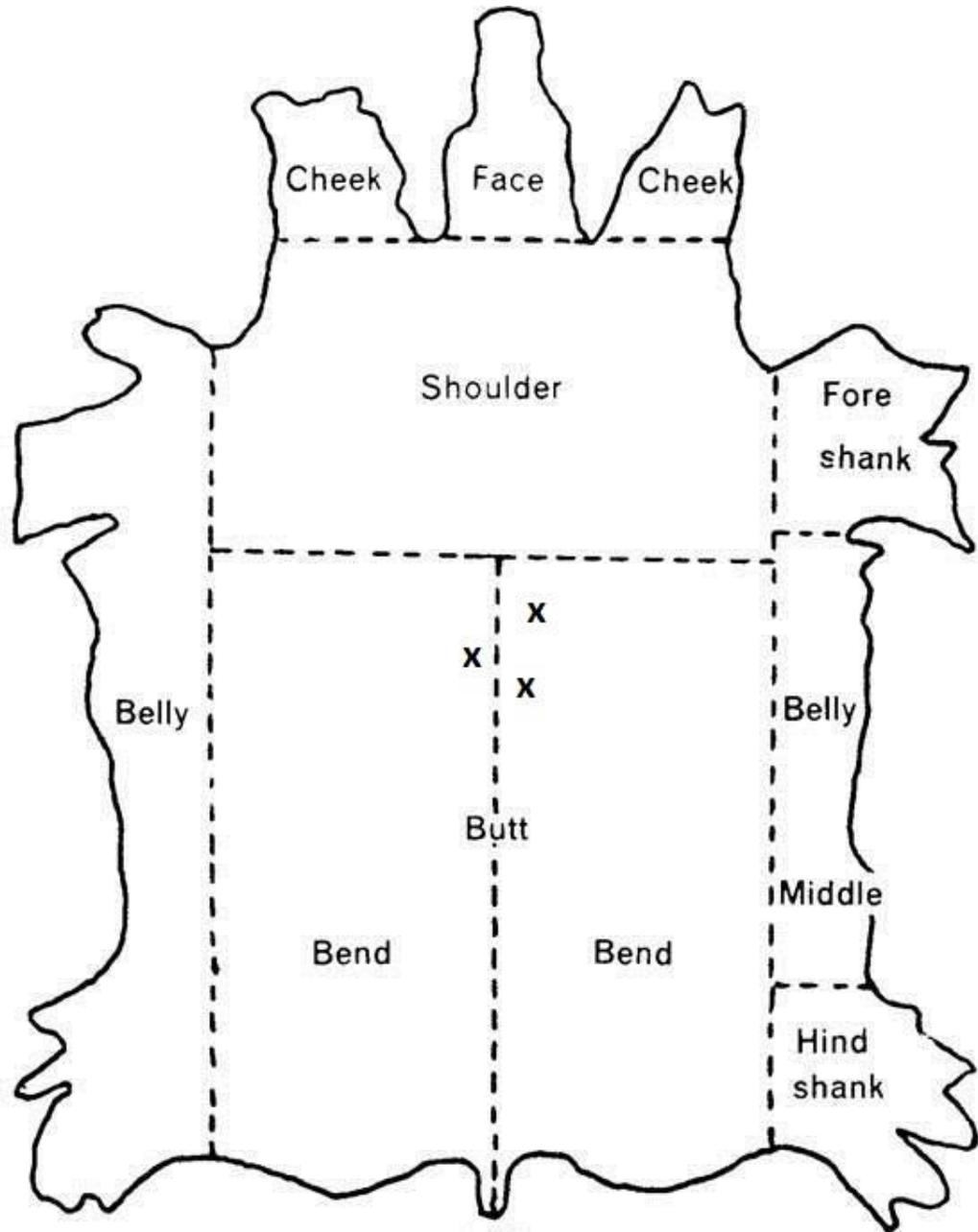
Appendix M

Animal 0016-041
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 12



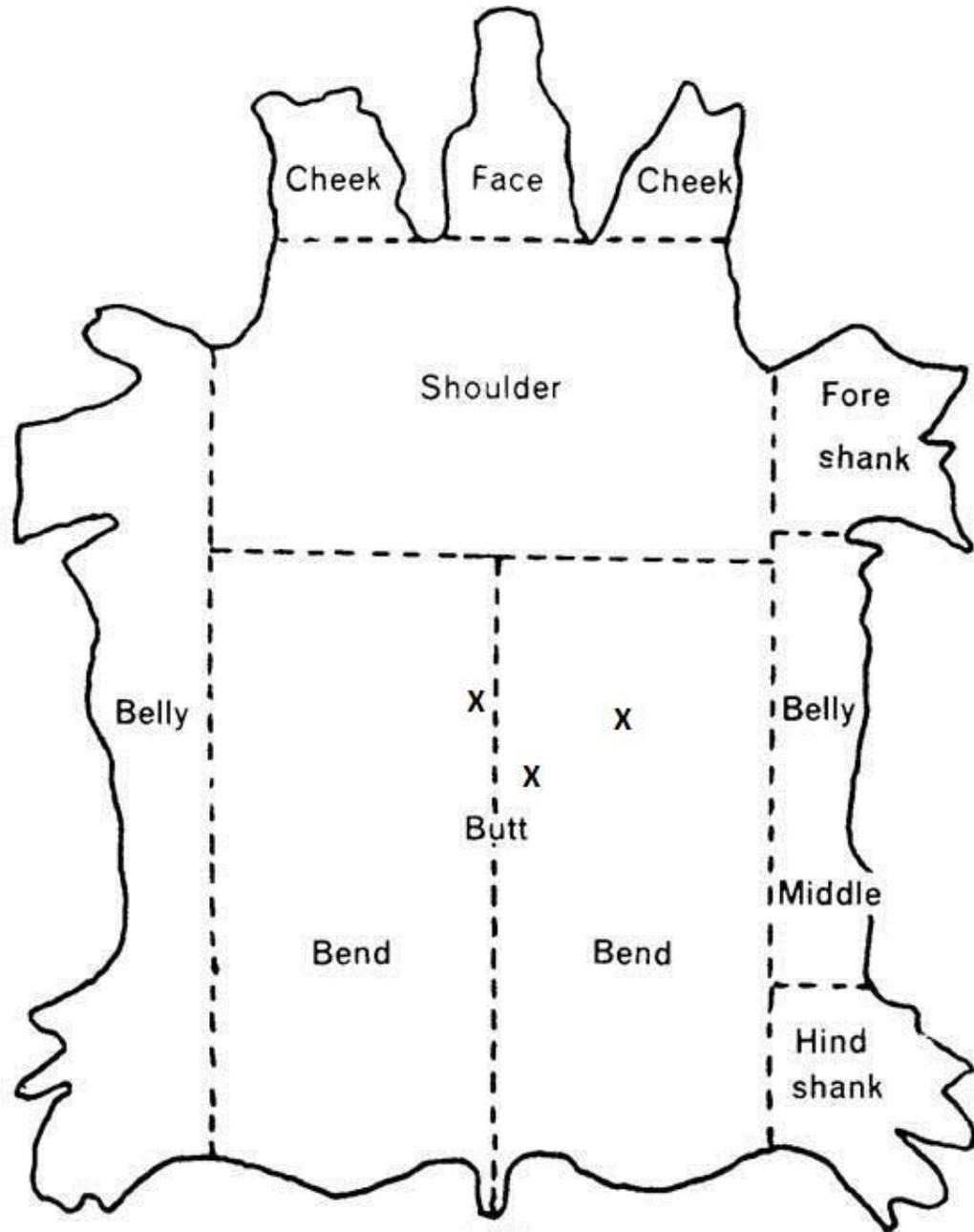
Appendix O

Animal 0016-043
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 15



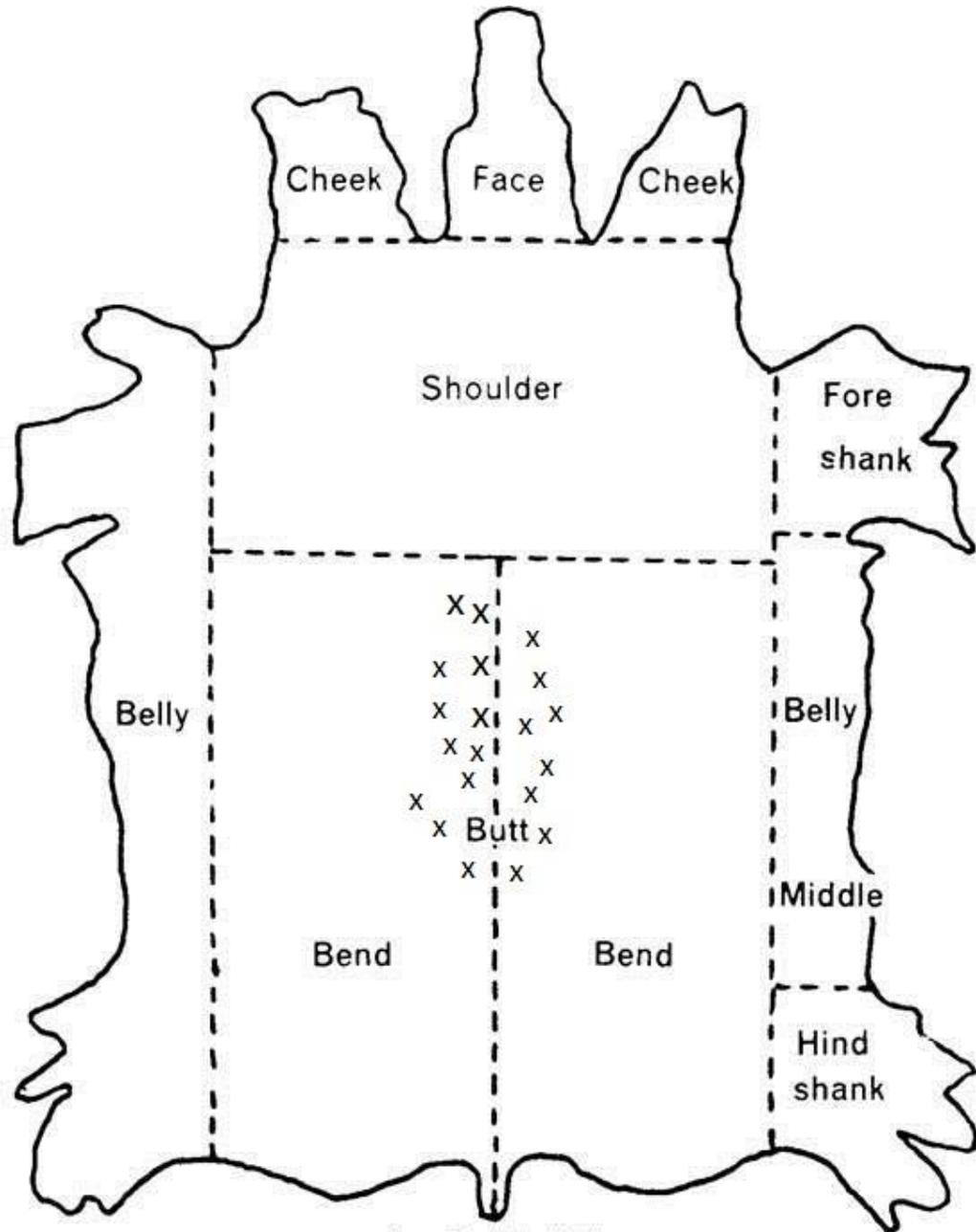
Appendix P

Animal 0016-044
Date Slaughtered: 7 July 2015
Total Grubs Palpatated: 3



Appendix Q

Animal 0017-017
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 3

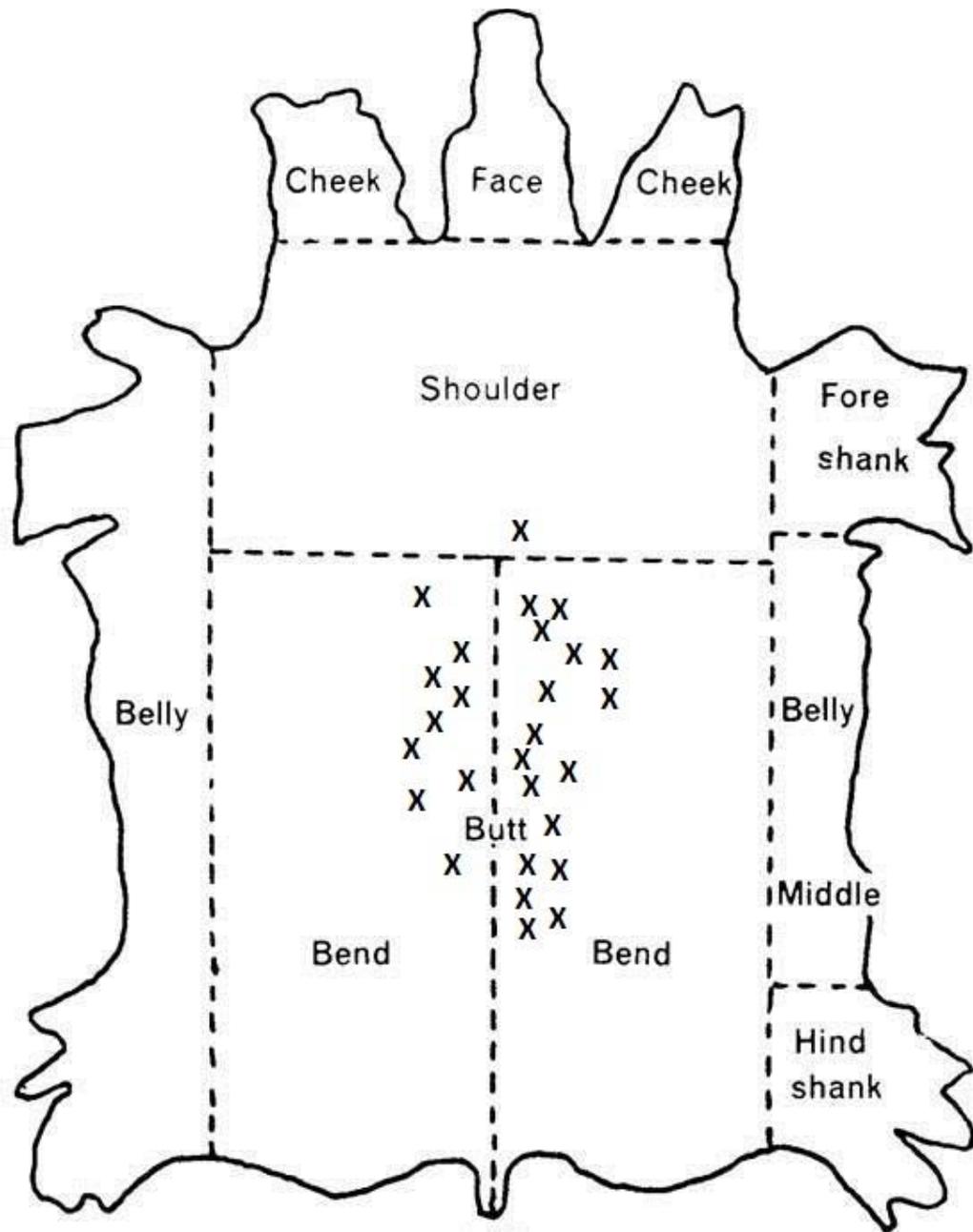


Appendix R

Animal 0017-018

Date Slaughtered: 2 December 2014 - Harvested at WTAMU Meat Laboratory

Total Grubs Palpated: 20

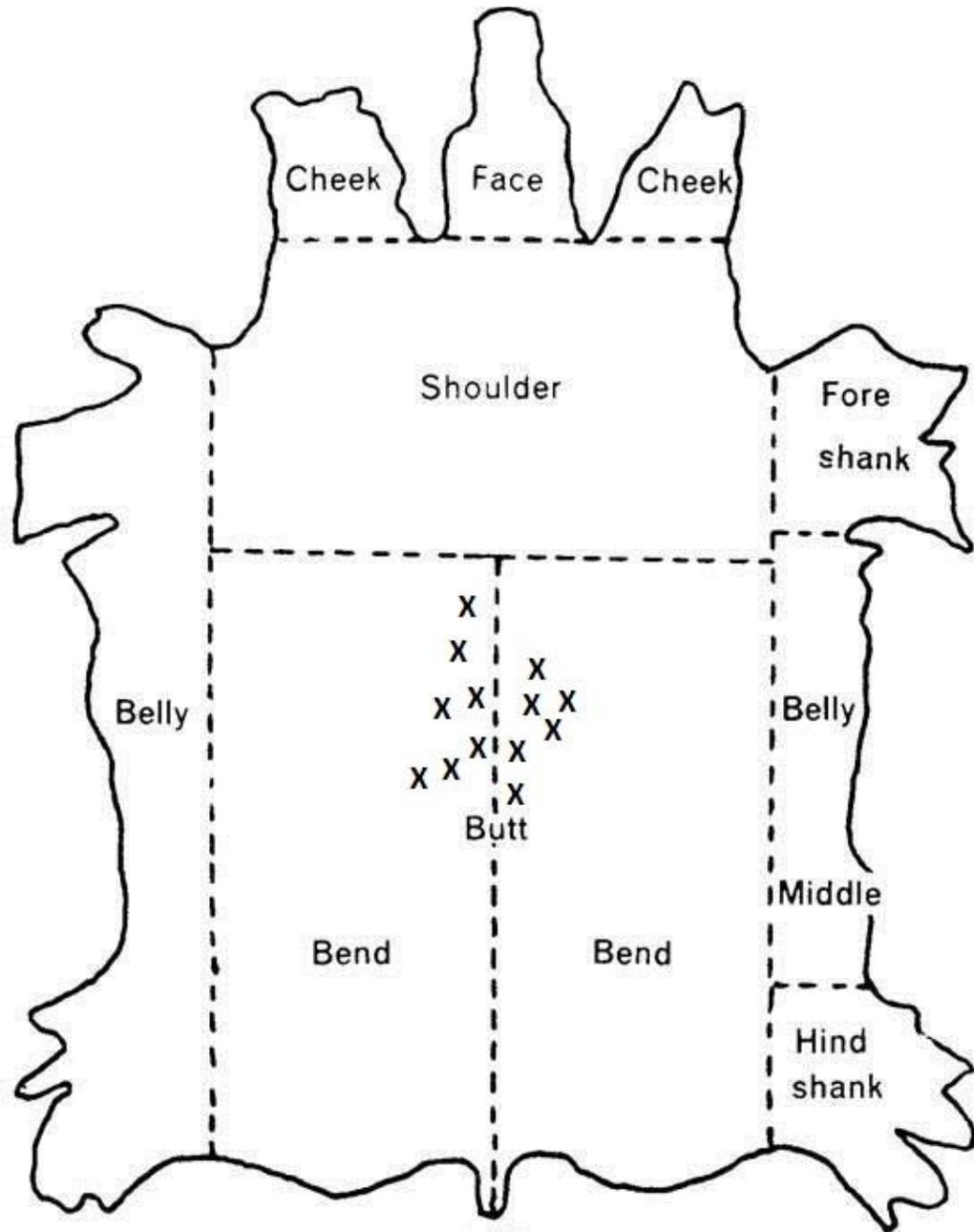


Appendix S

0017-019

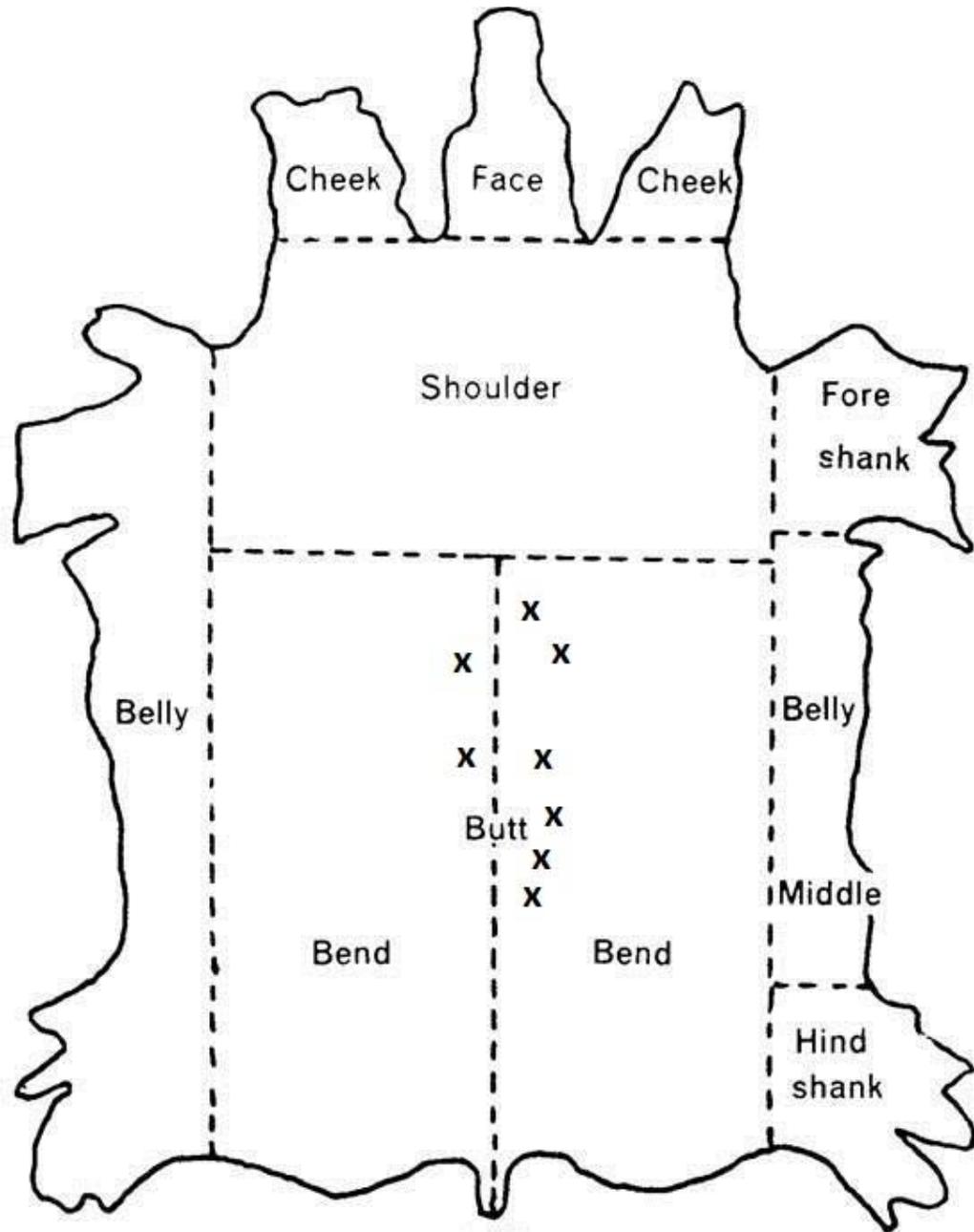
Date Slaughtered: 7 July 2015

Total Grubs Palpated: 27



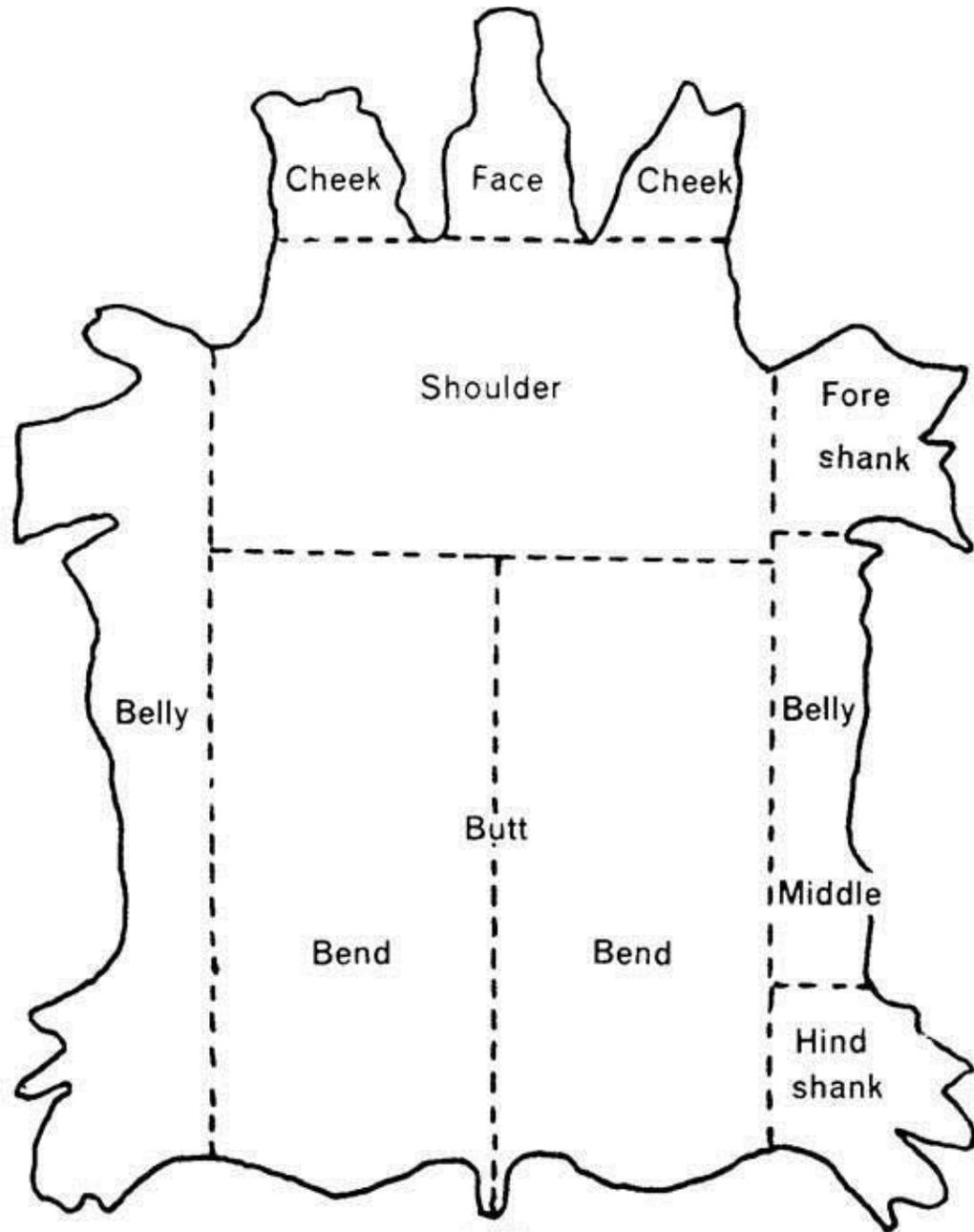
Appendix T

Animal 0017-020
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 13

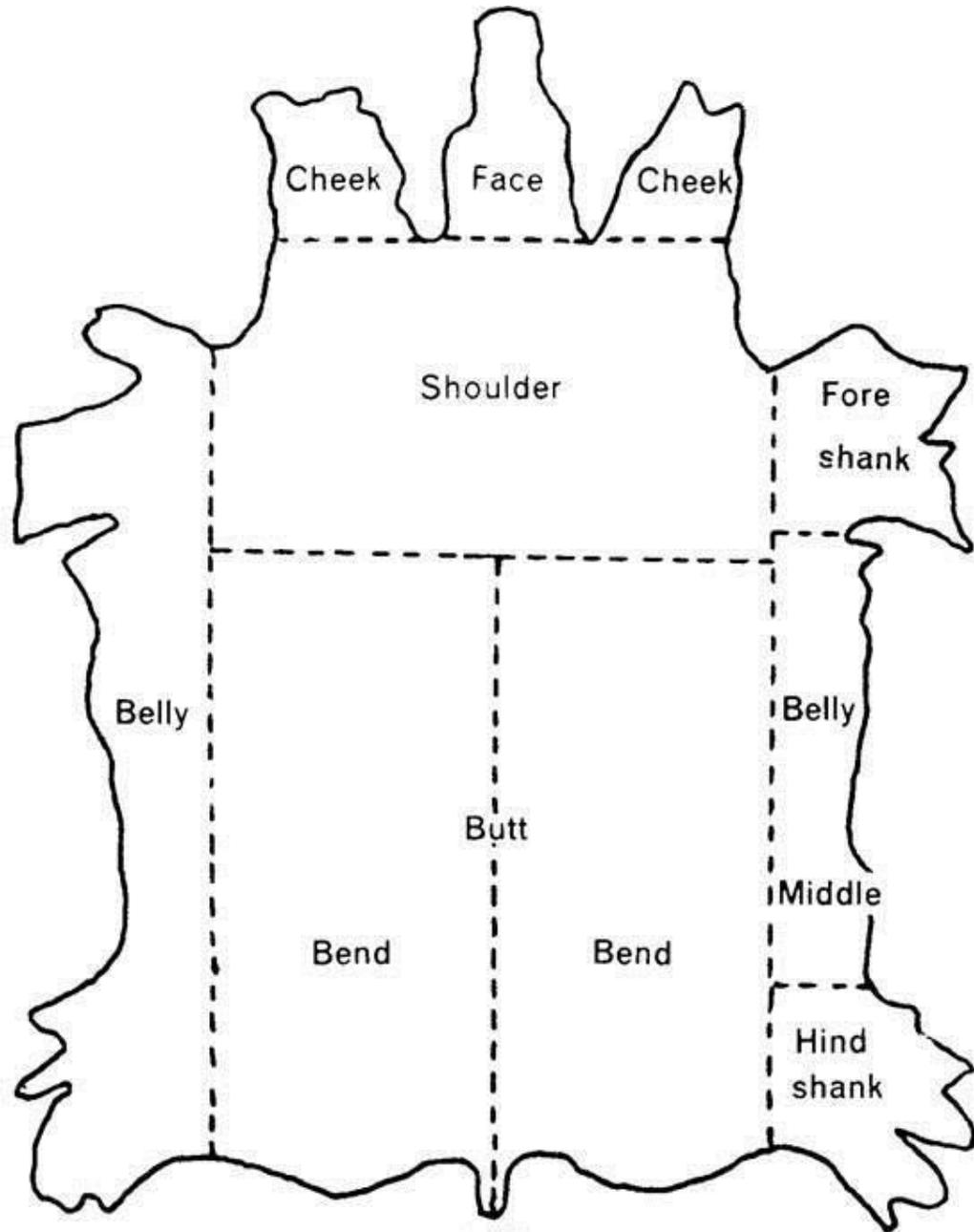


Appendix U

Animal 0017-021
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 8

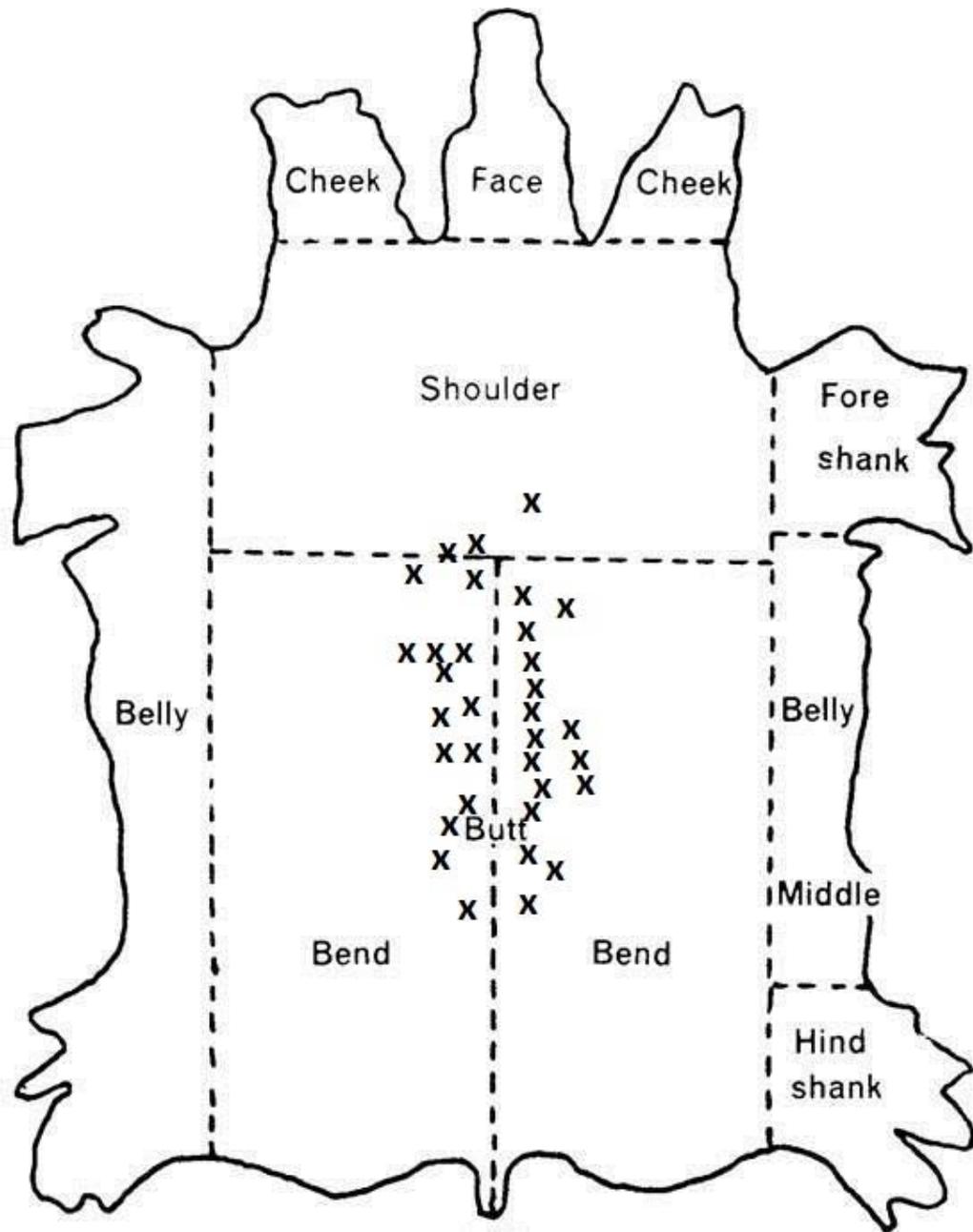


Appendix V Animal 0017-022
Date Slaughtered: N/A – Died 29 November 2014 – WTAMU Research
Feedlot
Total Grubs Palpated: 0



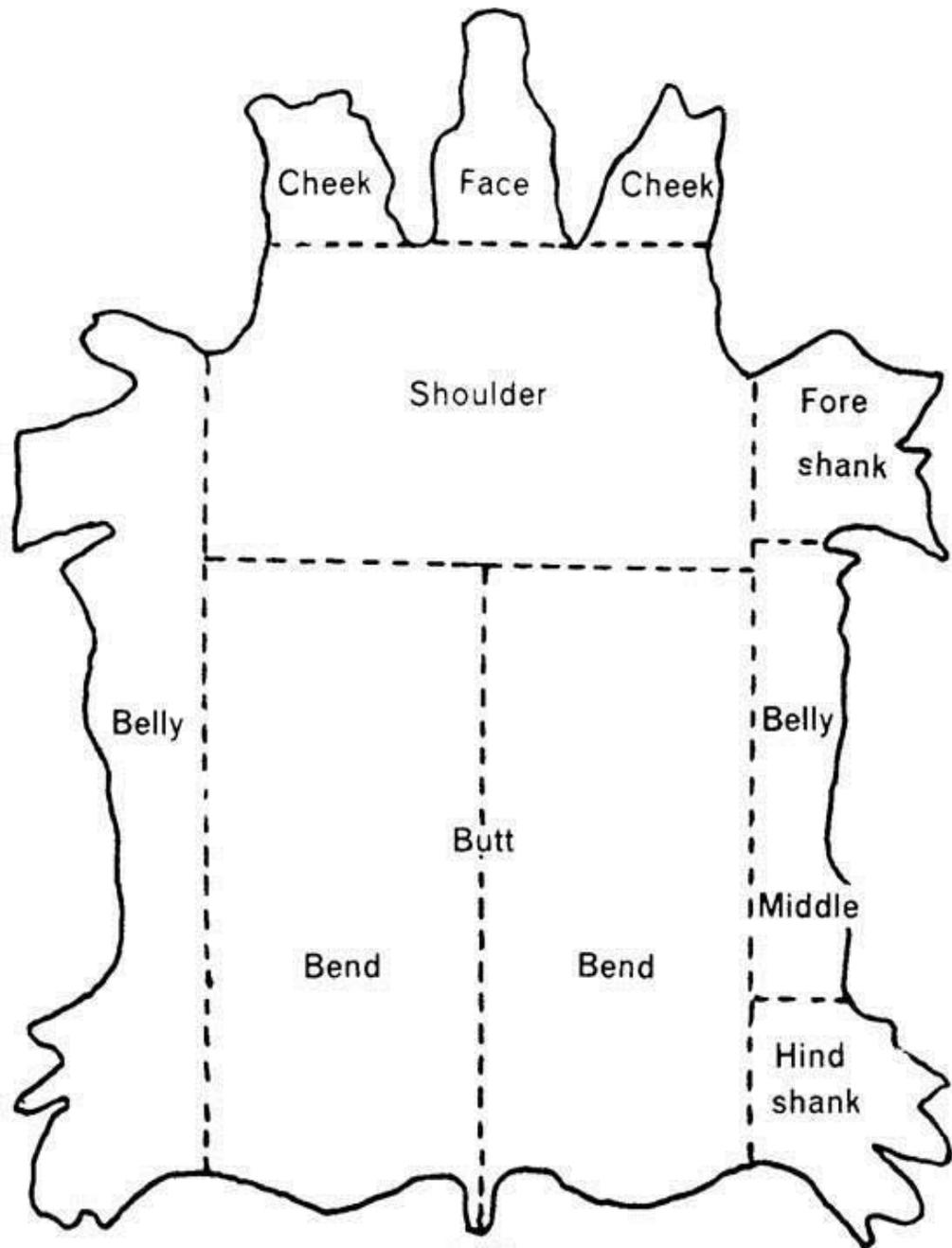
Appendix W

Animal 0017-023
Date Slaughtered: 7 July 2015
Total Grubs Palpated: 0



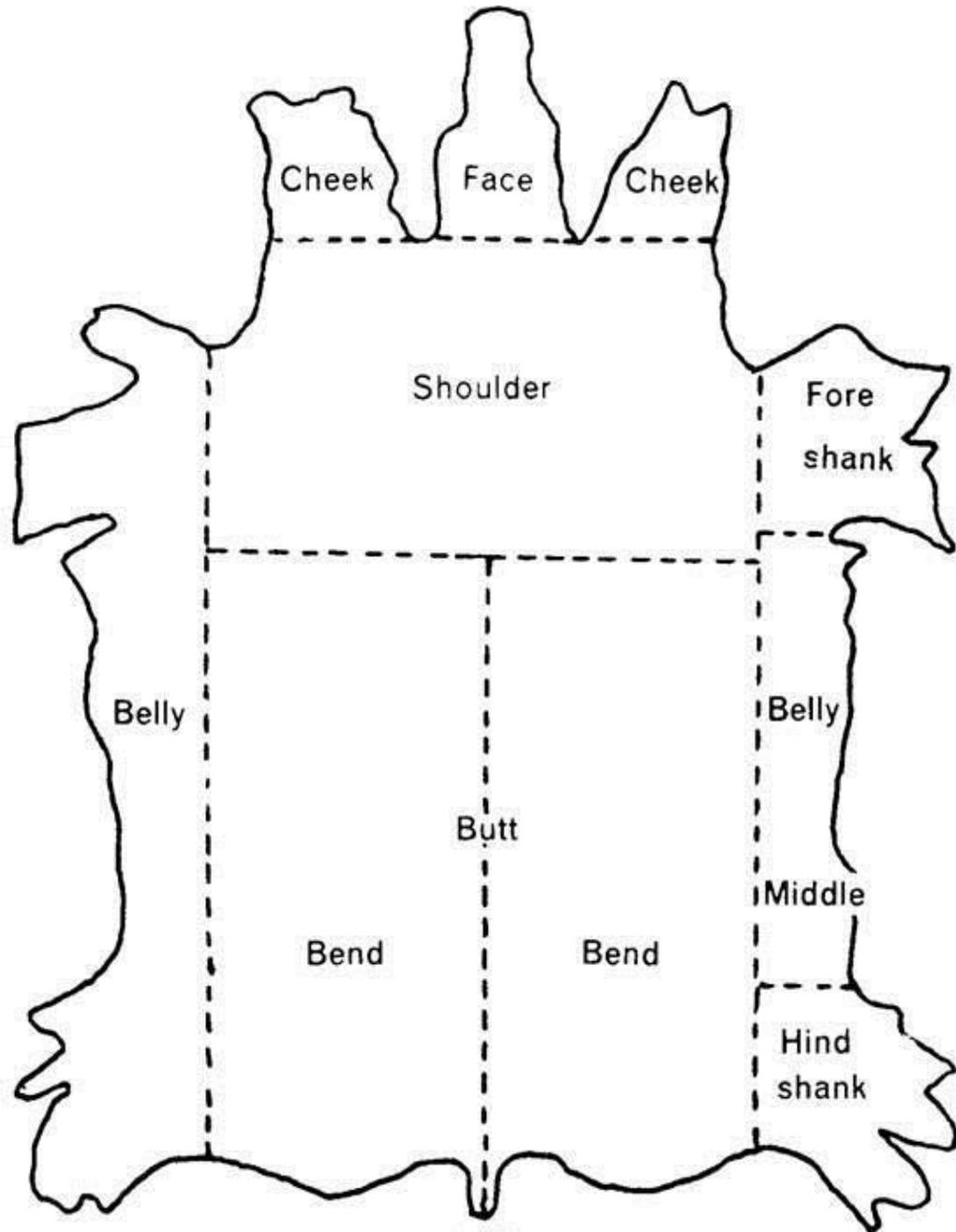
Appendix X

Animal 0017-024
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 33



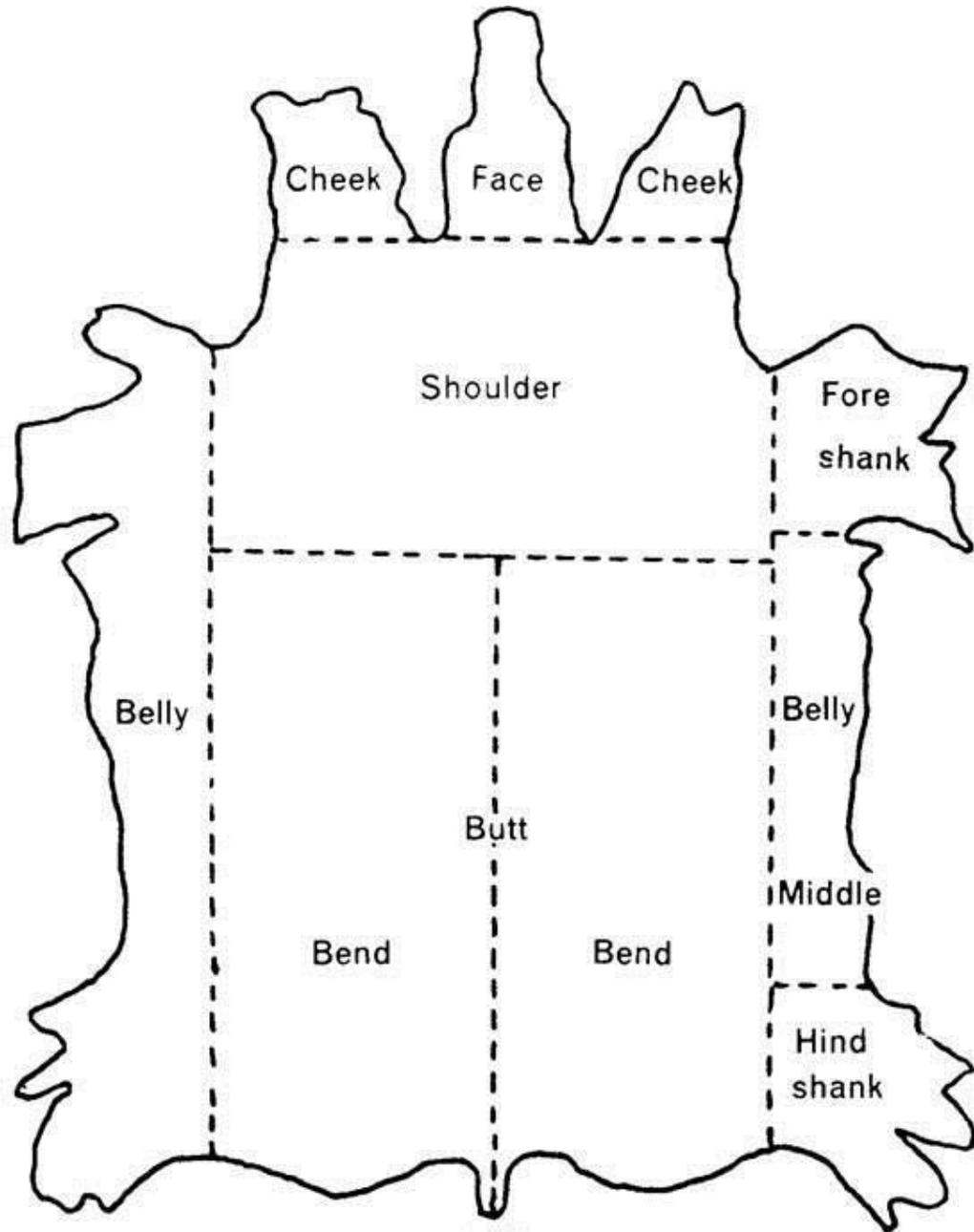
Appendix Y

Animal 0018-031
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 0



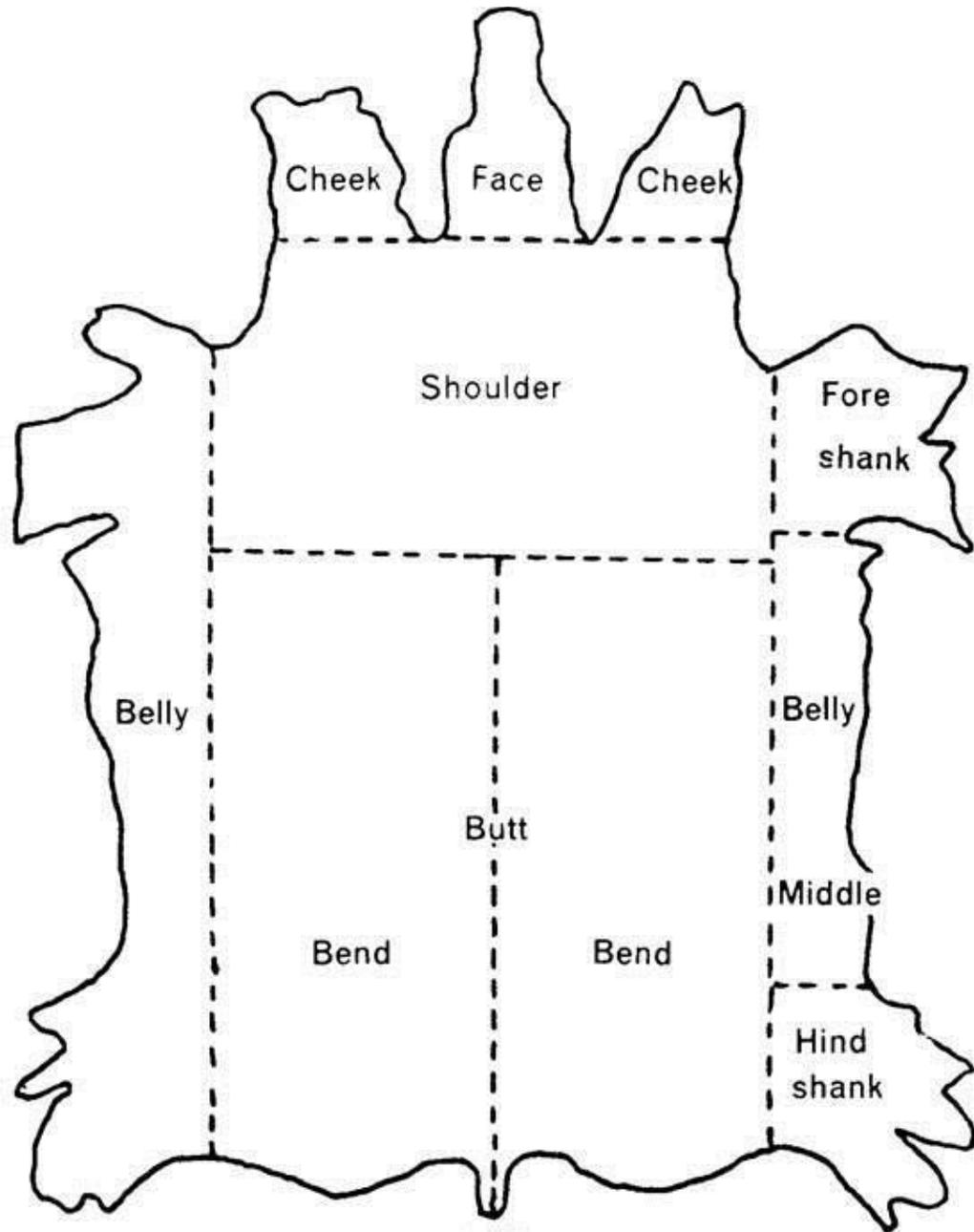
Appendix Z

Animal 0018-032
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 0



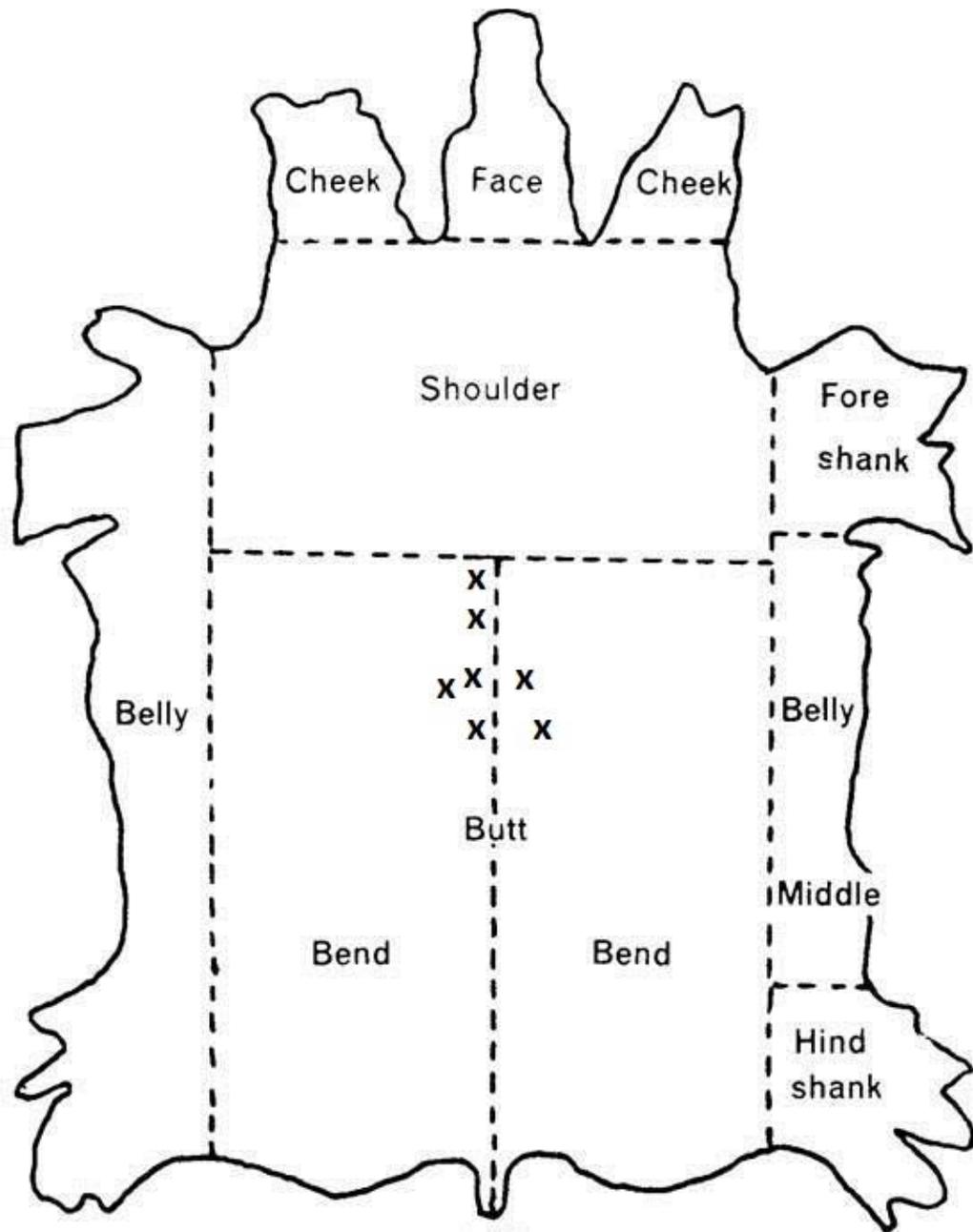
Appendix AA

Animal 0018-033
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 0



Appendix BB

Animal 0018-034
Date Slaughtered: 5 August 2015
Total Grubs Palpated: 0

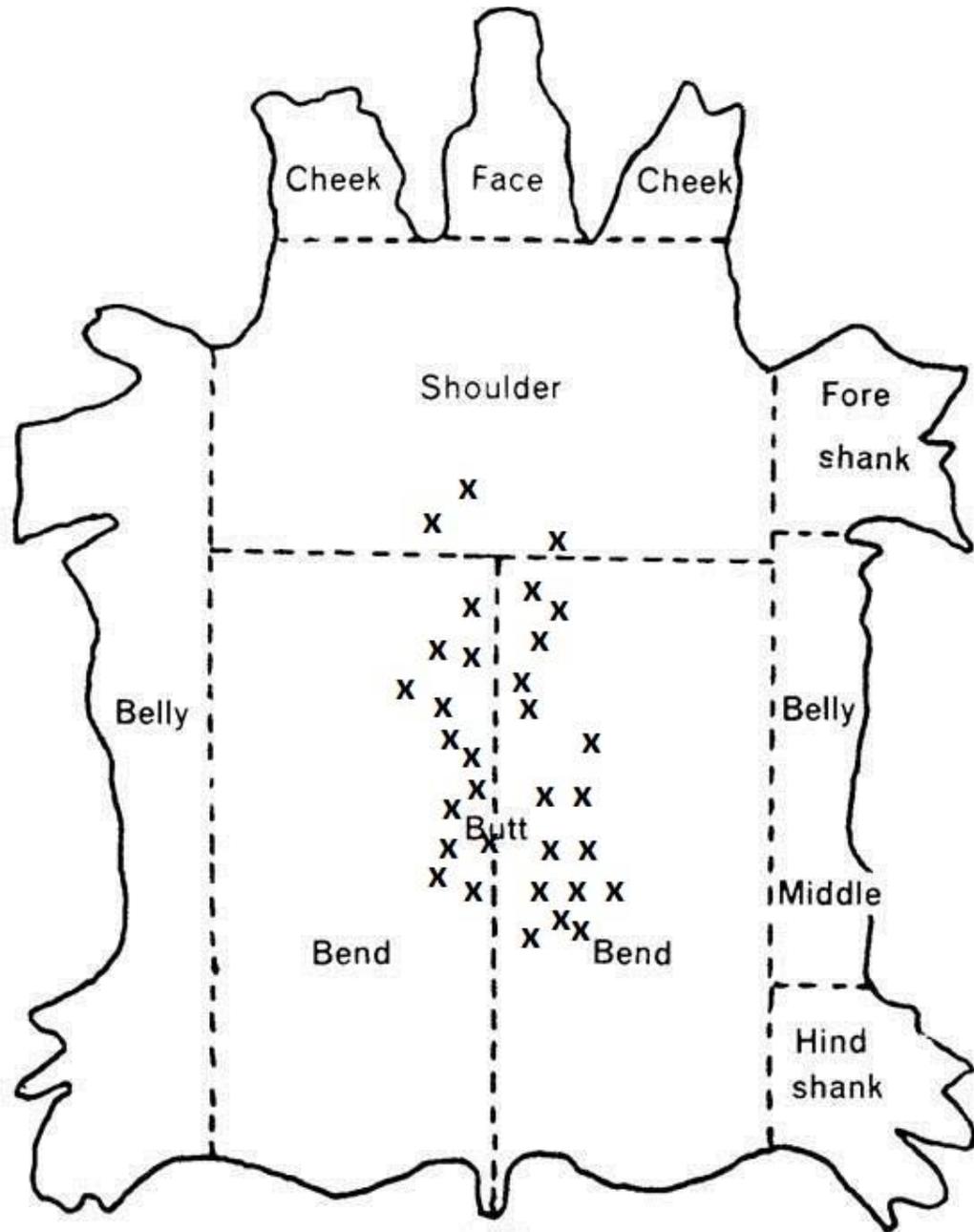


Appendix CC

Animal 0018-035

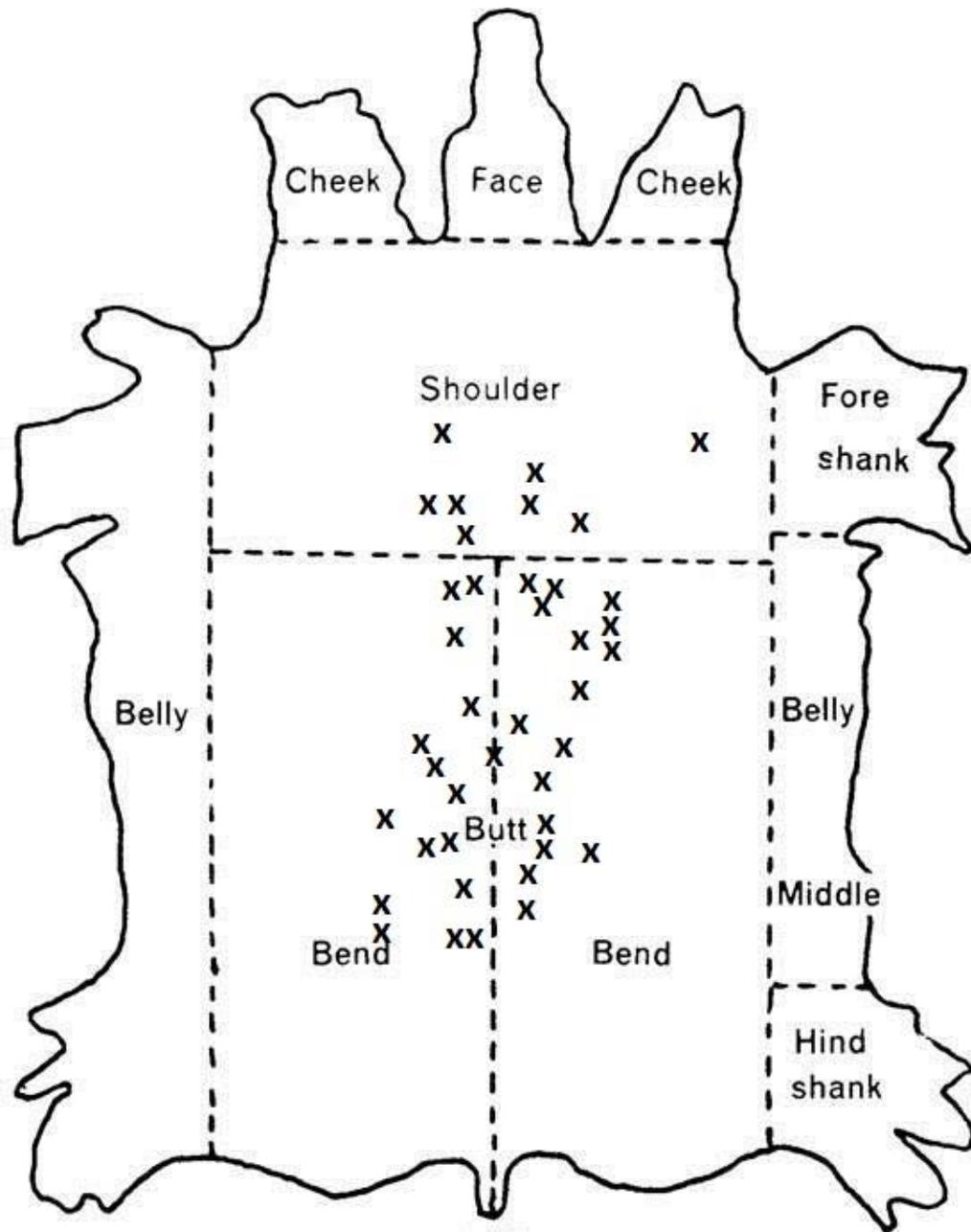
Date Slaughtered: 5 August 2015

Total Grubs Palpated: 7



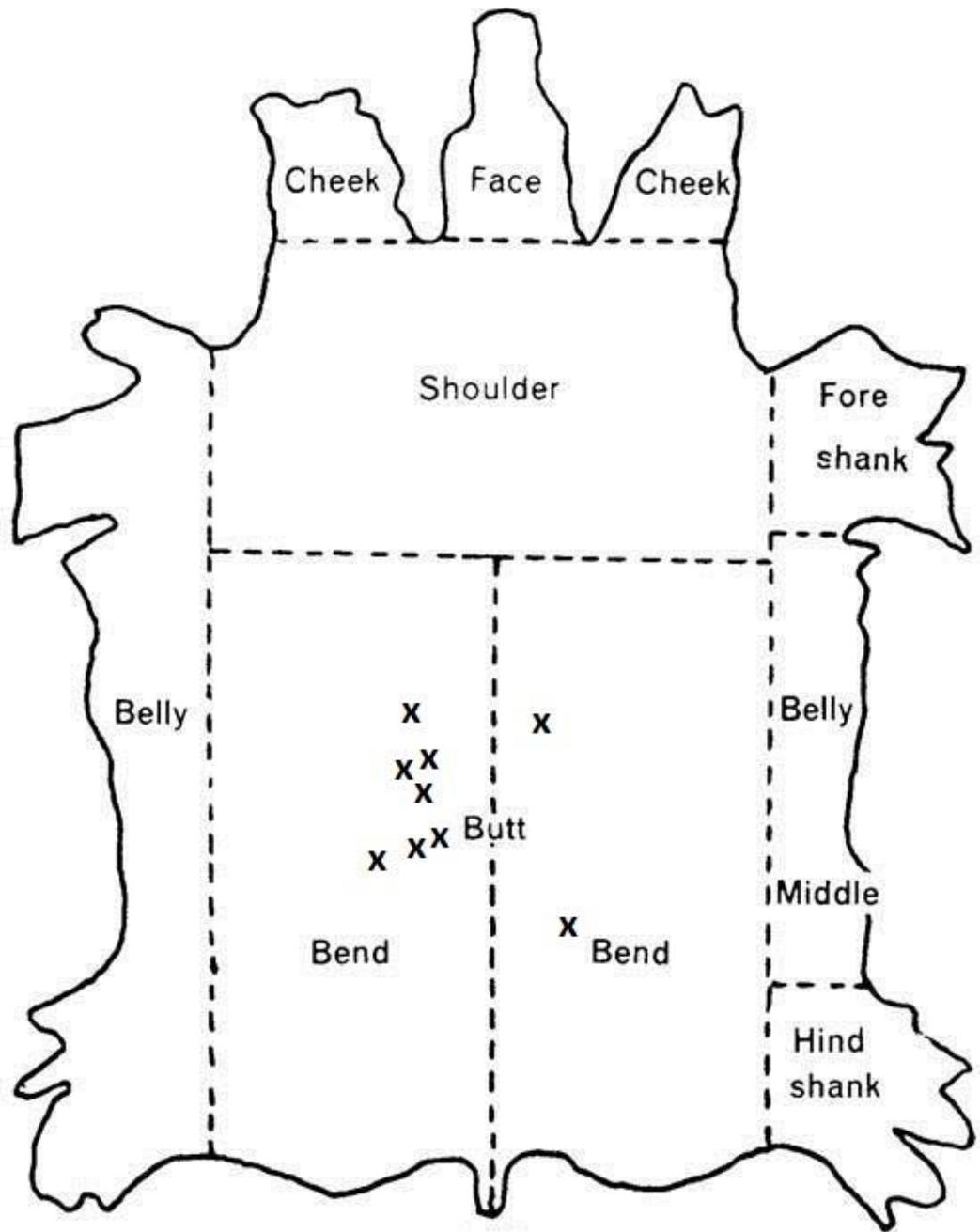
Appendix DD

Animal 0018-036
 Date Slaughtered: 7 July 2015
 Total Grubs Palpated: 32



Appendix EE

Animal 0018-037
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 40



Appendix FF

Animal 0018-038
 Date Slaughtered: 5 August 2015
 Total Grubs Palpated: 9

Lot-ET	14-Nov-14	26-Nov-14	24-Dec-14	23-Jan-15	18-Feb-15	18-Mar-15	15-Apr-15	13-May-15	10-Jun-15	6-Jul-15	8-Jul-15	5-Aug-15
0015-017	615	680	794	909	1003	1119	1260	1350	1426	1426	HARVEST 1	
0015-018	757	763	864	949	1038	1105	1240	1329	1409	1409	HARVEST 1	
0015-019	624	633	701	752	843	903	1011	1106	1184		1289	1289
0015-020	675	690	764	852	966	1039	1175	1285	1334		1459	1459
0015-021	519	560	HARVESTED ML									
0015-022	662	634	719	791	851	902	1006	1082	1158		1215	1215
0015-023	518	541	393	DIED 03 JAN 2015								
0015-024	703	720	834	958	1018	1089	1204	1307	1412	1412	HARVEST 1	
0016-037	580	601	715	819	920	1002	1119	1221	1315		1405	1405
0016-038	576	580	700	793	790	895	1003	1093	1175		1237	1237
0016-039	779	760	891	989	1057	1137	1254	1328	1418	1418	HARVEST 1	
0016-040	556	555	642	724	798	868	965	1063	1143		1244	1244
0016-041	602	613	746	833	951	1040	1207	1286	1335		1440	1440
0016-042	571	632	728	821	915	997	1104	1222	1271		1379	1379
0016-043	708	707	769	834	919	1018	1153	1264	1340		1464	1464
0016-044	693	732	876	959	1039	1118	1245	1341	1399	1399	HARVEST 1	
0017-017	618	639	724	839	927	1007	1027	1217	1259		1323	1323
0017-018	756	782	HARVESTED ML									
0017-019	700	745	855	971	1076	1176	1315	1415	1495	1495	HARVEST 1	
0017-020	653	688	803	840	919	986	1103	1164	1258		1344	1344
0017-021	595	615	715	876	986	1104	1231	1337	1435	1435	HARVEST 1	
0017-022	641	675	DIED 29 NOV 14									
0017-023	697	773	948	1088	1183	1284	1450	1556	1637	1637	HARVEST 1	
0017-024	612	639	754	866	961	1033	1154	1261	1328		1422	1422
0018-031	641	641	647	771	866	981	1120	1247	1325		1444	1444
0018-032	633	643	747	851	927	1012	1121	1225	1304		1378	1378
0018-033	581	617	714	794	901	960	1073	1162	1256		1360	1360
0018-034	562	677	660	728	818	902	1020	1108	1185		1301	1301
0018-035	602	613	719	826	901	980	1109	1215	1296		1417	1417
0018-036	658	684	755	870	982	1080	1220	1348	1392	1392	HARVEST 1	
0018-037	576	587	688	820	921	1016	1115	1229	1311		1455	1455
0018-038	777	800	806	853	916	993	1098	1203	1302		1402	1402

Appendix GG

LOT/ET	GRUB CONDITION	NOVEMBER GAIN	DECEMBER GAIN	JANUARY GAIN	FEBRUARY GAIN	MARCH GAIN	APRIL GAIN	MAY GAIN	JUNE GAIN	JULY GAIN	AUGUST GAIN	TOTAL LBS GAINED
0015-017	Yes	65	114	115	94	116	141	90	76	84		895
0015-018	Yes	6	101	85	89	67	135	89	80	76		728
0015-019	Yes	9	68	51	91	60	108	95	78	105	56	721
0015-020	Yes	15	74	88	114	73	136	110	49	125	103	887
0015-21	No	HARVESTED ML										
0015-022	Yes	-28	85	72	60	51	104	76	76	57	76	629
0015-23	No	-148										
0015-024	Yes	17	114	124	60	71	115	103	105	39		748
0016-037	Yes	21	114	104	101	82	117	102	94	90	73	898
0016-038	Yes	4	120	93	-3	105	108	90	82	62	104	765
0016-039	Yes	-19	131	98	68	80	117	74	90	80		719
0016-040	Yes	-1	87	82	74	70	97	98	80	101	59	747
0016-041	Yes	11	133	87	118	89	167	79	49	105	62	900
0016-042	Yes	61	96	93	94	82	107	118	49	108	70	878
0016-043	Yes	-1	62	65	85	99	135	111	76	124	56	812
0016-044	Yes	39	144	83	80	79	127	96	58	-60		646
0017-017	Yes	21	85	115	88	80	20	190	42	64	29	734
0017-18	Yes	HARVESTED ML										
0017-019	Yes	45	110	116	105	100	139	100	80	119		914
0017-020	Yes	35	115	37	79	67	117	61	94	86	61	752
0017-021	Yes	20	100	161	110	118	127	106	98	81		921
0017-22	No	DIED 29 NOV 14										
0017-023	No	76	175	140	95	101	166	106	81	81		1021
0017-024	Yes	27	115	112	95	72	121	107	67	94	85	895
0018-031	No	0	6	124	95	115	139	127	78	119	66	869
0018-032	No	10	104	104	76	85	109	104	79	74	65	810
0018-033	No	36	97	80	107	59	113	89	94	104	76	855
0018-034	No	115	-17	68	90	84	118	88	77	116	66	805
0018-035	Yes	11	106	107	75	79	129	106	81	121	27	842
0018-036	Yes	26	71	115	112	98	140	128	44	76		810
0018-037	Yes	11	101	132	101	95	99	114	82	144	67	946
0018-038	Yes	23	6	47	63	77	105	105	99	100	61	686

Appendix HH

LOT/ET	GRUB CONDITION	ADG 1	ADG 2	ADG 3	ADG 4	ADG 5	ADG 6	ADG 7	ADG 8	ADG 9	ADG 10
0015-017	Yes	5.42	4.07	3.83	3.62	4.14	5.04	3.21	2.71	3.23	
0015-018	Yes	0.50	3.61	2.83	3.42	2.39	4.82	3.18	2.86	2.92	
0015-019	Yes	0.75	2.43	1.70	3.50	2.14	3.86	3.39	2.79	3.75	2.00
0015-020	Yes	1.25	2.64	2.93	4.38	2.61	4.86	3.93	1.75	4.46	3.68
0015-022	Yes	-2.33	3.04	2.40	2.31	1.82	3.71	2.71	2.71	2.04	2.71
0015-024	Yes	1.42	4.07	4.13	2.31	2.54	4.11	3.68	3.75	1.50	
0016-037	Yes	1.75	4.07	3.47	3.88	2.93	4.18	3.64	3.36	3.21	2.61
0016-038	Yes	0.33	4.29	3.10	-0.12	3.75	3.86	3.21	2.93	2.21	3.71
0016-039	Yes	-1.58	4.68	3.27	2.62	2.86	4.18	2.64	3.21	3.08	
0016-040	Yes	-0.08	3.11	2.73	2.85	2.50	3.46	3.50	2.86	3.61	2.11
0016-041	Yes	0.92	4.75	2.90	4.54	3.18	5.96	2.82	1.75	3.75	2.21
0016-042	Yes	5.08	3.43	3.10	3.62	2.93	3.82	4.21	1.75	3.86	2.50
0016-043	Yes	-0.08	2.21	2.17	3.27	3.54	4.82	3.96	2.71	4.43	2.00
0016-044	Yes	3.25	5.14	2.77	3.08	2.82	4.54	3.43	2.07	-2.31	
0017-017	Yes	1.75	3.04	3.83	3.38	2.86	0.71	6.79	1.50	2.29	1.04
0017-019	Yes	3.75	3.93	3.87	4.04	3.57	4.96	3.57	2.86	4.58	
0017-020	Yes	2.92	4.11	1.23	3.04	2.39	4.18	2.18	3.36	3.07	2.18
0017-021	Yes	1.67	3.57	5.37	4.23	4.21	4.54	3.79	3.50	3.12	
0017-023	No	6.33	6.25	4.67	3.65	3.61	5.93	3.79	2.89	3.12	
0017-024	Yes	2.25	4.11	3.73	3.65	2.57	4.32	3.82	2.39	3.36	3.04
0018-031	No	0.00	0.21	4.13	3.65	4.11	4.96	4.54	2.79	4.25	2.36
0018-032	No	0.83	3.71	3.47	2.92	3.04	3.89	3.71	2.82	2.64	2.32
0018-033	No	3.00	3.46	2.67	4.12	2.11	4.04	3.18	3.36	3.71	2.71
0018-034	No	9.58	-0.61	2.27	3.46	3.00	4.21	3.14	2.75	4.14	2.36
0018-035	Yes	0.92	3.79	3.57	2.88	2.82	4.61	3.79	2.89	4.32	0.96
0018-036	Yes	2.17	2.54	3.83	4.31	3.50	5.00	4.57	1.57	2.92	
0018-037	Yes	0.92	3.61	4.40	3.88	3.39	3.54	4.07	2.93	5.14	2.39
0018-038	Yes	1.92	0.21	1.57	2.42	2.75	3.75	3.75	3.54	3.57	2.18

Appendix II

LOT/ET	Quality Grade	MARBLING	PYG	APYG	BACKFAT	KPH	REA	LIVER SCORE	HCW
0015-017	CHOICE	43	3.5	3.5	0.694	1.854	13.90	A+AD	939
0015-018	SELECT	35	2.9	3.0	0.445	1.870	14.00	Good	924
0015-019	SELECT	34	2.0	2.1	0.406	1.976	15.17	Good	862
0015-020	SELECT	33	4.1	4.3	0.817	2.050	14.76	Good	973
0015-022	CHOICE	64	1.6	1.8	0.317	2.028	14.32	Good	822
0015-024	CHOICE	44	3.0	3.0	0.364	1.821	14.10	Good	938
0016-037	CHOICE	47	4.6	4.6	0.913	2.580	12.51	Good	915
0016-038	SELECT	34	4.1	4.3	0.826	2.178	12.47	Good	870
0016-039	CHOICE	43	3.3	3.4	0.608	1.952	13.60	Good	956
0016-040	CHOICE	63	3.6	3.7	0.710	2.298	12.23	Good	796
0016-041	CHOICE	49	3.0	3.0	0.608	2.244	13.74	Good	944
0016-042	CHOICE	49	3.3	3.5	0.652	2.162	13.03	Good	920
0016-043	CHOICE	59	3.0	3.1	0.602	1.914	14.52	Good	974
0016-044	CHOICE	41	2.5	2.7	0.323	1.689	13.10	Good	855
0017-017	CHOICE	64	2.3	2.5	0.465	1.975	15.93	Good	871
0017-019	CHOICE	42	2.6	2.7	0.324	1.517	14.00	Good	972
0017-020	CHOICE	59	2.9	3.0	0.581	1.983	16.43	Good	930
0017-021	SELECT	37	2.5	2.5	0.239	1.538	13.70	Good	952
0017-023	CHOICE	43	3.5	3.8	0.800	1.644	14.40	Good	1075
0017-024	CHOICE	48	2.7	2.7	0.531	1.833	15.64	Cont.	975
0018-031	SELECT	39	1.7	1.8	0.338	1.528	17.83	Good	976
0018-032	SELECT	37	1.6	1.8	0.326	1.825	14.60	Good	928
0018-033	CHOICE	54	2.9	3.0	0.584	2.054	13.54	Good	935
0018-034	SELECT	37	2.7	2.8	0.549	2.087	12.00	Good	847
0018-035	CHOICE	66	3.8	3.9	0.766	2.178	12.84	Good	919
0018-036	CHOICE	42	2.7	2.9	0.363	1.556	14.30	Good	911
0018-037	CHOICE	61	3.1	3.1	0.618	1.971	15.86	Good	954
0018-038	SELECT	35	3.1	3.1	0.627	2.054	13.08	Good	919

Appendix JJ

**SLAUGHTER 1
07 JUL 2015**

TYSON FRESH MEATS

AMARILLO, TX.

LOT/ET	GRUB	CONDITION	ADG	OUT WEIGHT	HCW	Quality Grade	BACKFAT	REA
0015-017		Yes	3.73	1510	939	SM 30	0.694	13.9
0015-018		Yes	3.25	1485	924	SL 50	0.445	14
0015-024		Yes	3.26	1451	938	SM 40	0.3635	14.1
0016-039		Yes	3.32	1498	956	SM 30	0.6075	13.6
0016-044		Yes	2.69	1339	855	SM 10	0.3225	13.1
0017-019		Yes	3.92	1614	972	SM 20	0.324	14
0017-021		Yes	4.04	1516	952	SL 70	0.2385	13.7
0017-023		No	4.24	1718	1075	SM 40	0.7995	14.4
0018-036		Yes	3.53	1468	911	SM 20	0.3625	14.3

**SLAUGHTER 2
05 AUG 2015**

TYSON FRESH MEATS

AMARILLO, TX.

LOT/ET	GRUB CONDITION	ADG	OUT WEIGHT	HCW	Quality Grade	BACKFAT	REA
0015-019	YES	2.84	1345	862	SL40	0.4055	15.2
0015-020	YES	3.47	1562	973	SL30	0.8165	14.8
0015-022	YES	2.61	1291	822	MD40	0.317	14.3
0016-037	YES	3.48	1478	915	SM70	0.913	12.5
0016-038	YES	2.99	1341	870	SL40	0.826	12.5
0016-040	YES	2.97	1303	796	MD30	0.71	12.2
0016-041	YES	3.54	1502	944	SM90	0.608	13.7
0016-042	YES	3.25	1449	920	SM90	0.6515	13
0016-043	YES	3.23	1520	974	MT90	0.602	14.5
0017-017	YES	2.83	1352	871	MD40	0.465	15.9

Appendix LL